STUDIES ON JHUM (SLASH AND BURN CULTIVATION) AT HIGHER ELEVATIONS OF MEGHALAYA

By

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I certify that the thesis entitled "STUDIES ON JHUM (SLASH AND BURN CULTIVATION) AT HIGHER ELEVATIONS OF MEGHALAYA" submitted by Sri Bidyut Kumar Mishra for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. Degree. This work has not been submitted for any Degree of any other University.

Date: 6 Aug. 1981
Place: Shillong

Signature of the Supervisor

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Date: 6th August, 1981.

Forest Ecology Laboratory.

Bidyut Kumar Mishra

(Bidyut Kumar Mishra)

PREFACE

The thesis embodies the results of a comprehensive study on the 'Slash and burn' agriculture(Jhum) at higher elevations of Meghalaya taking into considerations, agro-ecosystem structure and function and also various aspects like weed biology, soil fertility changes, losses from the system, hydrology, biomass and nutrient cycling in agro-ecosystem and the communities developing subsequently during fallow period. This study also considers the socio-economic aspects of the village-ecosystem under jhum. These aspects form part of a larger study on the ecological impact analysis of jhum in the North-Eastern region of India. The thesis starts with a General Introduction followed by seven chapters on different aspects of jhum mentioned above. The thesis concludes with General Considerations and References.

The seven chapters(Chapter2-8) dealing with the different aspects of jhum have been prepared in the form of research papers for publication. Consequently some overlapping in the writing was unavoidable.

It is hoped that this comprehensive study on the ecology of jhum at higher elevations of Meghalaya would help in designing proper land use pattern for this region and for conserving the environment in the hill regions of the North-Eastern India.

CHAPTER — 1

GENERAL INTRODUCTION

More than 250 million people, thinly scattered over 300 million ha of forest land of the tropics, still follow an ancient form of agriculture which involves the slashing and burning of vegetation, followed by the cultivation of crops(Goodland, 1980). Rapid depletion of the fertility of the fields, which are often too steep to hold soil, water and nutrients compels the farmer to shift to a fresh site. After cultivation for only a short time, the land is left a fallow again to be cultivated after a few years. Thus this system of agriculture is characterised by the rotation of fields rather than the crops, and is most commonly known as 'Slash and burn' agriculture.

Historical and geographical background:

'Slash and burn' agriculture is frequently called as shifting agriculture because the farmer changes his field every year. The anthropologists prefer the term 'Swiddening' for this practice, after an old English dialect word Swidden (a burned clearing), resurrected by Ekwall (1955). This agriculture is also referred to by a number of local names, among which Conuco, Milpa, Roza y tumba or Agricultura nōmada from Latin America, Zande from Africa, Jhum or Chena from Middle Asia, Honunoo or Kaingin from South-East Asia, Tsembaga from New Guinea highlands are most common in the literature (Conklin, 1957). In India this system of agriculture is variously called in different tribal belts. While 'Jhum' is the common name in the entire

North-Eastern hill region of India, this practice is known as Podu in Orissa, Deppa in Bastar, Dahia in Madhyapradesh and Watra in Western Ghats.

Africa is the largest among the three great continental regions of 'slash and burn' agriculture in the tropics, with the greatest variety of annual conditions and cultural patterns, and has received comparatively adequate scientific study (Nye and Greenland, 1960). This system of agriculture has been discussed against a wider background of the conservation and development of natural resources of Africa by several workers (Harroy, 1949; Worthington, 1958). Hailey (1957) has discussed this agriculture in its socio-economic setting. Several others have given regional accounts of the native cultivation practices involving cutting and burning of forests before plantation of a mixture of crops(Tothill, 1940; Tothill,1948; Waldock et al., 1951; Tondeur, 1956). Among the study of 'Slash and burn' agriculture illustrating the varied responses of various tribes to different types of soil and vegetation in the African continent, the work of de Schlippe (1956) on the Zande tribe in the border of the Sudan and the Congo, of Bergeroo -Campagne (1956) on the N'Dranouas tribe in the high-grass savanna of the Ivory Coast, and that of Richards (1939) on the Bemba tribe in Northern Rhodesia are the most important ones. Allan(1965) has presented an excellent study of some African forms of 'slash and burn' agriculture.

Cook (1921) is probably the first man to describe the 'Milpa' system of agriculture in the humid forests of Latin America where maize is grown extensively after clearing the site by slashing and burning the vegetation. Watters (1971) has written the best general account of shifting agriculture in Latin America with special reference to the cultivation practice in Venezuela, Mexico and Peru.

Pelzer(1948) has given an account of the 'Slash and burn' agriculture in South-East Asia, and Gourou(1940) has described the practice in Indo-China. Freeman(1955) and Conklin (1957) have given accounts on the agricultural practices of the Iban in Sarawak and Hanunoo in the Philippines, respectively.

May (1978) has made a study on the socio-economics of the peasants of Chitagong hill tracts of Bangladesh, and some preliminary work in the North-East India has been done by Aurora et al.(1977). Recently, a detailed study involving the agro-ecosystem structure and function, hydrology, soil fertility changes, secondary succession patterns, biomass and nutrient cycling, microbial and soil animal ecology studies, and socio-economic aspects of people involved in 'slash and burn' agriculture in the North-Eastern India has been completed of which this study forms a part (Ramakrishnan et al., 1980; Ramakrishnan and Toky, 1981; Toky and Ramakrishnan, 1981; Mishra and Ramakrishnan, 1981; Kushwaha et al., 1981).

Regional differences:

'Slash and burn' agriculture is practised on such a wide range of soils under so many types of vegetation, and by people of such widely varying origin and culture that it shows great variations in the crop combination, methods of cultivation, productivity, technology, ecological, economic and socio-cultural features. However, all these variant forms show a great similarity in their general characteristics and conform to the minimum definition, involving a periodic shifting of site and a cycle of cultivation that includes clearing of forest by slash and burn method and the abandoning of the field for the natural regeneration of vegetation. To avoid over generalization on the topic on the one hand and excess of details on the other we shall pick up only some example of this agriculture in the forest and savanna regions of the tropics of the world for consideration.

The native subsistence agriculture practised by the Hanunoo in Philippines (Conklin, 1957) and the Garo in lower elevation of Meghalaya in the North-Eastern India (Ramakrishnan and Toky, 1978) are the best example of 'Slash and burn' agriculture in humid tropical forests. In these areas, the story begins with a piece of forested land which the farmer has been allotted by his tribal chief for clearing. The entire vegetation, including large and small trees, are felled by the farmers during the dry season. Larger boles and branches are removed from the site and used as firewood. The slash is allowed to dry on the ground during the winter months which are rainless and burnt during March-April. Dried leaves and small branches are burnt _in situ_, where as larger logs may be heaped up and burnt a few times. After the first few showers in April-May, weeding is done followed by the sowing of a mixture of crops by dibbling the seeds using a digging stick. While 8-13 crop species are grown together on a single field by the Garos, an extreme example of mixed cropping including 40-50 different crop species has been reported by Conklin (1957). During weeding, soil in between the planting holes are not disturbed as the farmer weeds the young crop by slashing with a cutlass. Crops are harvested successively as the season progress. In the second year, crops like sesamum, tapioca, banana and a few cucurbits are grown. The land is usually left a fallow after 1-2 years of cultivation, occassionally it may be used for another couple of years for banana cultivation. The developing brush springs from the stumps and large roots left after clearing the previous fallow, and also from the germination of seeds already present in the soil or transported in from adjoining areas of forest. Regrowth is rapid and the secondary forest may well be 3-4 m high after about 5 years and 8-10 m after 10 years. Forest regeneration is generally allowed to continue for 20-30 years. At this stage, the secondary forest is hardly distinguishable from the original one. When a fresh clearing is made the boundaries of the new patch may not necessarily coincide with those of the old. Thus there are no clear boundaries, individual fields can scarcely be discerned, and while some patches of land are under crops, and others are under a thick regrowth of forest, there is a middle category in which perennial crops survive amidst a regrowth of forest which is gradually choking them.

Example of 'Slash and burn' agriculture in the semi-deciduous forest regions of Ghana (Nye and Greenland, 1960) also fall under the category described above where cropping is started with maize plantation. When maize comes to its developing stage, or shortly after it has been harvested, cassava, and as a rule, other long growing tuber crops such as cocoyam and plantain are planted. Small patches of land may be reserved for vegetable crops. During the second year, plantains and some of the cassava and cocoyam is harvested, while the remainder are left to grow further into a third or fourth year to be harvested as needed, or left to the natural regrowth of forest. In this case, the developing secondary forest is soon dominated by the light loving species, among which Musanga cecropioides, Trema guineense, and Macaranga barteri are more common.

The best example of 'Slash and burn' agriculture in savanna regions is given by Nye and Greenland (1960). Under the moist savanna of West Africa, except a few valuable species which may be preserved, most of the trees are slashed and burnt. Soil under these areas is more thoroughly disturbed than in the forest to get rid of the roots of the grasses. In a typical cropping sequence, the soil is scraped into mounds of about ½ m high with the help of hand hoes, while it is still moist at the end of the rains. The climbing yam(Dioscorea sp.) is planted on the mounds, and a variety of side crops such as maize, squash and beans are added at the beginning of rain. The following year yam mounds are destroyed, and maize and sorghum are planted on the narrow ridges. The next year ground nuts, inter-planted thinly with millet, completes the cropping phase of the cycle. Weeding is comparatively a labourious job than in the forest, particularly if Imperata cylindrica is present. When the land is left a fallow, it is often dominated by Pennisetum sp. along with other herbs if it is clean, or by I.cylindrica if it is not. In a couple of years the tall perennial grass species, Andropogon gayanus appears and when this completely replace I.cylindrica in about 10 years or so, the farmer considers the land is fit to be cleared again. If it is not cleared, the A.gayanus is replaced by other tall members of the Andropogoneceae, such as Hyparrhenia rufa, to form a fire-climax which is established within 20 years.

The pattern of 'Slash and burn' agriculture in the entire lower elevations of the North-Eastern hill zones of India is basically same and is practised in the typical form described earlier (Ramakrishnan and Toky, 1978). However, the practice followed by the Khasi tribe in the higher elevations of Meghalaya in this region is a modified version of its typical type in that normally only the lower branches of the sparsely distributed pine trees are cut instead of the whole tree. Further, unlike in its typical form where the slash is burnt in situ and the seeds are dibbled directly into the soil-ash complex, in the latter case the slash is place in parallel rows running along the slope covered over by a thin layer of soil forming the elevated seed beds(ridges) alternating with narrow gaps(furrows) and are subjected to a slow burn. Planting of crops is confined only to the ridges. While fertilizer is not used in the former, in higher elevations both organic and inorganic fertilizers may be used. This, system can be best compared with the 'Chitemene' system of agriculture of Northern Rhodesia(Nye and Greenland, 1960), where branches are lopped over a large area and piled and burnt before cultivation, though there are significant differences between the two.

Yield aspect and weed problem:

The immediate cause of rotation of the fields under 'Slash and burn 'agriculture is the declining yields in the successive years of cultivation. In the British Honduras, Charter(1941) found the yields of maize on peasant milpas as about 1000-800, 800-600, 600-400 kg ha^{-1} in the suceessive years. Steggerda (1941) estimated that the yield in the second year, in the Yucatán peninsula (Mexico), is only about 80% as high as in the first year. In Malaya, Grist (1953) estimated that the yield of paddy in successive years of cultivation was to the tune of 1500-2000, 1200, 800 kg ha^{-1}. At Yambio Experiment Station (Southern Sudan), Anthony and Willimott (1956) estimated that the yields of cotton, groundnuts and Eleusine drooped significantly after 3 years of cropping. Tondeur (1956) reports that in Belgian Congo area the yields in the second year cultivation was reduced sharply and this reduction was to the extent of 76%, 86% and 33% for paddy, groundnuts and cassava respectively. The yield of maize in the second year of cultivation in the North Guatemala was reduced to about half compared to the first year crop(Popenoe, 1957), and so, too, in the humid forests of Ghana as reported by Nye and Stephens (1960). In the central Petên, Cowgill(1961) found second year milpa yields to be only 71% as high as compared to the first year yield.

Another cause forcing the peasant to abandon the land and cultivate elsewhere is the rapid invasion of weeds (Steggerda, 1941; Joachim and Kandiah, 1948; Freeman, 1955; Bergeroo-Capagne, 1956; Watters, 1958). In a situation where there is plenty of land, and little motive to produce a surplus for sale, infestation with weeds does not have to be so severe that it is impossible to continue cropping, but simply sufficient to make it easier to obtain subsistence by clearing a new site. The timing of operations also plays an important role(Nye and Greenland,1960). Clearing is mostly done in the dry season when the farmer has little work to do and by clearing a new site the farmer reduces the work of weeding at a busier time of the year, and so distributes his labour more evenly.

While various workers have discussed the influence of weeds in reducing the crop yield, others (Cowgill, 1962) found no significant relationship between the density of weeds and the years of cultivation or the subsequent yield. After analysing these examples, Nye and Greenland(1960) concluded that the extension of cropping with annuals is undesirable and is rarely practised because of increasing difficulty in controlling grasses, and the weakening of the woody regrowth. Where a succession of crops is grown, weeds seen to be the main cause for declining yield. Charter(1941) has described that the infestation of 'alang-alang(*Imperata cylindrica*)is the reason of declining yield of maize in the forests of Latin America. Emerson (1953) has related the influence of weeds in decreasing the yields of maize in the successive years of cultivation under the milpa system of agriculture of Latin America. Cutting et al.(1959) has given the best example of the importance of timely weeding of annual crops in Nyasaland. They have reported that maize yielded about 3816 kg ha^{-1} when wedded four weeks after germination, but only 2866 kg ha^{-1} when weeded six weeks after germination.

Energetics:

Information on the energetics of 'Slash and burn' agriculture is scant and indequate (Black, 1971;Norman, 1978). However, Rappaport(1971) provides relatively complete information on the major energy inputs for growing crops under the 'Swidden' system of agriculture of the New

Guinea highlands. According to his estimates, the peasant harvest 16.5 units of food energy for each unit of energy input, which may go up to 20 food calories under more favourable conditions. As mentioned earlier, 'Slash and burn' agriculture is chiefly dependant on the renewable resources of energy, the plant biomass developed during the fallow period. Thus, this system of agricultue is based on solar energy supplemented with human labour in contrast to modern agriculture based on high fossil fuel energy input.

The work of Pimentel et al.(1973) and Leach (1976) have compared the energy efficiency of different agriculture systems in the light of dwindling fossil fuel energy resources. The increasing cost of fossil fuel and petroleum products, and the fast depletion of this non-renewable commodity, essential for the modern agriculture, has led to analyse the relationship between fossil fuel inout and the output of food of the world's diverse food production systems to measure the energetic efficiency of these systems or their v ulnerability to the external costs of the fossil fuel. The way many societies have evolved in the past in harmony with low levels of energy supply to the society would provide clues as to how modern societies could adapt to the limitations imposed by energy scarcity. Among the detailed accounts of energy input-output analysis of single tribes illustrating their responses to their environment, the work of Lee (1966) and Rappaport(1971) are worth mentioning here. In Lee's study, the input-output approach to subsistence has shown that Kung Bushmen in the Dobe area can derive an adequate living from only a modest expenditure of their time and effort. He estimated that the per capita yield of food-stuff was 2140 k cal which was in excess of 165 k cal to the energy requirement per person per day. Rappaport (1971) has discussed the importance of Tsembaga Swine husbandry as a practical way to store the excess of food energy harvested during some of the productive years. Beside this, according to him it formed a connecting link in the detritus food chain by consuming the garbage, the unassimilated food content of the human faeces and other materials that would have otherwise been wasted. Further, the pigs converted the carbohydrates of cheap origin to high quality protein. During this study, Rappaport estimated an energy expenditure of 4.5×10^6 k cal over a 10 year period for rearing a single pig. On the basis of this data and the calculations of Pimentel et al;(1975) that 65 k cal of energy are required to produce 1 k cal of pork for human consumption, Pimentel and Pimentel(1979) calculated that the return from 4.5×10^6 k cal of pig feed would be 69230 k cal of pork, which is only 1.5% return on the food energy fed to the pigs. This led them to conclude that the Tsembaga Swine husbandry system is not very efficient one from an energetic view point.

Fertility aspects:

A good deal of evidence suggests that a significant change in the physico-chemical characteristics of the soil under 'Slash and burn' agriculture results in low yield per unit area which compel the farmer to abandon the land for fallow development (Popenoe, 1959; Nicolas, 1959 Nye and Greenland, 1960; Cowgill, 1961; Watters, 1971; Watters and Bascones, 1971). Popenoe (1959) has given an excellent account on the soil changes that occurs throughout the shifting agriculture cycle in the Polochic river valley of Northern Guatemala. He reported that changes occurred in the top 40 cm of soil only. The cutting and burning of the forest resulted in an increase in the soil bulk-density, pH and percent base saturation, and decrease in calcium and magnesium in the 0-5 cm layer of soil; calcium and magnesium increased in the 5-40 cm depth. Rapid restoration of the physico-chemical properties occurred during the fallow development stage. However, additions of organic matter under secondary growth had a high carbon to nitrogen ratio and consequently immobilized much of the nitrogen. Nitrate that percolated down the profile was absorbed rapidly into the developing vegetation. Thus, although the organic matter increased in the surface layer during the first five years of forest regeneration, it continued to decline in 5-15 cm layer. While working on the milpas of 40 peasants in the central Petén, Cowgill(1961) reported an increase in potassium and magnesium and decrease in all other nutrients due to burning. Cultivation had the effect of decreasing nutrient status in the soil pool:second year of cropping under this system caused a decline in pH by 1.3%, organic matter by 6-8%,nitrogen 5-9%, phosphorus 1.8% and the exchangeable cations by 3.5-30%. During the fallow development all elements improved markedly except pH; potassium was more or less stabilized after about 10 years.

The work of Watters and Bascones (1971) in the hilly areas of Altamaria-Calderas(Estado de Barinas) on the lower elevation flanks of the Andes, reports that the main limitations to crop production were the low nutrient levels; physical properties were probably not limiting to crop growth. Soil acidity was pronounced and there was a marked deficiency in available phosphorus. Potassium was rather poorly supplied. The total cations was low. Jenny et al. (1948) have reported that although nitrogen and organic matter levels are likely to be higher in areas receiving high rainfall such as in the sub-tropical zones, the rate of humus destruction is characteristically more rapid in these wormer areas than in the higher cooler temperate zones, and this would appear to be a significant factor in forcing fallowing. The work of Herrera (quoted by Watters, 1971) on Kánkab soils suggests that the rapid loss of organic matter, probably through leaching, is a basic reason for inducing the peasants to shift their cropping areas. He has also reported that the quantity of total nitrogen, and carbon to nitrogen ratio, in general shows increasing tendency with increase in the rainfall.

In the tropical semidesiduous forest of Ghana, Cunningham (1963) found that clear felling of the vegetation decreased the total nitrogen by about 30% in a period of 3 years, while the nitrogen level was maintained more or less in the same level over 100 years of cropping in a temperate climate at Rothamsted, England. These differences appear to be primarily due to the difference in mean temperature (Daubenmire and Prusso, 1963; Madge, 1966)thus it appears that the macroclimatic factors are important among the significant reasons of the different soil processes of humid tropical and temperate regions, and largely explain the occurrence of 'Slash and burn' agriculture in the former and more stable agriculture systems in the latter.

Secondary succession, and related changes in biomass, litterfall and nutrient cycle:

Although information on the process of secondary succession on abandoned land are vast in the literature, that on abandoned sites subsequent to 'Slash and burn' agriculture is rather scant and are often inadequate. While studying the process of secondary succession in moist evergreen forest, **Richards**(1952) have reported that the early phases of succession was dominated by weeds, including grasses, which are short lived and ephemerals rather than annuals. In the next phase, shrubs dominated the community. Shifting of dominance directly from herbs to trees in the community have also been mentioned, of course only in some cases. The young secondary forests tended to be even-aged and was often dominated by a single species. In due course of time the secondary forest became more mixed in age-structure and floristic composition till it reached the conditions of a mature forest.

Bernard (1949) at Yangambi and Ahn (1958) in South-West Ghana have worked on the early stages of secondary succession. In Nigeria and Congo basin, Nye and Greenland (1960) reports the process of secondary succession and the importance of gain in dominance by the Umbrella tree (Musanga cecropioides). This is a fast growing light loving species which dies out after about 20 years or so, and during this period it was reported to accumulate a high prportion of potassium in its plant body and thus help in potassium conservation in the ecosystem.

There have been very few studies on the changes in biomass, litter fall and nutrient cycling in the secondary successional communities developing after 'Slash and burn' agriculture. Data on the amount of nutrient stored, rate of accumulation and cycling in these successional comunities is rather scant and often inadequate than that for biomass and productivity. However, Barthelomew et al. (1953) have given relatively complete information on the nutrient cycling and its subsequent changes during the secondary succession upto a period of 18 years at Yangambi in the Belgian Congo. They have reported that the storage capacity of leaves and twigs gets saturated at an early stage, thereafter the total storage increases more slowely and in the woody materials and roots only. They have also observed that a relatively high amount of potassium accumulation occurred in the early stages of fallow development due to the dominance of Umbrella tree(Musanga cecropioides) in the community at that stage. Nye (1958) reports only the average nutrient composition of 14 dominant species in a mixed fallow of about 20 years at Kumasi in Ghana. Using the nutrient data of Nye (1958) and the biomass values obtained by Barthelomew et al.(1953) for a 18 year old secondary forest at Congo basin, Nye and Greenland (1960) have estimated the approximate amount of various nutrients stored in the vegetation compartment of the forested eco-system at Yangambi.

While literature on nutrient cycling in temperate forests is too vast to be reviewed here (Remezov et al., 1964; Rodin and Bazilevich, 1967; Whittaker et al., 1979), little is known about tropical and sub-tropical forests (Greenland and Kowl, 1960; Nye, 1961; Jordan and Klinge, 1972; Golley et al., 1975). Certain patterns are nevertheless suggested by these studies. Uptake and return of nutrients may be greater per year in tropical forests than in others and a larger proportion of the entire chemical inventory of the ecosystem may be held up in the vegetation comparatment (Rodin and Bazilevich, 1967).

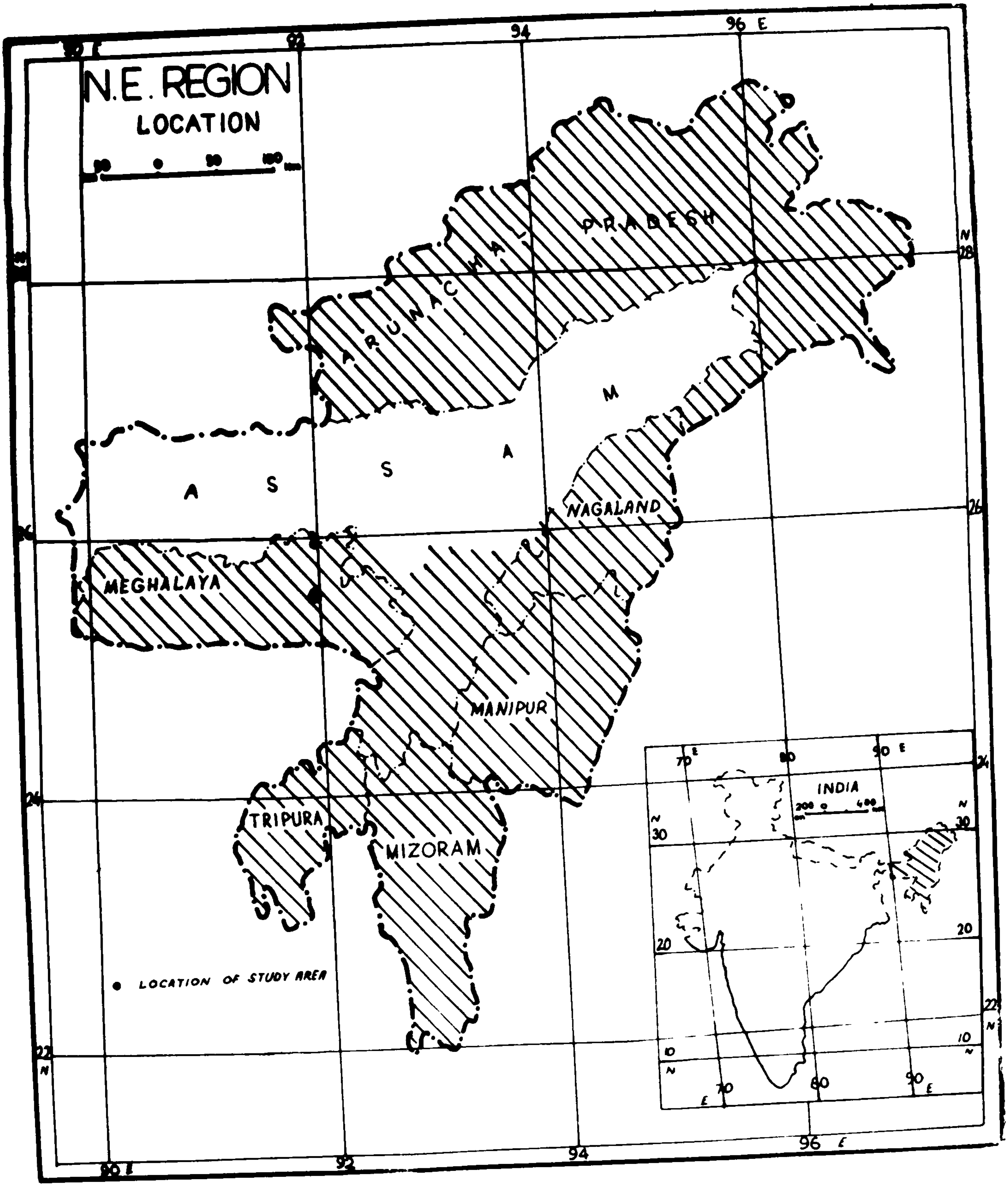
The present work:

'Slash and burn' agriculture (locally called as Jhum) is a predominant form of agriculture at higher elevations of the Khasi hills of Meghalaya and is also a common feature of the entire North-Eastern regions of India. After cultivation for a year or two, the land is left fallow, again to be cultivated after a few years. This time lapse before cultivation of the same site is called a jhum cycle. Formerly, the jhum cycle was fairly long, ranging from 20-30 years, which ensured that the system was selfsustaining and in harmony with the nature. However, under the present day conditions of increased population presure and reduced acreage, the jhum cycle has been reduced to 4-5 years. This, in turn, has adversely affected the quality of the environment both interms of soil fertility and forest cover (Ramakrishnan et al., 1980; Ramakrishnan, 1980).

The present comprehensive study on the 'Slash and burn' agriculture at higher elevations (1500 m) of Meghalaya around Shillong (25.34°N, 91.56°E) (Fig.1.1) is part of a broader study on the ecological impact analysis of this system of agriculture in the North-Eastern India. In the absence of many such studies of a comprehensive nature, it is hoped that this would yield information of value both from the point of view of the ecology of the region, land use practices, as well as from a conservational view point. This study, therefore, deals with agro-ecosystem yield patterns, energetics of agriculture, village ecosystem function, soil fertility patterns during agriculture and subsequent fallow development, and the ecology of the developing communities subsequent to jhum.

Fig.1.1 The area under 'Slash and burn' agriculture (Jhum) in North-Eastern India. ▨ , under jhum; ● study site.

FIG 1.1


N.E. REGION
LOCATION
50 0 50 100
90 E
92
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96 E
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26
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22 N
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96 E
ARUNACHAL PRADESH
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
LOCATION OF STUDY AREA
INDIA
200 0 400
70 E
80
90 E
N 30
20
10 N
E 70
80
90 E
30
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10

CHAPTER —— 2

THE ECONOMIC YIELD AND ENERGY EFFICIENCY OF HILL AGRO ECOSYSTEMS AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.

INTRODUCTION

One of the ancient forms of agriculture which is still practised in different tropical and sub-tropical regions of the world involves 'slash and burn'. Here a natural forested fallow is slashed and the dried slash is burnt to add to the fertility of the soil and then abandoned for the natural regeneration of the forest. A few years may lapse (one cycle) before the same piece of land is again cultivated. This agriculture is extensively practised by a large number of tribes inhabiting the north-eastern hill regions of India and is locally referred to as 'jhum'. In its traditional form the jhum cycle used to be 20-30 years, but has now been reduced to as short as 4-5 years due to increased population pressure and reduced acrage available for agriculture. Alongwith this, valley cultivation of rice is also practised by the local tribes. Further in recent times, the local soil-conservation and agriculture departments have introduced terrace cultivation in some selected areas.

The present study on the economic yield and energy efficiency pattern of the high elevation agroecosystems of this region was undertaken because of considerable confusion in the literature regarding the yield pattern of these systems. The Agroeconomic Research Centre, Jorhat(Assam), conducted surveys on jhum yield of rice and concluded that the annual average yield ranges between 800-900 kg ha^{-1}, which is comparable to the average annual yield of 1145 kg ha^{-1} for the country as a whole for 1971-72. On the other hand, the rice yield under jhum in Tripura was reported to be around 1200 kg ha^{-1} yr^{-1} (Misra, 1976). In a recent study of the socio-economy of shifting cultivation, Aurora et al., (1977) concluded that the yield of rice under jhum and dry-land cultivation on terraces are not significantly different under comparable situations. A study at Burnihat (Sahu, 1978) on rice yield gave an annual output of 3428, 738 and 853 kg ha^{-1} respectively under valley cultivation, terrace cultivation and jhum cultivation. According to a report of the Indian Council of Agricultural Research (Borthakur et al., 1978), the yield under jhum was found to be very low (190 kg ha^{-1}) compared to terrace cultivation (1860 kg ha^{-1}). Unfortunately, none of these studies specify the amount of fertilizer inputs under terrace cultivation nor do they indicate the jhum pattern, the cycle of which determines the yield. Also none of the above studies specify whether yield from other crops are included in the final figures. This study, along with that already done for the lower elevation agro-ecosystems (Toky and Ramakrishnan, 1981) would compare the different agricultural systems of this region from the yield and efficiency point of view.

This study was done around Shillong(25.34°N,91.56°E) in the Khasi hills of Meghalaya, at an altitude of 1500 meters. The climate is monsoonic with most of the annual rainfall of 1843 mm occurring during the monsoon season from May to

September. The average maximum temperature during this season was 23.7°C and the average minimum was 16.3°C. The humidity is very high during this period (84.1%). Winter is cold with occasional showers, extending from November to February with an average minimum temperature of 7.6°C. Frosts are common during December and January months. The brief summer which is warm and dry extends from March to April and is accompanied with strong winds (fig.2.1).

The entire area is characterised by Pine forests with Pinus kesiya as the only dominant species. The terrain is hilly with steep slopes, the angle average being 30°-40°. Soil is podsolic and since erosion outstrips the weathering process, the soil cover is scant.

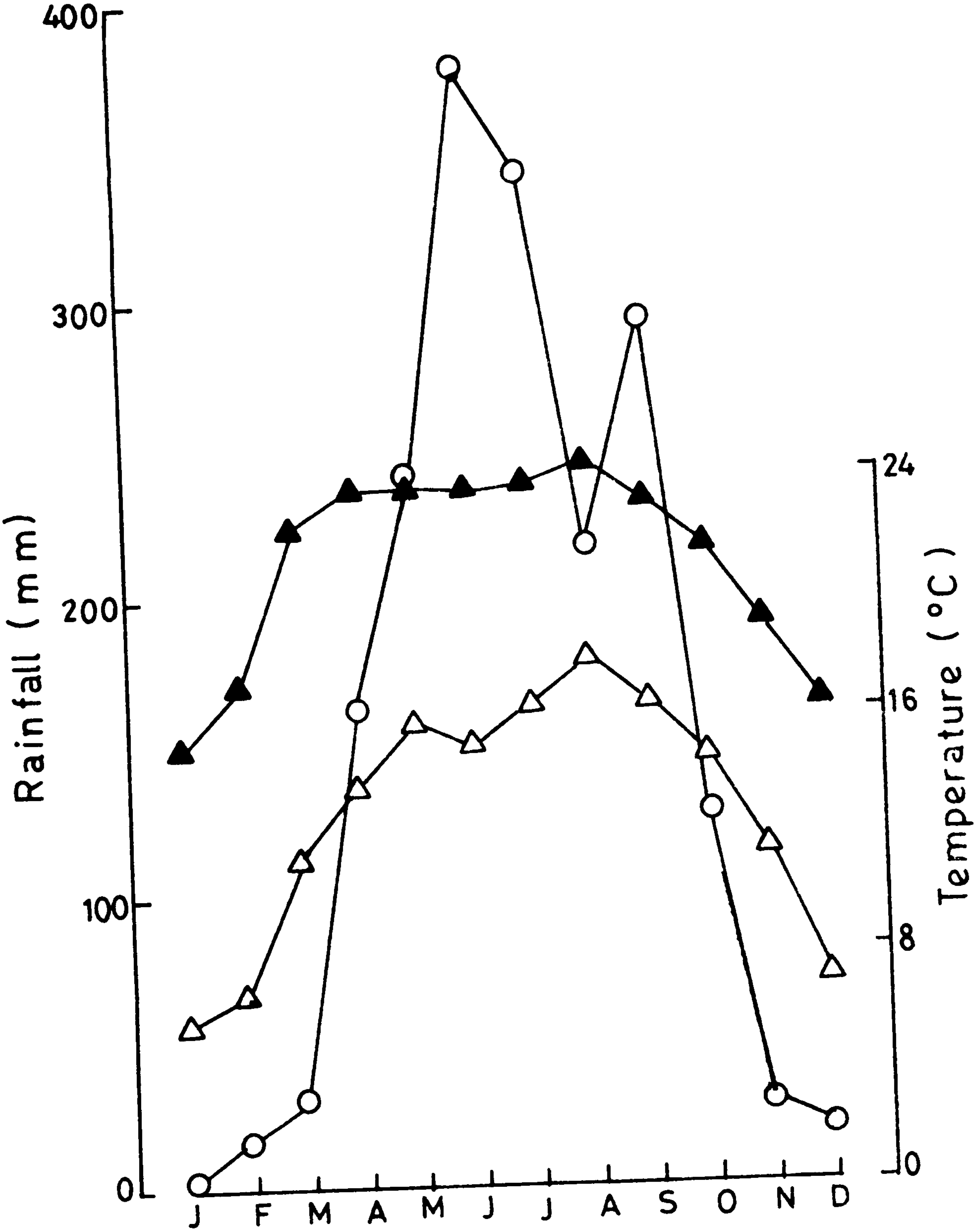
DESCRIPTION OF AGROECOSYSTEMS

Slash and burn agriculture:

Slash and burn agriculture (Jhum) is extensively practised by the tribal population of the north-eastern hill region of India. In its typical form, as is the case of lower elevations, this practice consists of slashing of the secondary forests and burning of the dried slash before growing a mixed crop on the hilly slopes. Cropping is generally done for one or two years before the land is left as a fallow for the forest to develop. The jhum cycle (the intervening fallow period after which the same forested land is again cultivated) is often short, ranging from 4-5 years, but in its traditional form the cycle may be as long as 20-30 years

Fig. 2.1 Ombrothermic diagram for the study area(average for 1977-1979). ○ , Rainfall; ▲ , Mean maximum temperature; △ , Mean minimum temperature.

FIG 2.1


400
300
200
100
0
Rainfall (mm)
24
16
8
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Temperature (°C)
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as was the case when the population pressure was not much (Ramakrishnan and Toky, 1978; Ramakrishnan et al., 1980). More than 85% of the total land area under cultivation is used for jhum. The average size of the jhum plots are about 1.5 - 2 ha for a family of 5 members consisting of two adults and three children.

The pattern of jhum at higher elevation of Meghalaya is a modified version of the typical type as outlined above. To start with pine trees are rather sparsely scattered with considerable undergrowth vegetation consisting chiefly of species like Eupatorium adenophorum, Imperata cylindrica, Lantana camara, Osbeckia crinita, Rubus ellipticus, Rubus micropetalus, various fern species like Pteridium equilinum and Dicranopteris linearis and tree seedlings like Goultheria fragrantissima, Myricà esculenta, Quercus griffithii, etc. The pine trees are not felled except for a few of the lower branches which are slashed. Slashing is done in December, the plant biomass is arranged in parallel rows running down the slope and then is allowed to dry. In the month of March, soil is placed on top of the slash so as to make ridges and furrows running along the slope. Consequently, the burn of the slash is controlled. A fire line to chack its spread is made around the field by clearing the vegetation.

A mixture of crops are grown together in the same field. Soon after the burn and a few weeks before the onset of monsoon, the tuber crops like Solanum tuberosum, Ipomoea *batatus* and *Colocasia antiquorum* are planted on the ridges. Sowing of cereal (*Zea mays*), legume (*Phaseolus vulgaris*) and a few cucurbits (*Cucurbita maxima* and *Cucumis sativus*) are done just after the onset of monsoon. Along each ridge, three distinct rows of sowing is done through dibbling with a mixture of both *Solanum tuberosum* and *Zea mays* mixed together. Planting of *Colocasia antiquorum* is confined generally to the top and bottom part of each ridge and the cucurbits are sown at random, but widely scattered on the ridge. *Phaseolus vulgaris* is sown around pine trees which provide support to it. After the harvest of the tuber crops in July-August, a winter crop of *Solanum tuberosum* is sown along the ridges. Harvesting of *Zea mays* and *Phaseolus vulgaris* is done in September-October, after which *Brassica oleracea* seedlings are planted alongwith the winter crop of *Solanum tuberosum.* Harvesting of the second crop of potato is done during November and then the field is left uncultivated between December-March. If a second year of cultivation is done the same procedures are followed; otherwise the field is abandoned for regeneration of natural vegetation.

Emphasis on the mixture of crops may vary according to the jhum cycle. Under 15 and 10 year cycles, all the crops mentioned above may be included during the cropping. However, cropping is done only for one year after which the land is left a fallow for natural regeneration of vegetation. Further, under a 15 year cycle, no fertilizer is applied during cropping. A 10 year cycle, however, may receive organic fertilizer in the form of pig dung and vegetable origin manure at the rete of 600 kg ha^{-1} yr^{-1} (oven dry wt). Under a 5 year jhum cycle cropping may be done for 2-3 years after slash and burn and then the land is fallowed for natural regeneration of vegetation. Solanum tuberosum, Zea mays and Brassica oleracea are the only croos grown here. This reduction in the number of species cultivated under a 5 year cycle is related to poor soil fertility and increased weed problem. During the cropping period both organic (pig dung and vegetable origin) and inorganic (NPK - 1:1:1) fertilizers are applied at the rate of 1000 kg ha^{-1} and 10 kg ha^{-1} respectively in the first year of cultivation and 1850 kg ha^{-1} and 20 kg ha^{-1} respectively in the second year.

With the onset of monsoon, weeds pose a serious problem particularly under a short jhum cycle of 5 year. Herbaceous weeds arise through seeds, rhizomes or as root sprouts. Eupatorium adenophorum, which is a noxious weed, may arise chiefly through seeds or through root sprouts. Regeneration of Imperata cylindrica is mainly through extensive, fire resistant underground rhizomes alongwith others like Pteridium equilinum and Dicranopteris linearis. These along with root or stem sprouts of tree and tree seedlings may be kept under control through frequent slashing. Hand hoeing along the ridges may also be done 2-3 times during the season.

Valley Cultivation:

Wet cultivation of Oryza sativa is done in the flat lands of valleys. Upland variety is grown year after year in the same field, because the land is comparatively fertile due to drainage of water and nutrients from the adjoining hills into the valley. Hence normally no fertilizer is applied to these fields except for a small amount of cow bone meal. This is a complementary system in selected favorable sites rather than an alternative to the jhum. Land is prepared thoroughly before sowing the seeds by broadcasting in June, after the first few showers. Weeding is subsequently done from time to time. Harvesting is done in November after which the land is left uncultivated until the following May-June. Weeding, harvesting, threshing and milling of rice is all done manually both by male and female members of the family. The average size of land under valley cultivation for a family of 5 members consisting of two adults and three children is 0.5-0.75 ha . Not more than 10-15% of the cultivated land area would be under this agriculture practice.

Terrace Cultivation:

In recent times, there has been an attempt by the governmental agencies like the local Soil Conservation Department to provide an alternative to jhum in the form of bench terraces for agriculture. The land is initially terraced by the Soil Conservation Department and handed over to the farmer. The same plot of terraced land is put into cultivation continuously for 6-8 years after which it may be abandoned probably due to decline in physical characteristics of the soil. The terraces are prepared into elevated seed beds alternating with furrows. The cropping pattern in terrace cultivation is similar to that in the 5 year jhum cycle where <u>Solanum tuberosum</u>, <u>Zea mays</u> and <u>Brassica oleracea</u> are grown. Cropping is done twice a year as in Jhum cultivation. This agriculture is characterised by heavy input of fertilizers with 3000 kg ha^{-1} of organic manure (pig-dung and vegetable origin) and some 741 kg ha^{-1} of inorganic NPK (1:1:1) fertilizers.

Terrace cultivation is rather rare in this region and is not a normal land use practice except on an experimental basis. The average size of terraced plots for a family of 5 members consisting of two adults and three children where-ever it is practised is about 1-1.5 ha. The reduced number of crops grown under terrace cultivation may be more related to the work power available in relation with working times as land preparation and weeding are major problems under this practice, rather than related to fertility problem since heavy fertilizer application is done in this case.

METHOD OF STUDY

Agricultural systems under three jhum cycles of 15, 10 and 5 years were identified around Shillong taking care to ensure the same topographic conditions. Sites under terrace cultivation and valley cultivation were also identified in the same area. Detailed observations were made on the various agricultural operations in each of these sites. All observations are based on two years of study during 1978-1979 using 7 field sites under each system. The entire field under cropping was taken into consideration for calculating yield data and therefore refers to the hectare effectively cultivated.

The soil was sampled from a depth of 0-14 cm on two occasions in the case of agro-ecosystem under 15 and 10 year jhum cycles, once in April just before seed sowing and again in December after one year of cropping. These two sampling were also done under 5 year jhum cycle and terrace cultivation except that a third sampling was done at the end of two years of cropping in the following December. The soil analysis data represents a mean of 10 replicates. Soil analysis was done by standard procedures obtained by Allen (1974). Thus carbon was determined by the Walkey-Black method, Organic nitrogen by the micro-kjehldahl method, No_3-N by the phenol-di-sulphonic acid method and Po_4-P by the phosphomolybdate blue method, both colorimetrically. Among cations, calcium and magnesium was determined by the EDTA titration method and potassium by the flame emission method after extraction of the samples in I N Ammonium acetate at pH 7. The concentration of nutrients upto a depth of 14 cm were converted into g m^{-2} using bulk density values.

The various weed species which came up during the cropping were analysed at their peak growth before first weeding in June for frequency, density and basal area using

I m^2 quadrats following standard procedures given by Misra (1968) and Kershaw (1973). The results are based on 20 observations in each site.

For the cost-benefit analysis, labour cost for m n and women workers were calculated on the basis of the present daily wage rates of Rs 9 and Rs 7 respectively. Cost of manure, chemical fertilizers and seeds were calculated as per the current market price. The monetary return for each of the agricultural systems was also calculated on the basis of the prevailing market price of each commercializable commodity. The economic sustainability of these systems were measured in terms of return per rupee invested or the monetary output:input ratio. The economic yield of different crops was also calculated. Economic yield refers only to the commercializable part which is edible.

The caloric values for the seeds of different crop species sown and the economic yield harvested were estimated after burning the samples in a bomb-calorimeter. The caloric values thus obtained (Table 2.1) were then expressed in terms of the seed sown or yield harvested per hectare. The caloric values given in the table are on the basis of the weight including the moisture content indicated.

For calculations on energy expenditure on labour, a man-hour under sedentary labour was considered equal to 0.1 hp and a woman-hour under moderate labour as 0.09 hp (Singh

Table 2.1. Caloric values for different crops/fertilizers

Category		Moisture content (%)	Energy value k cal kg^{-1}
Heat of combustion:			
Seed/ Grain	*Zea mays*	14.30	3397
	Oryza sativa	13.42	3429
	Phaseolus vulgaris	10.15	3357
	Cucumis sativus	8.97	2830
	Cucurbita maxima	8.20	5823
Leaf vegetable	*Brassica oleracea*	89.95	277
	Colocasia antiquorum	80.20	738
	Ipomoea batatus	80.00	625
	Solanum tuberosum	85.00	428
	Cucurbita maxima	82.00	600
Roots & Tuber	*Solanum tuberosum*	72.20	962
	Colocasia antiquorum	71.80	979
	Ipomoea batatus	70.00	1188
Stem vegetable	*Colocasia antiquorum*	92.80	168
	Ipomoea batatus	62.00	220
Fruit vegetable	*Cucumis sativus*	96.50	130
	Cucurbita maxima	93.00	257
Others	*Cucurbita maxima*(flower)	91.00	400
	Brassica oleracea(seedling)	89.00	262
	Ipomoea batatus(Stem cutting)	62.00	220
	Production cost[1]		
	N	-	18400
	P_2O_5	-	3335
	K_2O	-	2310
	Replacement cost[2]		
	Manure(oven dry)	-	332.01
	Bone meal(oven dry)	-	1403

(1) From Pimentel et al, 1973
(2) Percentage of N, P_2O_5 and K_2O in the manure sample was 1.4, 1.4 and 1.2 respectively. Percentage of N and P_2O_5 in the bone meal sample was 4 and 20 respectively.

and Chancellor, 1975 and Gopalan et al., 1978). Conversions of the horse power values thus obtained was done by considering one horse-power hour as equivalent to 641.5 kilo-calories of energy (Mitchell, 1979).

Energy inputs through chemical fertilizers was calculated on the basis of the fossil fuel energy that is required to manufacturer the chemical fertilizers (Table 2.1). The fossil fuel equivalents given in table 1 were used to calculate the replacement cost of the organic manure in terms of fossil fuel energy.

RESULTS

Soil fertility status of different agro-ecosystem:

A comparative study of the nutrient status of the soil under jhum agro-ecosystems suggests that carbon status in the soil initially was higher under a 10 year cycle compared to others. However, at the end of one year of cultivation under a 5 year cycle the level was much lower though there was a slight improvement at the end of the second year of cultivation. Nitrogen status in the soil was lowest under a 5 year cycle at the beginning of cultivation but improved at the end of cropping, more so under 10 and 15 year cycles. PO_4-P was maximum under a 10 year cycle initially as well as at the end of 1 year of cropping. In general, the cations were markedly lower under a 5 year cycle and very low values at the end of second year of cropping. While the initial values given under terrace cultivation was obtained before fertilizer application which accounts for the markedly low levels of nutrients compared to jhum agroecosystems, the values obtained at the one/two years of cropping show a generally sharper decline in fertility compared to even the agro-ecosystem under a 5 year jhum cycle (Table 2.2).

Phytosociology of weeds in different agro-ecosystems:

The data on weeds studied in jhum agroecosystems under 10 and 5 year cycle suggest (Table 2.3) that the weeds are generally more vigorous under the latter. Thus species like Alternanthera philoxeroides, Erigeron linifolium, Eupatorium adenophorum, Gnaphalium hypolencum, Gnaphalium luteoalbum and Imperata cylindrica are all more vigorous under the shorter jhum cycle. A comparision of the weed problem under terrace cultivation suggests that the weeds are in general more vigorous here compared to that under a 10 year jhum cycle (Table2.3).

Crop yield and economic return under different agro-ecosystem:

The input of seed/seedlings into the agro-ecosystems differ to some extent (Table 2.4). Zea mays and Brassica oleracea was emphasized more with the shortening of the jhum cycle though the input of tubers of Solanum tuberosum were also somewhat higher under a 5 year cycle. The seed input of vegetable crops like Cucurbita maxima and Cucumis sativus also was higher under a 10 year cycle than under 15 year cycle . Under terrace cultivation, only three crops were grown as in a 5 year jhum cycle of which Solanum tuberosum

Table 2.2. Nutrient status(g m^{-2}) of the soil (0-14 cm) before sowing and at the end of 1 year/2 years of cropping.

Nutrient	Jhum cultivation			Terrace cultivation
	15yr cycle	10 yr cycle	5 yr cycle	
C	2075 -2315	2182 -2333	2168 - 1973 (2058)	2518 - 1952 (1818)
N	294 - 326	295 - 334	259 - 278 (298)	291 - 258 (178)
PO_4 -P	0.379 -0.387	0.384-0.426	0.376-0.387 (0.367)	0.40[illegible]-0.345 (0.340)
K	66.5 -17.3	60.8-20.1	56.0 - 12.9 (9.5)	17.0 - 6.1 (6.2)
Ca	39.2 -16.6	32.4-18.6	25.6 - 6.4 (3.7)	17.7 - 9.9 (7.0)
Mg	25.9 - 9.7	27.0- 9.7	24.3 - 10.0 (7.3)	12.5 - 3.8 (2.3)

values in the parentheses indicate nutrient status at the end of second year of cropping.

Table 2.3 Intensity of weed problem under different agro-ecosystems before manual weeding.

Weed species	Frequency (%)			Density (individuals m^{-2})			Basal area (cm^2 m^{-2})		
	Jhum 10 yr cycle	Jhum 5 yr cycle	terrace	Jhum 10 yr cycle	Jhum 5 yr cycle	terrace	Jhum 10 yr cycle	Jhum 5 yr cycle	terrace
Ageratum conyzoides L.	60	90	80	7.1	6.5	7.5	2.84	3.50	4.5
Alternanthera philoxeroides Crai.	20	50	60	0.8	1.9	1.0	0.40	1.52	0.8
Chrysanthemum cinerarifolium(Trev) Vis.	30	60	40	1.0	1.5	0.6	0.20	0.45	0.18
Drymaria cordata (L.)Wild.ex Roem & Schulf.	20	70	50	1.3	2.5	0.9	0.13	0.375	0.135
Dicranopteris linearis Burm.f.	70	60	70	1.5	1.3	1.6	0.45	0.325	0.4
Erigeron linifolius Willd.	50	100	100	2.0	9.5	13.0	0.80	4.75	9.1
Eupatorium adenophorum Spreng.	90	100	100	29.0	32.4	27.8	5.80	6.48	5.56
Galinsoga parviflora Cav.	60	100	100	3.0	3.1	2.8	0.60	0.62	0.56
Gnaphalium hypolencum D.C.	-	60	40	-	1.0	0.7	-	0.20	0.14
Gnaphalium luteoalbum L.	-	50	50	-	0.9	0.8	-	0.18	0.16
Hypochaeris radicata L.	80	100	80	1.8	3.3	3.2	0.54	0.99	9.6
Imperata cylindrica P.Beauv.	60	100	100	11.0	16.1	6.1	2.20	4.025	1.83
Oxalis latifolia H.B.K.	100	100	100	17.3	28.6	13.1	1.73	4.29	1.965
Plantago major L.	70	100	70	2.0	2.9	7.2	0.50	0.87	2.56
Pteridium aquilinum (L.)Khun ex Decken	100	100	70	3.2	2.6	2.1	1.19	1.82	1.47

Table. 2.4. Seed sown (kg ha^{-1} yr^{-1} oven dry wt) and the number of seedling planted in different agro-ecosystem.

Category of seed/seedling	Jhum cultivation				Terrace cultivation (mean±S E)	Valley cultivation (mean± S E)
	15 yr cycle (mean±S E)	10 yr cycle (mean± S E)	[illegible] yr cycle			
			I yr crop (mean± S E)	IIyr crop (mean± S E)		
Root & Tuber crops:						
Solanum tuberosum	55.6±0.52	55.6±0.48	62.55±0.6	63.4±0.6	139±1.26	-
Ipomoea batatus	19.0±0.23	23.94±0.27	-	-	-	-
Colocasia antiquorum	0.49±0.03	4.23±0.11	-	-	-	-
Cereals:						
Zea mays	2.14±0.1	8.57±0.21	12.85±0.22	13.3±0.27	42.85±0.56	-
Oryza sativa	-	-	-	-	-	13.2±0.33
Legume:						
Phaseolus vulgaris	1.35±0.07	1.12±0.09	-	-	-	-
Vegetables:						
Cucurbita maxima	0.09±0.01	0.55±0.03	-	-	-	-
Cucumis sativus	0.23±0.02	0.36±0.02	-	-	-	-
Brassica oleracea	1200±40	1440±47	2640±42	2700±48	2610±45	-

was the major crop. Input of Solanum tuberosum tubers and Zea mays seeds were more here comparable to that for jhum cultivation.

The economic yield of different crops declined markedly with the shortening of the jhum cycle, this being particularly evident in the case of tuber crops like Solanum tuberosum which are emphasized most on these sites (table2.5). The yield of Zea mays improved under a 5 year jhum cycle(first year cropping) but this is chiefly due to the emphasis laid on this crop. Similarly, Brassica oleracea also showed higher yield under a 5 year cycle for the same reason. The number of different crop species cultivated under a 5 year jhum cycle were fewer in comparison to that under long jhum cycles of 15 or 10 years and the yield here was markedly reduced in the second year of cultivation compared to the first year.

The yield of Solanum tuberosum was lower under terrace cultivation than under a 15 year jhum cycle, though the yield of Zea mays and Brassica oleracea was higher in this casedue to greater emphasis placed on these two crops. Valley cultivation, on the otherhand was a monoculture of Oryza sativa, the yield of which was comparable though somewhat lower than the national average of 1145 kg ha yr for 1971-72 (Misra,1976).

Labour input accounted for a major proportion of the cost for inputs followed by that for seed input under all jhum cycles (Table 2.6). The cost of organic manure accounted

Table 2.5 Economic yield of crops (kg ha^{-1} yr^{-1} oven dry wt) under different agroecosystem

Crop species	Moisture content (%)	Jhum cultivation: 15yr cycle (mean±S E)	Jhum cultivation: 10yr cycle (mean±S E)	Jhum cultivation: 5yr cycle: Iyr crop (mean±S E)	Jhum cultivation: 5yr cycle: II yr crop (mean±S E)	Terrace cultivation (mean± S E)	Valley cultivation (mean± S E)
Root & Tuber crops:							
Solanum tuberosum	72.30	1579.95±23.75	1099.10±5.55	748.76±2.29	449.25±1.86	1236.48±2.41	-
Ipomoea batatatus	70.00	444.78±7.85	148.26±2.10	-	-	-	-
Colocasia antiquorum	71.80	4.87±0.27	5.57±1.91	-	-	-	-
Cereals:							
Zea mays	14.30	42.35±1.07	59.29±1.92	61.62±1.39	8.57±0.31	122.82±1.24	-
Oryza sativa	13.42	-	-	-	-	-	855.75±2.71
Legume:							
Phaseolus vulgaris	10.15	6.66±0.27	3.99±0.26	-	-	-	-
Fruit vegetables:							
Cucurbita maxima	93.00	272.43±3.67	257.55±1.95	-	-	-	-
Cucumis sativus	96.50	9.08±0.58	6.31 ±0.35	-	-	-	-
Leafy vegetables:							
Brassica oleracea	89.95	76.48±2.11	27.31±1.29	163.90±1.42	50.25±1.88	170.85±3.09	-
Colocasia antiquorum	80.20	2.38±0.13	2.47±0.15	-	-	-	-
Cucurbita maxima	82.00	3.09±0.24	2.79±0.27	-	-	-	-
Ipomoea batatus	80.00	0.98±0.07	1.13±0.15	-	-	-	-
Other vegetables:							
Colocasia antiquorum (stem)	92.80	0.44±0.02	0.41±0.02	-	-	-	-
Cucurbita maxima (flower)	91.00	0.41±0.02	0.47±0.03	-	-	-	-
By-products:							
Oryza sativa (straw)	10.73	-	-	-	-	-	2118±4.08

Table 2.6. Cost-benefit analysis for different agro-ecosystems (Rupees ha^{-1} yr^{-1}).

Production measures	Jhum cultivation				Terrace cultivation	Valley cultivation
	15 yr cycle	10 yr cycle	5 yr cycle: I yr crop	5 yr cycle: II yr crop		
Input costs:						
Labour	2220	2049	1613	1604	1022*	1522
Organic manure	-	175	287	537	870	104
Fertilizer	-	-	19	39	1431	-
Seed	1061	1206	1235	1254	2681	45
Interest on working capital (12%)	394	412	378	412	720	201
Outputs:						
Root & tuber crops	14711	9875	6463	3914	10675	-
Cereal grains	65	90	94	13	186	2822
Legumes	16	9	-	-	-	-
Fruit & other vegetables	4220	3908	-	-	-	-
Leafy vegetables	778	289	1631	500	1700	-
By-product	-	-	-	-	-	339
Cost of production(a)	3675	3842	3532	3846	6724	1872
Gross return(b)	19790	14171	8188	4427	12561	3161
Net return (b-a)	16115	10329	4656	581	5837	1289
Return per rupee invested(b/a)	5.4	3.7	2.3	1.2	1.9	1.7

*During the first year of terrace cultivation the terracing cost worked out to Rs.6239 for another input into jhum and this markedly increased with reduction in cycle time from 10 to 5 years; this was even more during the second year cropping under a 5 year cycle. Tuber crops accounted for a major monetary output and this declined with shortening of the cycle. Vegetatable like Brassica oleracea, Cucurbita maxima and Cucumis sativus accounted for another major monetary output from the jhum under 15 and 10 year cycles only. Eventhough the cost of inputs were more or less the same, the monetary output for jhum cycles of 15 and 10 year were 2-4 times more than that of the first year cropping under a 5 year cycle. The net return from the system declined sharply with shortening of the cycle and the return during second year cropping under a 5 year cycle was too meagre. Similarly return for a rupee invested followed the same pattern.

In terrace cultivation, labour cost for terracing alone worked out to Rs 6239 ha^{-1} which was more than half of the total cost of inputs. Labour for weeding and heavy cost of manure and fertilizers contributed to one of the major monetary inputs into the system. As in Jhum, Solanum tuberosum accounted for a major monetary outputs from the system. The net profit was only Rs 5837 ha^{-1} which was a little more than that from a 5 year jhum cycle during the first year cropping. The return per rupee invested also was not high (Table 2.6).

For valley cultivation too, the labour cost for weeding was high. Organic manure input cost was very low compared to other systems. Oryza sativa accounted for the only monetary output from the system both in the form of grain and by-products like straw and husk. The net return from this system and the net return per rupee invested was very low (Table 2.6).

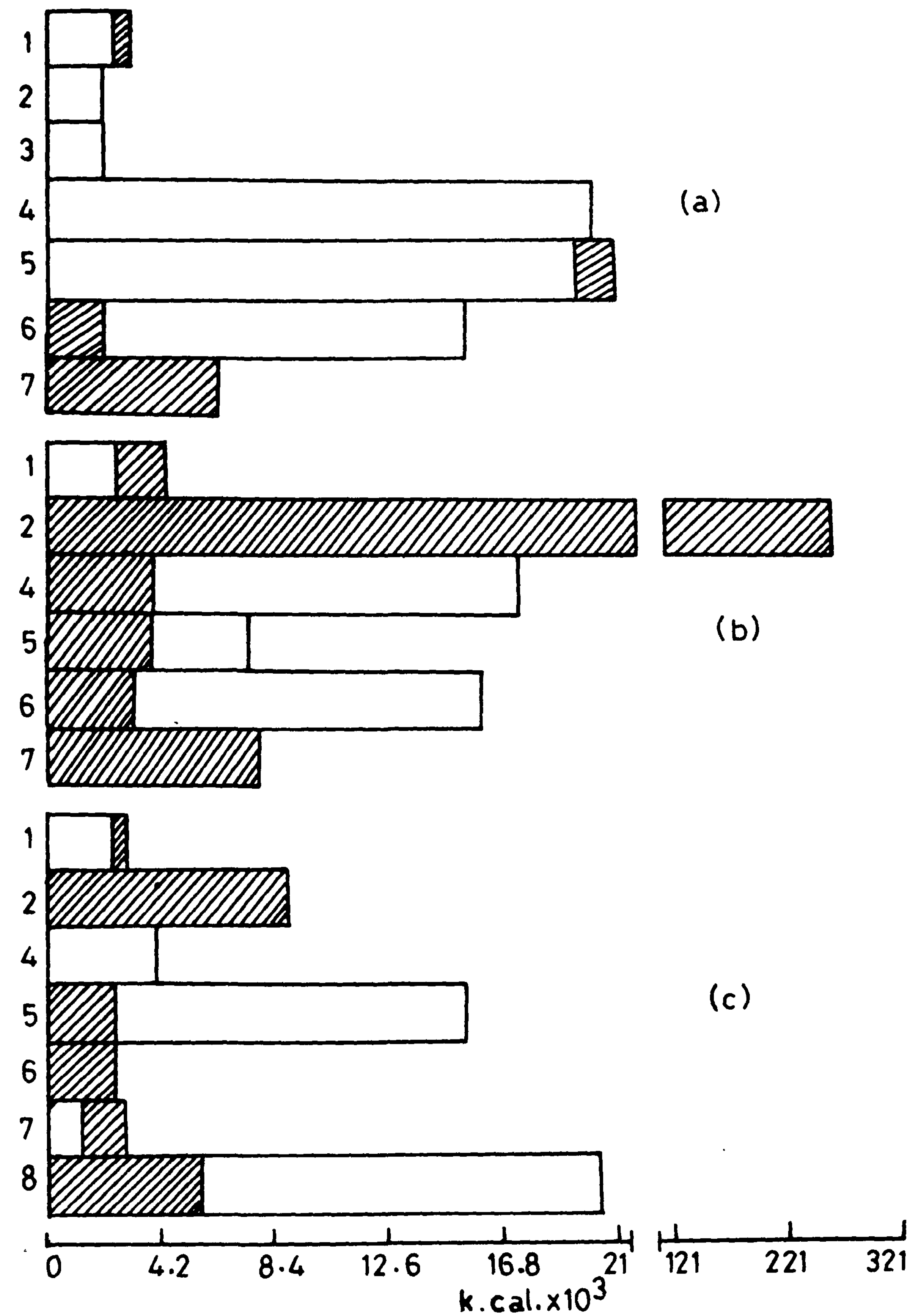
Energy budget of different agro-ecosystems:

The Khasi women performed most of the operations involved in jhum and valley cultivation (Fig.2.2). Figure 2.2a which shows the allocation pattern of labour between male and female for a 5 year jhum cycle, which was generally the same as for a 15 and 10 year cycle, showed that more than 65% of the total work was done by the female members of the family. However the work done by both male and female for the initial operation of slashing of understory vegetation was more or less the same. While preparation of land into ridges and furrows along with burning and seed sowing operation was an exclusively female operation, weeding and maintenance of the field was almost equally shared between male and female members. Transport of harvest and sale was exclusively done by the male members. On the other hand under terrace cultivation the land preparation was done by male members of the family and other operations like sowing, weeding and field maintenance, harvesting, etc. was mostly done by the females (Fig.2.2b). Under valley cultivation also the females contributed some 63% of the total labour input (Fig.2.2c).

Much of the energy input for jhum cultivation was in the form of labour energy. The slash and burn procedures including the land preparation involved an energy expenditure of

Fig.2.2 Allocation pattern of labour between male and female members of the family under different agricultural system(a,5 year jhum cycle; b, terrace cultivation; C, Valley cultivation). Hatched column,Male labour; open column,Female labour. 1,clearing the vegetation; 2, Land preparation; 3,Burning; 4,Seed sowing; 5,Weeding and field maintenance; 6, harvesting; 7, Transportation; 8, Threshing and milling.

FIG 2.2


1
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21143 and 9861 k cal ha^{-1} yr^{-1} for a 15 and 5 year cycle, respectively (Table 2.7) which is 17.5% and 10.5% of the total labour input into the system. Seed sowing by dibbling on the hill slopes was quite a laborious job. This operation involved 19.05% in the case of a 15 year cycle and 21.36% in the case of a 5 year cycle out of the total labour input that went into the systems. Seed input was to the extent of 64.56%, 45.32% and 37.93% of the total energy input in 15,10 and 5 year cycles respectively. Weeding and field maintenance operations required maximum energy expenditure for any single operation and it consumed 30.52%,33.92% and 42.67% of the total labour input in case of 15,10 and 5 year jhum cycle respectively. This operation was more laborious under a 5 year short cycle, particularly so during the second year of cultivation. For harvesting of crops 17.7% of energy was required under a 15 year cycle compared to 18.7% only under a 5 year cycle. Transport and sale of part of the harvest involves more energy expenditure with increase in length of the jhum cycle. It may be noted that all the cereals and legume, but only part of the tuber crops and vegetables are consumed by the farmers.

Use of organic manure and inorganic fertilizers formed another important source of energy input into the agroecosystems under 10 and 5 year jhum cycles only. This input accounted for 34.4% and 48.9% respectively, of the total energy input into these two jhum cycles.

Table 2.7. Energy inout (k cal ha^{-1} yr^{-1}) under different agro-ecosystems.

Agricultural operations	Jhum cultivation 15 yr cycle	Jhum cultivation 10 yr cycle	Jhum cultivation 5 yr cycle I yr crop	Jhum cultivation 5 yr cycle II yr crop	Terrace cultivation	Valley cultivation
(A) Labour input total	120518	117617	93619	88493	60680	63772
1. Clearing understory vegetation.	17088	16448	5707	-	- (6974)	- (5548)
2. Preparation of land	1997	2255	2189	3424	1427 (253623)	8877
3. Burning	2058	1933	1965	-	-	-
4. Seed sowing	22969	23354	20005	19973	21114	3995
5. Weed and maintenance of the field	36778	39899	39946	41540	11128	17976
6. Harvesting	21304	22018	17500	17439	19244	2568
7. Transportation	18324	11710	6307	6117	7767	4280
8. Threshing and milling	-	-	-	-	-	26076
(B) Seed input total	219621	263381	269272	273857	653567	53910
(C) Organic manure input total	-	200202	328690	614219	996030	91195
(D) Fertilizer input total	-	-	18276	36551	1370675	-
(E) Total energy input	340139	581200	709857	1013120	3080952	208877

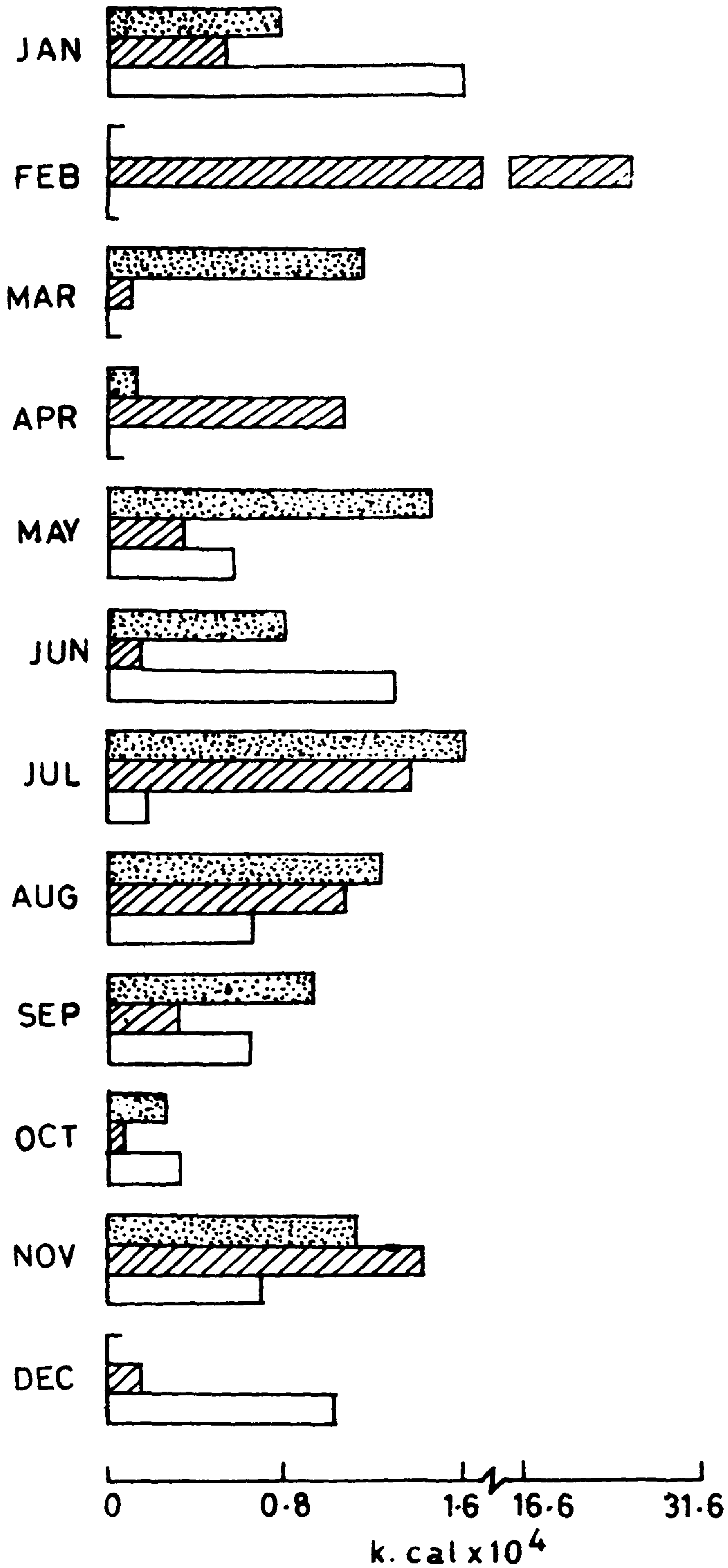
Figure in the parenthesis are the values of first year cultivation.

Converting a secondary forest into a terrace agro-ecosystem was very laborius and more than 79% of the labour energy was expended for this. In the subsequent years energy requirement for field preparation was only 1427 k cal ha^{-1}. Another major input into the terrace system was in the form of organic manure and inorganic fertilizers and this accounted for 76.8% of the total energy input and 70.8% if the initial land preparation cost alongwith the underbrush clearing cost are included in the final figure. Labour input needed for seed sowing, harvesting and transportation was more or less the same comparable to a 5 year jhum cycle. Input for weeding was less (11128 k cal ha^{-1} yr^{-1}) compared to 36778-41540 k cal ha^{-1} yr^{-1} for jhum agriculture (Table 2.7).

Of all the labour input required for valley cultivation, land preparation and seed sowing cost 20.2% of energy expenditure. Hand hoeing for weeding purposes and processing of the harvested crop (threshing and milling) were two major labour inputs which accounted for 28.3% and 40.9% of the total labour energy. Organic manure used in this cultivation was only a small fraction comparable to the other systems of agriculture. The pattern of labour distribution throughout the year for different jhum cycles was similar and therefore the the pattern for a 5 year cycle alone is given in Fig.2.3. Labour input is more or less uniformly distributed throughout the year though the input may be greater at certain times like during slash and burn, land preparation and harvest time. Maximum labour input was during July when the first crop is

Fig.2.3 Distribution pattern of labour over the year under different agricultural systems (Dark column, 5 year jhum cycle; Hatched column, Terrace cultivation; Open column, Valley cultivation).

FIG 2.3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k. cal x 10⁴

harvested and the second crop of Solanum tuberosum is sown. Another peak season for labour was in the month of May for weeding and repair of the ridges washed out by heavy rain. For terrace cultivation, maximum labour input goes during February when the land is terraced. In subsequent months the labour input was uniformly distributed except in July when the first harvest of Solanum tuberosum is done and in November when the second crop is taken out. Weeding is done throughout the cropping season. Under valley cultivation, more labour input went in June at the time of land preparation and seed sowing. With the sowing of Oryza sativa in June, the work was uniformly distributed for hand hoeing and weeding for the rest of the year upto harvest in November. Threshing and milling during December-January required maximum labour. Between February-April there was no work as the land was left a fallow.

Energy equivalents of the various crop harvested under different agricultural systems are shown in Table 2.8. Under a 15 year jhum cycle, the total caloric yield due to all the crops harvested was measured to be more than that for a 5 year cycle, the 10 year cycle falling in between the two. Of this, the energy output through Solanum tuberosum was proportionately more than that of others. It may be noted that under 5 year jhum cycle where cropping is done for the second year, the total energy output was drastically reduced to almost half.

11.7 and 2 times more caloric yield was obtained for tubers and cereals respectively, under terrace cultivation compared to the first year of the 5 year jhum cycle. Total caloric output from terrace cultivation was closer to a longer jhum cycle where as valley cultivation approximated to that of the first year cropping under a 5 year cycle only.

In Table 2.9, the energetic efficiency for the different agricultural systems in terms of the energy output: input ratio is presented. The efficiency of the 15 year jhum cycle worked out to be 25.6 and was drastically reduced under 10 and 5 year cycles. This ratio was even lower during the second year cropping under a 5 year cycle. The ratio for terrace cultivation was also very low and was the same as for the second year cropping under a 5 year cycle. Valley cultivation gave higher ratio though lower than under a 15 year cycle.

DISCUSSION

Mixed cropping accompanied by successive harvesting of the crops is a typical feature of slash and burn agriculture practised in different parts of the world (Schlippe, 1956; Conklin, 1957; Nye and Greenland, 1960). A much more complex pattern of mixed cropping where as many as 13 crop species are sown together at the same time and successively harvested at different times so that more space is created for the remaining species at the peak of their growth, has been shown for low elevation jhum in Meghalaya(Toky and

Table 2.8. Energy output (k cal ha^{-1} yr^{-1}) under different agro-ecosystems.

Crop species	Jhum cultivation				Terrace cultivation	Valley cultivation
	15 yr cycle	10 yr cycle	5 yr cycle			
			I yr crop	II yr crop		
(A) Tuber crops total:	7245598	4409826	2591041	1554625	4278784	-
Solanum tuberosum	5467335	3803363	2591041	1554625	4278784	-
Ipomoea batatus	1761329	587110	-	-	-	-
Colocasia antiquorum	16934	19353	-	-	-	-
(B) Cereal grains total:	167880	235032	244265	33970	486851	3389224
Zea mays	167880	235032	244265	33970	486851	-
Oryza sativa	-	-	-	-	-	3389224
(C) Legumes total:	24885	14931	-	-	-	-
Phaseolus vulgaris	24885	14931	-	-	-	-
(D) Fruit vegetables total:	1033928	969035	-	-	-	-
Cucurbita maxima	1000199	945585	-	-	-	-
Cucumis sativus	33729	23450	-	-	-	-
(E) Leafy vegetables total:	233032	97272	451748	138500	470913	-
Brassica oleracea	210816	75291	451748	138500	470913	-
Colocasia antiquorum	8808	9118	-	-	-	-
Cucurbita maxima	10319	9311	-	-	-	-
Ipomoea batatus	3089	3552	-	-	-	-
(F) Other vegetables total:	2834	3035	-	-	-	-
Colocasia antiquorum(stem)	1025	959	-	-	-	-
Cucurbita maxima(flower)	1809	2076	-	-	-	-
Total food energy output:	8708157	5729131	3287054	1727095	5236548	3389224

Table 2.9 Energy output:input ratio for different agro-ecosystems.

Agro-ecosystem	Energy k cal ha^{-1} yr^{-1}		Efficiency ratio
	Input total	output total	(output:input)
(A) Jhum cultivation			
15 yr cycle	340139	8708157	25.60
10 yr cycle	581200	5729131	9.85
5 yr cycle(I yr crop)	709857	3287054	4.63
" " (II yr crop)	1013120	1727095	1.70
Average for 5 yr cycle	-	-	3.17
(B)Terrace cultivation	3080952	5236548	1.7
(C)Valley cultivation	208877	3389224	16.22

Ramakrishnan, 1981). The main advantage of this system lies in that the fast depleting resources in short supply are utilised more effectively by the species in the mixture. It also provides the farmer an 'insurence policy', as some crops are likely to give a good return even if there is partial or complete failure of others. Further, the farmer gets all his diverse requirements of cereals, vegetables, tubers, etc. from the same field.

While the total yield of crops under a 5 year jhum cycle is markedly lower than that under a 15 or 10 year cycle, the yield of the individual crops obtained is dependent to a considerable extent on the amount of seeds sown. Thus a number of crops like Phaseolus vulgaris, Cucurbita maxima, Cucumis sativus, Ipomoea batatus and colocasia antiquorum are not at all sown under a 5 year cycle, whereas the input of seedlings of Brassica oleracea is double that under a 15 or 10 year cycle. One of the major causes for the low yield under a 5 year jhum cycle is the poor fertility build up during the intervening fallow period. This becomes more obvious during the second year of cropping under a 5 year cycle. This decline in fertility under a short jhum cycle of 5 years is more obvious for potassium, calcium and magnesium though carbon, nitrogen and phosphorus levels at the end of the cropping period generally was lower than under longer jhum cycles. The increase in carbon and nitrogen level under a given system may be related to the initial effect of fire which volatalizes a major fraction of these two elements which recover rather rapidly during the following mon hs (Ahlgren and Ahlgren, 1965, Ramakrishnan and Toky, 1981). Even phosphorus may be volatalized due to fire but may recover subsequently as seen from the present study and also suggested by Nye and Greenland (1960) and Zinke et al (1978).

It has been shown by Ramakrishnan and Toky(1981) that four to five years is not sufficient time to restore the soil nutrient status and improve the physical conditions of the soil. During the first few years of natural regeneration of a forest fallow rapid depletion of nutrients occur due to uptake by fast developing vegetation; release of the nutrients held up in the living biomass starts only after this phase of depletion. Besides, high rainfall on the steep cultivated slopes results in severe nutrient losses during cropping through erosion, surface runoff and leaching (Ramakrishnan et al.,1980). According to Watters (1971) agro-ecosystems under short fallow period suffered declining yield in the case of three major staple crops in Venezuela; maze decreased from 803 kg ha^{-1} to 640 kg ha^{-1} and yield of yucca and bean was reduced by 60% and 100% respectively.

Weeds are recognised to be another important cause for declining yield under slash and burn agriculture in many parts of the world and include Eupatorium odofatum in Thailand (Zinke et al.,1978), Imperata cylindrica in Sarawak (Freeman, 1955) and these weed species along with a few others also dominate at lower elevations of Meghalaya and other parts of the north-eastern India (Ramakrishnan et al.,1980). Eupatorium adenophorum and Imperata cylindrica are important weeds in the present study and a minimum of 10 years is needed for natural elimination of weeds like Eupatorium adenophorum and Imperata cylindrica (Ramakrishnan et al., 1980) and as the lands are cultivated frequently at intervals of 4-5 years, the secondary succession gets arrested at the weed stage over vast areas, aggravating the weed problem.

Although a heavy input of fertilizers goes into terrace cultivation, the yield is not very high. This may be due to the heavy losses through leaching which may be as high as 50% of the total losses from the system (Ramakrishnan et al., 1980). The yield of Oryza sativa in monoculture under valley cultivation is comparable to the national average for 1971-72 of 1145 kg ha^{-1} (Misra, 1976).

The cost benefit analysis for different jhum cycles shows that apart from monetary input for seed, one of the major inputs goes towards labour. Though this cost is higher under 15 and 10 year cycles compared to a 5 year cycle, a large proportion of the labour under the 5 year cycle goes for weeding as seen from the energetic study. This is due to the acute weed problem under a short jhum cycle, as discussed earlier. This is reflected in the net return from the different jhum systems where the return gets drastically reduced with the shortening of the cycle. A second year cropping under a 5 year cycle is not at all economical inspite of heavy inputs of fertilizers. For this region, terrace cultivation is also not profitable and hence has not been widely accepted by the local tribes. It may also be interesting to mention here that even under terracing the same piece of land is not cultivated for more than 6-8 years after which it is abandoned. Valley cultivation, which needs very little nutrient inputs because of natural drainage of these, is sustainable economically year after year.

The information on the energetics of 'Slash and burn' agriculture is rather scant and inadequate. However, Rappaport (1971) provides relatively complete information on the major energy inputs for raising various crops under the Tsembaga 'Slash and burn' agriculture (Swiddening) of New Guinea Highlands. According to his figures the Tsembaga people harvest 16.5 food colories for each calorie of energy input, which may go up to 20 food calories under more favourable conditions. This ratio is comparable to that obtained for a 15 year cycle which is drasticaly reduced with its shortening. A comparison of jhum with the more modern sedentary terrace cultivation tends to suggest the greater energetic efficiency of jhum particularly under longer cycle (Conkin, 1957; Carneiro, 1960; Nye and Greenland, 1960; Rappaport, 1968 & 1971; Steinhart and Steinhart, 1974; Bodley, 1976). Valley cultivation is one form of sedentary agriculture that seems to be efficient from an energetic point of view. Since slash and burn agriculture is chiefly dependent upon renewable resources of energy due to fixation of Sun's energy by plants during the fallow period, it is unrealistic to include this as one of the inputs into the system as was done by Ramboo (1978) while calculating an energetic efficiency ratio of 0.11 for this system. On the other hand, as in the present study, even the labour is in a way free as it comes from the members of the family practising jhum and if this is not considered as one of the inputs into the system, the efficiency may go even higher.

Comparing all the different systems of agriculture discussed above with the typical model for Indian agriculture with an energetic efficiency of 1:9 (Mitchell, 1979), a 10 year jhum cycle is favourably comparable to this where as a 15 year jhum cycle and sedentary valley cultivation are by far superior.

SUMMARY

Three agro-ecosystems, namely, slash and burn agriculture (Jhum), terrace cultivation (both of which involve mixed cropping) and valley cultivation of a monoculture of Oryza sativa, as practised in the higher elevations of Meghalaya, are compared and contrasted for their economic yield and energetic efficiency patterns. A comparatively longer jhum cycle of 15 year was contrasted with two others of 10 and 5 year. From an economic point of view, a 15 year cycle was most efficient followed by a 10 year cycle; a 5 year cycle was extremely inefficient, this being further aggravated in the second year of cropping. While the yield from valley cultivation was reasonable, terrace cultivation gave poor returns due to labour cost for terracing and maintenance and also due to heavy cost for fertilizers. Comparing the three jhum cycle from an energetic efficiency point of view, a 15 year cycle which is very rare now due to increased population pressure and reduced acreage was found to be the most efficient with an output:input ratio of 25.6 compared to 9.85 for a 10 year cycle and only 4.63 for a 5 year cycle. While the energy efficiency of valley cultivation was high (16.2) as it needs fewer inputs, that of terrace cultivation was very low (1.7) due to the heavy labour and fertilizer inputs required to sustain this. It is suggested that only a long jhum cycle of 10 years could be sustained alongwith valley cultivation, both from an economic and energetic point of view.

CHAPTER —— 3

ENERGY FLOW THROUGH A VILLAGE ECOSYSTEM WITH SLASH AND BURN AGRICULTURE (JHUM) AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.

INTRODUCTION

Incorporation of irreversible responses into a human society's system structure and organization reduces its flexibility making it difficult to adjust to any changes that may be imposed on it. The industrialized societies of today face such a problem owing to their strong dependence on petroleum and other fossil fuel products which are becoming scarce. The way many societies have evolved in the past in harmony with low levels of energy supply to the society may provide clues as to how modern societies could adapt to the limitations imposed by energy scarcity.

Apart from examining the relationship between food and energy, the present study on a typical Khasi village ecosystem under at higher elevations of Meghalaya in north-eastern India aims at:(i) an analysis of the range of inputs to produce different kinds of food, (ii) an understanding of the relations between energy, labour and land use pattern in food production, (iii) a study of the primary production, as the population lives close to the land, and relate it to secondary production, (iv) a consideration of the fuel requirements and the way in which it is presently met and (v) cost-benefit analysis from an economic point of view as it may be helpful in understanding the self-sufficiency of the system. Very few studies on energy flow through village ecosystems under subsistence farming (Rappaport, 1971; Odum, 1971; Leach, 1976) are available.

Hence, during this study, the energy flow patterns through various compartments of the village ecosystem under 'slash and burn' agriculture (locally called Jhum) has been analyzed as this is a society adapted to low-energy inputs.

VILLAGE ECOSYSTEM

This study was done at Setthliew village (25.25°N, 91.52°E), 25km south of Shillong in the Kahsi hills of Meghalaya, at an elevation of 1540 m, where 'slash and burn' agriculture is practised by the local Khasi tribe. The climate here is monsoonic with most of the average rainfall of 1843 mm occurring during the monsoon period from May to September. The average maximum temperature during this season is 23.7°C and the average minimum temperature is 16.3°C. The humidity remains very high during this period (84.1%). Winter is cold with occasional showers, extending from November to February with an average minimum temperature of 7.6° C. During December - February, frosts are very common. The brief summer which is warm and dry extends from March to April and is accompanied by strong wind. The entire area is characterised by pine forests with Pinus kesiya as the only dominant species. The terrain is hilly with steep slopes, the average angle being 30°- 40°. The soil cover is scant as erosion outstrips the weathering process and is podsolic.

Setthliew is a small village with 5 families and a total population of 20, with 12 adults and 8 children.

The families are of an average size of 4 members and live in huts made of locally available stone, bamboo and thatching grass (*Imperata cylindrica*). Agriculture with *Solanum tuberosum* as the major crop and animal husbandry with emphasis on swine forms the main economy of the village. For convenience of study, the structural organization of the Setthliew village ecosystem can be described under the following sub-systems: (i) agriculture under jhum, (ii) that under valley cultivation, (iii) animals constituting animal husbandry and (iv) humans forming the domestic sub-system.

The jhum sub-system:

Jhum is extensively practised throughout the north-eastern hill region of India. In its typical form this agriculture in the north-east region consists of clearing the forest and burning the dried slash before cultivatinn of cfops for a year or two. However, in the higher elevations of the Khasi hills, as in the present case, this agricultural practice is a modified version in that normally only the lower branches of sparsely distributed trees are felled instead of the whole trees. Slashing is done in December. Further, unlike the system practised at lower elevations where cropping is done directly on the slopes by dibbling, at higher elevations the land is prepared into ridges and furrows running along the slope of 30^{o}-40^{o}. While the slash is burnt directly on the surface of the soil in its typical form, in the present case the slash is placed along the ridges, covered over by a thin layer of soil before slow and controlled burning during March. Before cropping, organic manure of vegetable and pig dung origin is applied at the rate of 640 kg ha^{-1} (dry weight basis).

A mixture of 6 root and tuber crops, like Solanum tuberosum, Colocasia antiquorum and Ipomoea batatus, Cereal like Zea mays, legumes such as Phaseolus vulgaris and vegetables like Cucurbita maxima are grown together. However, major emphasis is placed on S.tuberosum. After burning and a few weeks before the onset of monsoon, the tuber crops are planted on the ridges and the rest of the crops are sown on the ridges after the first few rains. Along each ridge, three distinct rows of sowing are done by dibbling the seeds of both S.tuberosum and Z.mays mixed together. While sowing of C.antiquorum is confined to the top and bottom part of the ridges, C.maxima is sown at random, but widely scattered on the ridges. P.vulgaris is mostly planted around the pine trees which provide support to this climber. After the first harvest of tuber crops in July-August, a second crop of winter potato alone is sown along the ridges. Harvesting of Z.mays and P.vulgaris is done in September-October and that of the winter potato is done in November after which the land is abandoned for forest regeneration. The jhum cycle (the time lapse before the same piece of land is cultivated again after a fallow period during which, time natural regeneration of vegetation is allowed to take place) in the present study site was 10 years. While a longer cycle of 15-20 years in the region is extremely rare, a 4-5 year cycle is most common. After 'Slash and burn', cropping is done for 1-2 years only before the land is abandoned. In Setthlicw village 5 ha of land was under jhum agriculture.

In jhum, the major inputs are seed, organic manure and manpower. Seed is obtained from the previous year's stock. Manure is generated in the compost pit within the village itself from crop residues and animal dung, the by-products of agriculture and animal husbandry. Manpower is also generated from within the village ecosystem itself. Other power such as draught animal power, gasoline or electric engine power is not at all used. Tools and implements used for various agricultural operations ar very simple and of primitive type, either made within the village or, rarely, imported ; in either case the cost is negligible.

Part of the slash is burnt in situ for agriculture while the rest is used as fuel in the domestic sub-system described below. Part of the crop yield is consumed within the village and a part is exported. A major fraction of the by-products from jhum go into the compost pit, some may be used by the animals while a small fraction goes into the domestic sub-system for fuel.

The valley sub-system:

The valley lands of the village (2 ha in the present case), under cultivation, are included in this sub-system.

Wet cultivation of Oryza sativa is done in the flat lands of the narrow valleys situated in between the hills. Except for a small quantity of imported bone meal (65kg ha^{-1} yr^{-1}), other fertilizers are not used here. The valley receives natural drainage of nutrients from the adjoining hills and this sustains continued cultivation year after year. Labour is the major input for all the agricultural operations like field preparation, sowing, weeding, harvesting, processing of the harvested crops (threshing and milling), etc. as is also the case for jhum. Unlike at lower elevations where two crops of O.sativa may be raised (Toky and Ramakrishnan, 1981), only one crop of O.sativa is obtained at higher elevations.

The only simple implements used for valley cultivation of rice are hand hoes and sickles which are imported, the cost of which is negligible. The output utilization pattern is similar to that described for jhum.

The animal husbandry sub-system:

Animal husbandry consists chiefly of pig production, which is the chief protein source for the village, but part of which is exported. In addition, some goats are kept exclusively for export and poultry may be raised for internal use and also for export. The juvenile animals are imported. S.tuberosum and I.batatus of poorer quality not consumbed by humans may be fed to pigs, but the vegetable waste in the compost pit of the village is the chief source of food for swine husbandry. Poultry are fed partly on maize grains but they too depend upon vegetable waste. Goats are allowed free to browse on plants. The compost pit which is the main source of food for the animals also generates about 3684 kg yr^{-1} (dry weight basis) of organic meanure used for agriculture.

<u>The domestic sub-system</u>:

Agriculture and animal husbandry form the main occupation of the inhabitants of Setthliew village. Consumption of food energy generated within the village ecosystem provides the manpower required for production. The food production system of the village (agriculture and animal husbandry) is basically labour intensive requiring large inputs of man-power and thus allowing little time for other activities. Energy required for coocking comes from the renewable biological sources such as fuel wood and crop residues. However, a major part of this comes from the forest outside the village. Other basic requisities of the villagers such as clothing and medicine also come from the market outside the village ecosystem.

METHODS OF STUDY

For this study, all the five households of Setthliew village with their agriculture and animal husbandry subsystems were taken into consideration (Table 3.1). All observations related to the energy flow study through the

Table 3.1. A Khasi village ecosystem structure at Setthliew (1978-79).

Number of households	5
Total population:	20
Adult male	5
Adult female	7
Children 5-7 year old	4
Children7-9 year old	2
Children 9-12 year old	2
Total area under cultivation (ha):	7
Under jhum(ha)	5
Under valley (ha)	2
Total animal population:	45
Pigs	16
Goats	9
Fowls	20

village ecosystem are based on two-year study period. Inputs and outputs of diverse types (heat of combustion, nutritive value, replacement cost in terms of fossil fuel, etc.)are assumed to be homogeneous. Inputs of energy due to tools/implements was negligible. Other basic requisites of the villagers like clothing and medicine are excluded from the study due to difficulties in accounting the energy values for them.

Solar energy which is the primary source of energy as well as slash burnt during agriculture do not enter the calculations for energetic efficiency as they are considered to be 'free' inputs and no special effort goes into obtaining these.

Amount of seed/seedlings sown in the field and economic yield were based on 7 observations in each of the 5 fields. The energy values for the seeds of different crops sown and the economic yield of various crop/fodder harvested were estimated after burning the samples in a bomb calorimeter. The value thus obtained (Table 3.2) were then expressed in terms of the seed sown or the yield harvested per ha and also for the total cultivated area. The energy values given in the table are on the basis of the oven-dry weight of the samples at 80°C. Calculations of the amount of slash burnt in jhum was based on 7 observations in each field and the calculation of the fuel wood collected from the jhum field was based on the observation that 1/10 of the total

Table 3.2. Energy value of crops and manure.

	Category	Av.water content (%)	Energy value MJ kg^{-1}
	a) Heat of combustion:		
	Solanum tuberosum	72.20	14.478
Root/Tuber	Colocasia antiquorum	71.80	14.525
	Ipomoea batatus	70.00	16.570
	Zea mays	14.30	16.585
	Oryza sativa	13.42	16.571
Seed/Grain	Phaseolus vulgaria	10.15	15.633
	Cucurbita maxima	8.20	26.539
Fruit vegetable	Cucurbita maxima	93.00	15.357
Others	Ipomoea batatus(stem cutting)	62.00	2.421
	Slash	18.11	17.142
	Solanum tuberosum(leaf & stem)	67.61	17.425
	Zea mays(leaf,stem & cob)	24.73	17.994
By-products	Oryza sativa(husk)	10.13	18.390
	Oryza sativa(straw)	10.73	13.831
	b) Production cost[1]:		
	N	-	76.986
	P_2O_5	-	13.954
	K_2O	-	9 .665

(contd...)

c) Replacement cost[2]:

Pig dung	-	1.318
Goat dung	-	1.996
Fowl dung	-	4.782
Manure(dung and vegetable matter)	-	1.464
Bone meal	-	5.870

---

1. after Pimentel et al.(1973).

2. percentage of N, P_2O_5 and K_2O in various items was as follows: in manure, 1.5,1.4 and 1.2; in pig dung, 1.4, 0.83 and 1.3; in goat dung 2.2,0.8 and 1.97; in fowl dung, 5.14, 4.19 and 2.5; in bone meal, 4, 20 and 0.

slash produced is used as fire wood. The values were then expressed in terms of their energy equivalents using the value of 17.142 MJ kg^{-1} for slash, calculated using the bomb calorimeter. Energy input through organic manure was calcucated on the basis of their replacement cost values in terms of fossil fuel. Fossil fuel equivalents for N, P_2O_5 and K_2O given in Table 3.2 were used to calculate the replacement cost of the organic manures.

For calculation on energy exdenditure on labour, a man hour under sedentary labour was considered equal to 0.1 hp and a women hour under moderate labour as 0.09 hp (Singh and Chancellor, 1975;Gopalan et al., 1978). Conversion of the horse power values thus obtained was done by considering one horse power hour as equivalent to 2.6845 MJ of energy. Calculation of the energy expenditure on cartage is based on the work performed by the number of horses employed.

For thw estimation of annual meat production, the weight gained by each category of animal at the time of slagghter was calculated and the values thus obtained were corrected using a dressing percentage of 75,56 and 70 for pig, lamb and fowl, respectively, as suggested by Ranjhan (1977). Using the energy values of 4.937, 4.560 and 7.238 MJ kg^{-1} for goat meat, chicken and egg respectively (Gopalan et al.,1978) and 17.121 MJ kg^{-1} for pork (Ranjhan, 1977), the energy equivalent of secondary production of meat and poultry was calculated.

Estimation of the actual amount of food/fuel consumed by humans was done on the basis of regular observations in the village, and the energy equivalent of all the items consumed were calculated using their respective energy values given in Table 3.2. The estimation of the feed/fodder consumed by the live-stock was based on the daily rations given to the animals by each household. For calculation of browsing by the animals it was assumed that the energy equivalent for this would be equal to the value obtained after substracting the energy value of the actual feed consumed (based on our observation) from their standard food energy requirement (Ranjhan, 1977).

The protein equivalent of all food (crop and meat) harvested and that part of it consumed by the villagers was found out by multiplying the quantities of food and their respective protein contents (Table 3.3), estimated calorimetrically by the standard method followed by Lowry et al. (1951).

For calculating the theoretical food energy/protein requirement of humans, the total consumption unit (adult man value) for the whole village was calculated as per the energy consumption scale suggested by Gopalan et al. (1978): 1 adult male, 1 unit; 1 adult female, 0.9 unit; children of 5-7 years, 7-9 years and 9-12 years, 0.6,0.7 and 0.8 unit, respectively. The total number of units for this village works out at 16(5+5.6+2.4+1.4+1.6). This was then multiplied by the food

Table 3.3 Protein content of various food items (dry weight basis).

Category	Protein ($g\ kg^{-1}$)
Crops:	
Solanum tuberosum	46.8
Colocasia antiquorum	99.3
Ipomoea batatus	43.3
Zea mays	128.4
Oryza sativa	83.2
Phaseolus vulgaris	237.0
Cucurbita maxima	214.3
Animal products:*	
Pork	831
Goat meat	839
Chicken	935
Egg	500

*Pork, goat meat and chicken contain 77.5%, 74.5% and 72.3% moisture.

energy equivalent of an adult (1 unit) of 10.042 MJ day^{-1} and the protein equivalent of an adult (1 unit) of 55 g day^{-1} (Gopalan et al.,1978) to calculate the daily food energy/ protein requirement of the different categories of humans. The values of food energy thus obtained (nutritive values) were then corrected to the heat of combustion by multiplying with the co-efficient of 1.149 (Mitchell, 1979). To find the energy equivalent of fuel wood needed per day for cooking purposes it was assumed that the potential energy required for 1 adult man (1 unit) would be 15.759 MJ (Mitchell,1979). This was then multiplied by 16 units obtained for the whole village.

For the economic input: output analysis of the village ecosystem, labour costs for men and women workers were calculated on the basis of the present daily wage rates of Rs 9 and Rs 7 respectively. The cost of organic manure, seed, live-stock and the food, fuel and fodder used in the village were calculated at their current market prices. The monetary return in terms of crop, fodder, meat and eggs from agriculture and animal husbandry were calculated from the prevailing market price of each commodity.

RESULTS

The Jhum sub-system:

The jhum is a low energy input system involving labour, manure and seed as the only inputs. Of the total labour energy input of 2872 MJ(11263 man hours) of energy

787 MJ of energy is expended in clearing the fallow and field preparation while 947 MJ is expended in weeding operations alone. The rest goes for seed sowing, harvesting and transport of the crops. Slash which is burnt during jhum accounting for 326.7×10^3 MJ of energy is in a way 'free' to the farmer and therefore is not considered as an input.

The output from jhum is chiefly economic crop yield and the plant by-products. Out of 99.6×10^3 MJ of energy yield from crops, 69.1×10^3 MJ is obtained from potato alone, with other crops forming minor components of the system. The output: input ratio works out to 6.82 to 10.01 depending upon whether the crop yield alone or other secondary outputs are also considered. For every unit labour energy input into the system, 34 units of energy was harvested as economic crop yield. The results are presented in Fig.3.1a.

The valley sub-system:

Apart from labour and seed, small quantities of bone meal go into valley cultivation of rice, which otherwise receive nutrition from hill slopes through drainage. Because of very low energy input and due to high energy output through grain yield and by-product such as straw and husk, the output; input ratio is very high. For every unit of labour energy input, the economic crop yield works out to 86 units (Fig.3.1b).

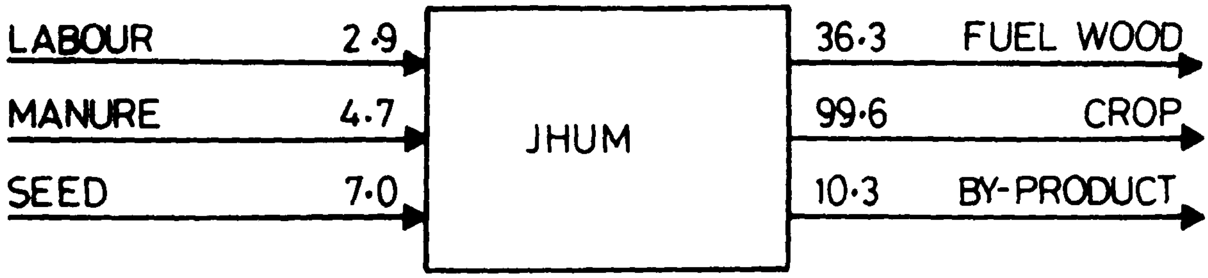
Fig.3.1 Energy input:output pattern and efficiency ratios.

a, jhum sub-system; b, valley sub-system.

Unit = MJ x 10^3.

FIG 3.1

(a)



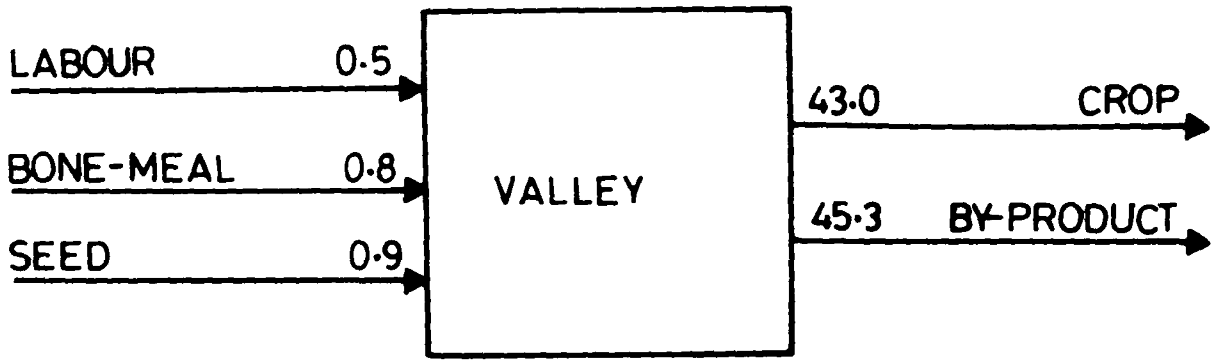
Output : Input ratios

Crop = 6·82

Crop + by-product = 7·53

Crop + by-product + fuel wood = 10·01

(b)



Output : Input ratios

Crop = 19·55

Crop + by-product = 40·14

The animal husbandry sub-system:

A major fraction of the total energy input for animal husbandry is the feed; crops accounted for about 4.9% while the crop residues plus browsing accounted for the rest of the input. Besides juvenile animals, labour for rearing animals was another input into the sub-system. Apart from meat, dung was an important output from the system. The output: input ratio is low if by-products and grazing are included as inputs into the system but higher if they are excluded (Fig.3.1c).

The domestic sub-system:

Food and fuel for cooking are two inputs into this sub-system which generates man-power(4.2×10^3 MJ) used for agriculture and animal husbandry. The energy efficiency (output: input ratio) of this system works out to a low 0.03 (Fig.3.1d).

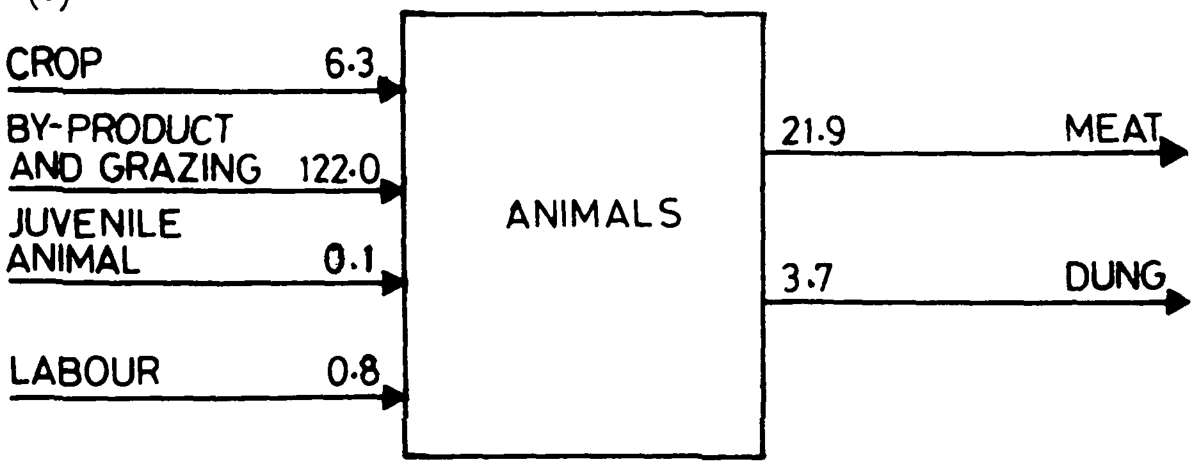
The village ecosystem:

A large fraction (98%) of the input into the village ecosystem comes as fuel wood of which only a part is obtained from within the village. The major output exported out of the village are crops accounting for about 85%, meat and eggs contributing the rest. The energetic efficiency(output: input ratio) worked out to be low (1.57) compared to other sub-systems, except the domestic one (Fig.3.1e). It may be noted here that other inputs like clothing and medicine are

Fig.3.1 Energy input:output pattern and efficiency ratios. c, animal husbandry sub-system; d, domestic sub-system. Unit = MJ x 10^3.

FIG 3 1

(c)



Output : Input ratios

Meat (+ by-product + grass) = 0·17

Meat (− by-product + grass) = 3·04

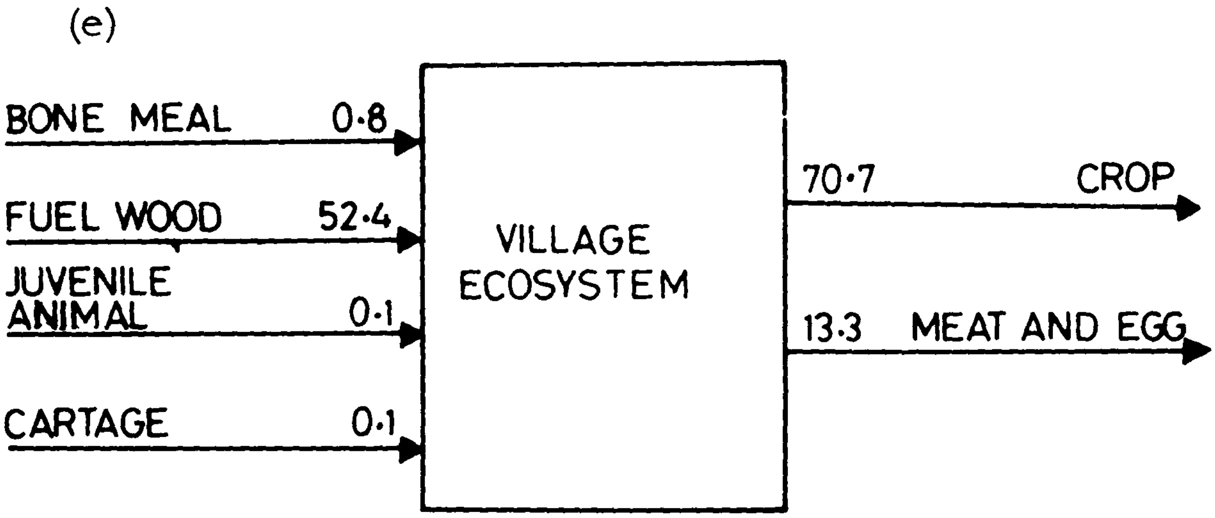
Meat + dung = 0·20

(d)

Output : Input ratio = 0·03

Fig.3.1 Energy input:output pattern and efficiency ratio. e, village ecosystem. Unit = MJ x 10^3.

FIG 3.1



Output : Input ratio = 1·57

also imported into the village but have not been included in this study.

About 70% of the protein yield is of plant origin and the rest is of animal origin. Rice (oryza sativa)is the staple diet of the people. This, along with Zea mays accounted for over 70% of the total food energy and about 67% of the protein consumed by humans. Pork is the only form of meat consumed and this account for about 13% of the total food energy consumed by the village (Table 3.4).

Table 3.5 presents the fire wood consumption pattern in the village ecosystem. Energy for cooking is mainly in the form of fire wood and rice husk. 3060 kg of fire wood (52455 MJ) is imported into the village in a year, accounting for about 58% of the total consumption of this commodity. The fuel consumed is close to the standard requirement for cooking under Indian conditions (Mitchell, 1979).

Of the total food energy exported out of the village ecosystem, about 85% was from crops of which potato (Solanum tuberosum) alone accounted a major fraction. About 92% of the meat export out of the village was in the form of pork (Table 3.6).

Fig.3.2 which represents the economic pattern for the village ecosystem shows the various inputs into the village as compared to outputs. The net income of a single household consisting of 4 members was Rs 963. The monetary output;input ratio for this village is fairly high coming to 19.62.

Table 3.4. Annual food and protein consumption in the village ecosystem.

Category	Food		Protein equivalent
	Quantity (kg)	Energy equivalent (MJ)	(kg)
Solanum tuberosum	88.96	1288	4.16
Colocasia antiquorum	43.30	629	4.23
Ipomoea batatus	360.00	5965	15.59
Zea mays	342.80	5685	44.02
Oryza sativa	2567.00	42538	213.57
Phaseolus vulgaris	10.78	169	2.55
Cucurbita maxima	28.00	430	6.00
Pork	112 .50	8560	93.49
Total :		65264 (67383)	383.61 (321.20)

Values in parentheses are the standard requirements.

Table 3.5. Annual fuel consumption for cooking in the village ecosystem.

Category	Quantity(kg)	Energy equivalent(MJ)
Fire wood	5033	86276
Rice husk	328	6032
Total:		92308 (92033)

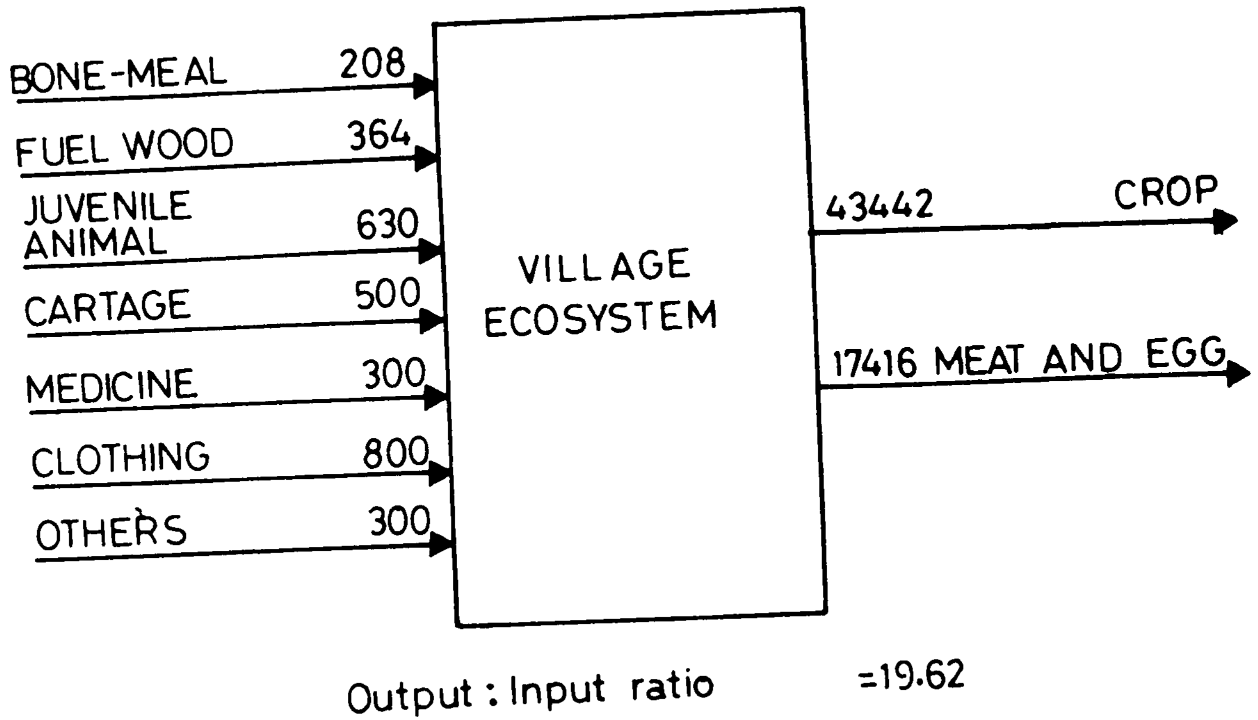
Value in parenthesis is the standard requirement.

Table 3.6.Annual energy export from the village eco-system.

Category	Energy (MJ)
Solanum tuberosum	61821
Ipomoea batatus	1640
Zea mays	514
Cucurbita maxima	6772
Crop export total:	70747
Pork	12259
Goat meat	933
Chicken	68
Egg	78
Meat and egg export total	13338
Grand total:	84085

Fig.3.2 Monetary input:output pattern and efficiency ratio of the village ecosystem. Unit = Rupee.

Fig 3.2


BONE-MEAL
208
FUEL WOOD
364
JUVENILE ANIMAL
630
CARTAGE
500
MEDICINE
300
CLOTHING
800
OTHERS
300
VILLAGE ECOSYSTEM
43442
CROP
17416 MEAT AND EGG
Output : Input ratio
=19.62

The detailed economic input:output analysis for the various sub-system of the village ecosystem is shown in Table 3.7 which indicates that the net return of jhum is 10 times more than that of valley sub-system and the net return from animal husbandry is somewhat less than the return from jhum. However, the return per rupee invested is more than double for animal husbandry compared to jhum. The monetary output: input ratio for the valley sub-systems is much less (1.84) compared to the other two sub-systems. In the domestic unit, there was a net loss of Rs 5307 per year and thus the output: input ratio worked out at 0.76.

DISCUSSION

Land use:

Slash and burn agriculture (jhum) which is the most important land use practise in the north-eastern hill regions of India, in the present case has a 10 year jhum cycle which make it not only economically sustainable as shown for the low elevation situation (Toky and Ramakrishnan, 1981) but also permit sufficient time for nutrient recovery during the fallow period (Ramakrishnan and Toky, 1981). One of the chief advantages of jhum is that it provides an all-crop diet for the people out of the same land (Leach, 1976). As labour is the chief input and is based on the simple way in which solar energy is harvested through forest, the system is efficient from an energetic point of view. Thus it has been held up as a model of productive efficiency where 5 to 50

Table 3.7 The monetary input:output pattern in various sub-systems of the village ecosystem(rupees per annum).

Category	Jhum	Valley	Animal husbandry	Domestic
Inputs:				
Labour	10926	2801	3285	-
Manure	928	-	-	-
Bone meal	-	208	-	-
Seed	6437	180	-	-
Juvenile animal	-	-	630	-
Food	-	-	-	18782
Feed	-	-	118	-
Fuel wood	-	-	-	562
Interest on working capital(12%)	2195	383	484	2321
Total:	20486	3572	4517	21665
Outputs:				
Crop	51030	6000	-	-
By-product	-	581	-	-
Meat and egg	-	-	27489	-
Manure	-	-	1068	-
Manpower	-	-	-	16358
Total:	51030	6581	28557	16358
Net return	30544	3009	24040	-5307
Return per rupee invested(output: input ratio)	2.49	1.84	6.3	0.76

units of food energy are harvested for each unit of input (Rappaport, 1971; Steinhart and Steinhart, 1974; Toky, 1980) compared to the energy-intensive agricultural systems of the western countries (Daniel, 1956; Black, 1971; Pimental et al., 1973; Spedding and Walsingham, 1976; Pimental and Pimental, 1979).

Valley cultivation has many advantages over jhum in that soil and nutrient losses are heavy from the slopes from land under jhum (Ramakrishnan et al., 1980). The former is a nutrient sink without any major losses from the system. This makes the system 3-4 times more energy efficient than jhum. From a monetary point of view jhum is more favourably placed due to diversification of crops and the higher returns from potato compared to rice. However, land use under this system in the hilly terrain is restricted for want of suitable sites. But, a distinct advantage that valley cultivation of rice has over jhum is that the re-use factor for the former is 1 whereas that for the latter is 0.1/0.2 (ie.the land is cropped only once or twice in 10 years). The energy output:input per ha per year for both the systems work out similar to that discussed by Leach (1976) for pre-industrial farming with jhum showing up badly due to the low re-use factor.

Animal husbandry:

With an energy expenditure of 18.8 x 10^6 MJ over a 10 year period for raising a single pig under Tsembaga swine husbandry in New Guinea highlands (Rappaport, 1971) and with only 1.5% return on the food energy feed to pig as per calculations of Pimentel and Pimentel (1979), this system is not very efficient though it is a practical way of storing excess food energy. The efficiency of the system studied here is, however, much better because of the lighter demands on the farmer. Thus the animals are chiefly dependent upon vegetable waste and browsing besides cheap feeds like poor quality tubers unfit for human consumption. Further the slaughter of pigs every year as they mature rather than every 10 years during festival time as in the Tsembaga system also help in bringing down the energy cost for rearing.

Apart from this sub-system forming an important link in the detritus food chain, it provides a protein rich diet, nutrient rich manure and a subsidiary source of income as excess meat and poultry products are sold in the market. In fact, animal husbandry from its economic angle, is markedly superior to agriculture with high returns per rupee invested because very low monetary input and high selling price of meat.

Fuel wood:

Fuel for cooking is an important need of the domestic sub-system, more than 50% of which are imported from outside the village ecosystem. One of the consequences of shortening of the jhum cycle (Ramakrishnan et al., 1980) has been a fast depletion in the fuel wood resources of the region.

This is agravated due to low efficiency of utilization of fuel wood energy in the developing world (Leach, 1976), where the per capita consumption of energy for cooking is considered to be 2.5 to 5 times more than in the west.

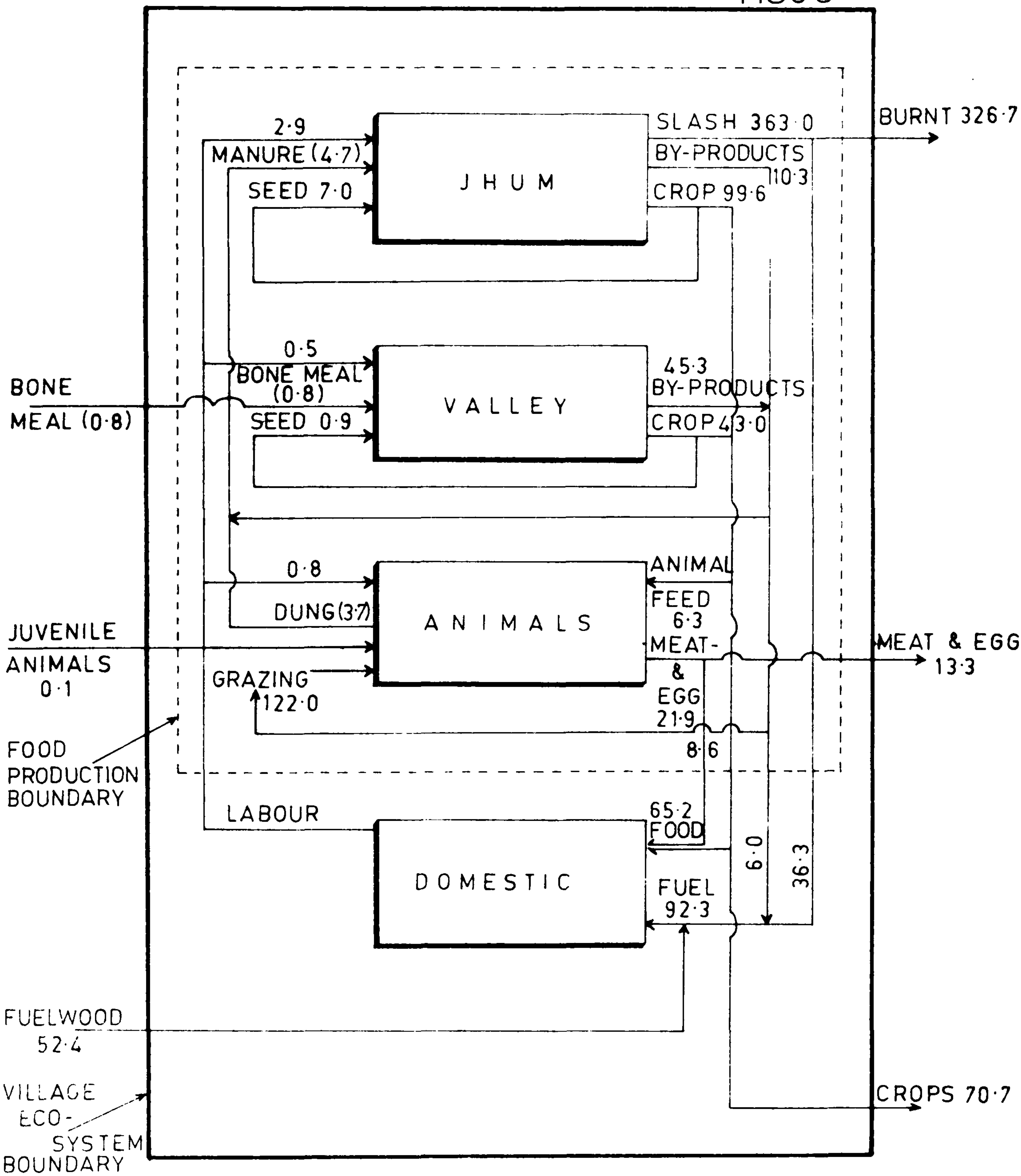
Village ecosystem function:

The schematic presentation of energy flow through the village ecosystem (Fig.3.3) brings out the intricate relationships existing between the agricultural, animal husbandry and domestic compartments. Utilization of renewable resources of the forest in the form of slash alone forms the basis for the functioning of the system. The compost pit is an important component of the system as it provides food for secondary production and generates organic manure which is cycled back into agriculture. The annual manure output in terms of N, P and K works out 55.26, 51.57 and 44.21 kg, respectively which is significant.

The per capita food production in the village exceeded the food energy consumed by the people by 16.64 MJ per day. A small fraction only of this extra energy was utilized for maintaining pig and poultry, some kept as seed so that the rest (84×10^3 MJ per year) is exported out of the village. While developed countries use heavy inputs of commercial energy for food production (Leach, 1976; Stout et al., 1979), developing countries depend on large inputs of human labour. Thus Revelle (1976), in a study of rural India, estimated

Fig.3.3 Energy flow model for the village ecosystem at Setthliew. Values within parentheses refer to the replacement cost in terms of fossil fuel. Unit = MJ x 10^3.

FIG 3.3



JHUM
SLASH 363·0
BURNT 326·7
BY-PRODUCTS
10·3
CROP 99·6
2·9
MANURE (4·7)
SEED 7·0
VALLEY
0·5
BONE MEAL
(0·8)
SEED 0·9
45·3
BY-PRODUCTS
CROP 43·0
BONE
MEAL (0·8)
ANIMALS
0·8
DUNG (3·7)
JUVENILE
ANIMALS
0·1
GRAZING
122·0
ANIMAL
FEED
6·3
MEAT-
&
EGG
21·9
8·6
MEAT & EGG
13·3
FOOD
PRODUCTION
BOUNDARY
DOMESTIC
LABOUR
65·2
FOOD
FUEL
92·3
6·0
36·3
FUELWOOD
52·4
VILLAGE
ECO-
SYSTEM
BOUNDARY
CROPS 70·7

that over 50% of working hours are spent directly in agriculture and 39% in other domestic activities related to food preparation. In this context, quantification of the interdependency of energy resources and supplies in a village ecosystem such as the present one is significant.

It may be concluded that the high energy efficiency of the village ecosystem in Sethlliew as a whole is related to:(i) high labour input, (ii) exploitation of a large area of land around the village under a 10 year jhum cycle (with 5 ha in a given year) which permits sufficient recovery of nutrients for jhum, (iii) 2 ha of valley agriculture which gives a sustained yield due to enrichment of nutrients from adjoining hill slopes, (iv) efficient re-cycling of food wastes and crop residues in manure pits and (v) swine husbandry which is sustained through agricultural waste inputs at practically no cost to the farmer.

Fuel wood production within the village ecosystem through fastgrowing native trees and more efficient utilization as through biogas technology would help in conserving the forest resources. In a hilly terrain as this with high intensity rainfall confined to a few months during monsoon, horticulture and plantation crops seem to be an attractive alternative to annual cropping through jhum on steep slopes (Ramakrishnan, 1980). These possibilities for selfsufficiency in fuel wood and more diversified primary production should be considered for an integrated rural development in this region, which is currently receiving our attention.

SUMMARY

The pattern of energy flow through four major sub-systems (Jhum, Valley, Animal and Domestic) of a typical Khasi village ecosystem with 'slash and burn' agriculture (Jhum) at an elevation of 1540 m in the north-eastern hill region of India was studied. The energetic efficiency (output:input ratio) of jhum in 5 ha of land worked out to 7.53 and that of valley cultivation on 2 ha of land worked out to 40.14. The animal husbandry sub-system had swine husbandry as its predominant component. This had an energetic efficiency of 3.04. The village ecosystem as a whole, however, had an efficiency of 1.57. Animal husbandry formed an important link in the detritus food chain by utilizing the garbage and vegetable waste of the agriculture system. The forest, apart from providing the basis for agriculture also meets part of the fuel requirement of the village. The compost pit is a very important component in the functioning of the village ecosystem as it provides feed for secondary production and generates organic manure both of plant and animal origin which is cycled back into agriculture. The intricate relationship existing between the production and consumption compartments of the village ecosystem has been worked out both from economic and energetic points of view and discussed.

CHAPTER — 4

SEDIMENT, WATER AND NUTRIENT LOSSES UNDER SLASH AND BURN AGRICULTURE (JHUM) AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.

INTRODUCTION

Slash and burn agriculture (locally known as 'Jhum') which involves slashing the natural vegetational cover, burning the dried slash and cultivating the land for a few years before it is abandoned for natural regeneration is a predominant form of agriculture in the north-eastern hill region of India. The jhum cycle which is the time interval, when forest fallow development occurs due to natural re-generation, before the same site is again cultivated has in recent times been reduced from a more favourable 20-30 years to as short as 5 years. Further, in the recent past, terracing of land has been introduced into this region as an alternative to jhum.

Jhum is practised along the steep slopes of the hills (slope angle being 30^{o}- 40^{o}) and therefore large losses of top soil, water and nutrients occur during the cropping period due to run-off and infiltration. Some losses may also occur during various stages of the fallow development depending upon the vegetational cover. Losses of nutrients, chiefly through infiltration of water are also likely to occur under terrace cultivation. The present work done at Shillong (25.34^{o}N and 91.56^{o} E) is an attempt to study the hydrology and the pattern of sediment and nutrient losses through water that may occur under jhum at the time of cropping as well as during the subsequent fallow development and to compare it with the pattern under terrace cultivation.

STUDY AREA AND DESCRIPTION OF THE SYSTEM

Shillong located in the Khasi hills of Meghalay is at an altitude of 1500 meters. The climate is monsoonic with most of the annual rain-fall of 1843 mm occurring during the monsoon period, from May to September. The average maximum temperature during this season was 23.7°C and the average minimum temperature was 16.3°C. The humidity percentage remained very high during this period (84.1%). Winter is cold with occasional showers, extending from November to February with an average maximum temperature of 16.8°C and a minimum of 7.6°C. Frosts are very common during December and January. The brief summer which is warm and dry extends from March to April with a maximum temperature of 23°C.

'Slash and burn' agriculture (jhum) is extensively practised by the local khasi tribe at higher elevations of Meghalaya and is also a common feature of the entire north-eastern hilly states of India. While at lower elevations in the subtropical forests, the entire forested cover is slashed which is the typical and more common form of jhum (Toky and Ramakrishnan, 1981), at higher elevations the lower branches of trees alone (chiefly *Pinus kesiya*), which already are sparsely spaced due to previous land use practice, are slashed. Further, unlike at lower elevations where slash is burnt *in situ* and seeds of the crop mixture are planted directly on the soil-ash complex by dibbling, in the present case the slash is placed in parallel rows running down the slope, covered over with a layer of soil placed on the dried slash so as to make ridges and furrows. Thus the slash is burnt under more controlled conditions and the seeds of the crop mixture are planted on the ridges. While fertilizer is not used in the typical form of jhum at lower elevation, in the present case both organic (pigdung and compost) and inorganic (NPK-1:1:1) fertilizers are used depending upon the type of jhum cycle. Agro-ecosystems under a 10 year jhum cycle generally receive 600 kg ha^{-1} yr^{-1} (oven dry weight) of the organic fertilizer only and that under a 5 year cycle may receive both organic and inorganic fertilizers at the rate of 1000 kg ha^{-1} yr^{-1} and 10 kg ha^{-1} yr^{-1} respectively in the first year and 1850 kg ha^{-1} yr^{-1} and 20 kg ha^{-1} yr^{-1} respectively in the second year of cropping (Mishra and Ramakrishnan, 1981).

A mixture of 8 crops consisting of root and tuber crops like *Solanum tuberesum*, *Colocasia antiquorum* and *Ipomoea batatus*, cereals like *Zea mays*, legumes like *Phaseolus vulgaris* and vegetables like *Brassica oleracea*, *Cucurbita maxima* and *Cucumis sativus* are grown together in the same site. Emphasis on the mixture of crops may vary according to the type of jhum cycle imposed on a given site. Thus, while all the crops mentioned above may be grown together in the same field during cultivation under a fairly long jhum cycle of 10 years, only three crops like S.tuberosum, Z.mays and B.oleracea are grown under a short jhum cycle of 5 years. While cultivation is done only for one year in the case of a long jhum cycle, under a 5 year cycle cropping may be done for 2-3 years before the land is fallowed for natural regeneration of vegetation. S.tuberosum, however, is the major crop in both the cases. After the burn and a few weeks before the onset of monsoon, the tuber crops are planted on the ridges while the rest of the crops are planted after the first few showers. Along each ridge three distinct rows of planting is done by dibbling the seeds of S.tuberosum; Z.mays seeds are dibbled at intervals. While C.maxima and C.sativus are planted at random, but widely scattered on the ridges, planting of C.antiquorum is confined mostly to the top and bottom of the ridges. Likewise, the planting of P.vulgaris is confined around the pine trees which may provide support. During July-August the first crop of tubers are harvested and then a second crop of winter potato is raised alongwith B.oleracea on the ridges. Harvesting of the cereals and legumes is done in September-October. The harvesting of winter potato and B.oleracea is done in November after which the land is left uncultivated between December-March. If a second year cultivation is done the same procedures are followed; otherwise the field is left abandoned for natural regeneration of forest. The jhum cycle studied during the present investigation are of 10 and 5 years. It may be mentioned here that, while the longer jhum cycles of 15-20 years are extremely rare in this area, a 5 year cycle is more common. Soil of the present study area is podsolic and since the erosion outstrips weathering process, the soil cover is scant. The soil is sandy, loose and highly porous with a pH of 4-6.

In recent times, terrace cultivation was introduced to this area by governmental agencies. Either a mixture of crops as in jhum or a monoculture of one crop species, namely S.tuberosum or B.oleracea may be raised on bench terraces. The terraces have a width of 3-4 meters. This involves heavy inputs of organic (3000 kg ha^{-1} yr^{-1}) and inorganic fertilizer 1:1:1 of NPK (74 kg ha^{-1} yr^{-1}). The crop mixture in the present study under terrace had S.tuberosum, Z.mays and B.oleracea.

METHODS OF STUDY

Sites under jhum under a 5 and 10 year cycle and that under terrace cultivation were identified at Shillong taking care to ensure similar aspects and topographic conditions (the average slope angle in these sites was 40^{o}). One five and ten year old fallows developed after cropping under a 10 year jhum cycle, under natural vegetational cover were also identified taking care to ensure similar aspect and topographic conditions. Each of the site selected covered an area of about 2 ha.

For studies partaining to sediment and water loss due to erosion and run-off, the loss from a confined area of 2 x 20 m along the slope was collected in large collectors and sampled periodically for chemical analysis. For the study of percolation loss of water, 'Russian' type lysimeters were employed (Buckman and Brady, 1960). Soil was cut vertically in each site to expose the profile. A small tunnel was excavated at a depth of 40 cm (the depth to which most roots penetrate) and the lysimeter (30 x 30x15 cm^3) was placed inside it. By pressing from below, the rim of the lysimeter was firmly inserted in the undisturbed soil above. The percolated water was tapped out from the lysimeter from time to time for analysis. The observations are based on four replicates at each site.

After analysing the water/soil samples for No_3-N and P_o4-P, soon after collection, the water samples were preserved in polythene jars for subsequent analyses. Soil samples were air dried, ground and after passing through 0.2 mm sieve, it was stored in glass jars. The samples were analysed by standard procedures(Allen, 1974). Thus, No_3-N and $Po4$-P were estimated colorimetrically by the phenol-di-sulphonic acid method and the molybdenum blue method respectively . Organic nitrogen was estimated by the microkjehldahl method. Calcium and magnesium were analysed by the EDTA titration method and potassium was analysed by the flame emission method. Soil extraction for cations was done with 1 N Ammonium acetate at pH7.

RESULTS

Sediment and water losses:

Table 4.1 presents the total loss of sediment and water from the agro-ecosystems and the fallows of different ages. The sediment yield due to erosion was significantly more ($p < 0.01$) in the case of jhum fallows. When the sediment loss due to erosion during the first year of cropping under a 5 year jhum cycle was compared with that of the second year, the differences were not significant. Sediment loss during cropping under terrace cultivation was significantly lower than that under jhum ($P < 0.01$) and this reduction was to the extent of 38.3% and 24.9% in the first and second year of cropping respectively compared to first year cropping under a 5 year jhum cycle. During the second year of terrace cultivation, the sediment loss increased significantly ($P < 0.01$) by 25.1% compared to the total sediment loss that occurred during the first year of cropping on terraces.

The run-off water loss significantly increased ($P < 0.05$) in the agro-ecosystem under a 5 year jhum cycle compared to a 10 year one. The shortening of jhum cycle, however, does not seem to have any effect on the loss of

Table 4.1. Total loss of sediment (m.ton ha^{-1} yr^{-1}) and water (cm).

Category of loss	Agro-ecosystem under jhum		Jhum fallows of different age			Terrace Agro-ecosystem (Mean±SE)
	10 yr cycle (mean±SE)	5yr cycle (mean±SE)	1 Yr (mean±SE)	5 Yr (mean±SE)	10 Yr (mean±SE)	
Sediment	49.72±0.97	54.85±1.1 (56.34±1.3)	7.38±0.2	3.47±0.1	1.92±0.09	33.82±0.9 (42.3±1.1)
Run-off water	54.16±1.4	59.28±1.7 (84.5±1.5)	44.86±1.2	38.16±1.3	23.46±1.1	49.4±2.0 (63.14±1.8)
Percolation water	12.11±0.8	13.34±0.5 (10.59±0.9)	17.84±0.8	30.76±0.95	17.67±0.5	16.08±0.4 (12.74±0.5)

Values within the parentheses indicates the total loss during the second year of cropping.

percolation water. The run-off loss dropped significantly ($P \angle 0.01$) during the fallow development period, whereas the perculation loss was higher. While during the first year of cropping under a 5 year jhum cycle, 38% and 8.6% of the annual precipitation of 156.1 cm was lost through run-off and percolation respectively, these losses changed significantly ($P \angle 0.05$) to 46.5% and 5.8% during the second year. Compared to jhum agro-ecosystem under a 5 year cycle the run-off losses was significantly reduced ($P \angle 0.05$) by 16.7% and 25.3% during the first and second year of cropping on terraces. Percolation losses under terrace agro-ecosystem was significantly higher ($P \angle 0.05$) compared to that under jhum agro-ecosystems (Table 4.1).

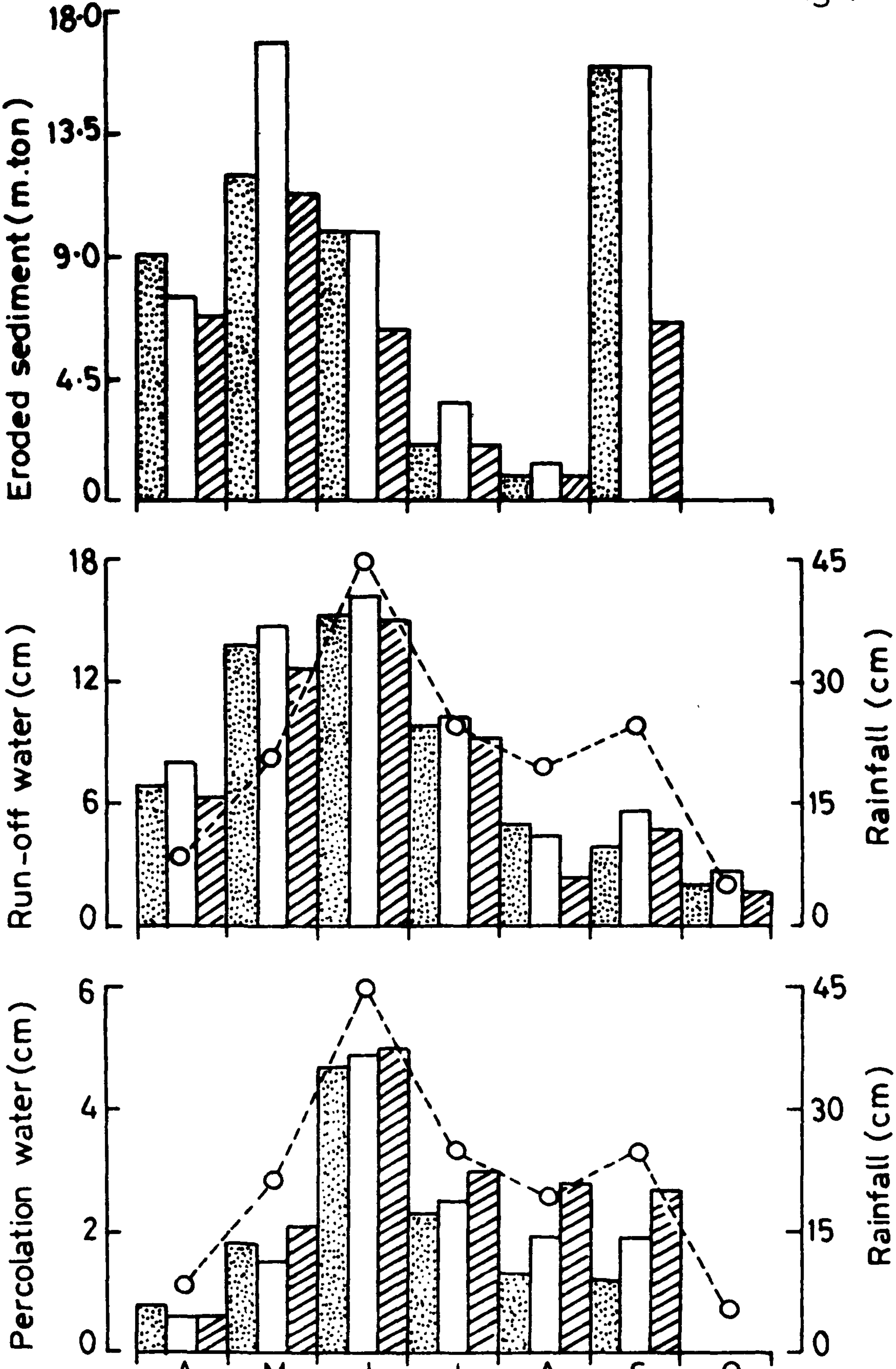
The sediment loss due to erosion during the monsoon showed two distinct peaks one in May and another in September. However, the loss from the jhum agro-ecosystem was greater than under terrace system. The run-off losses of water, however showed one major peak during the monsoon in May-June with a sharp decline on either side. Percolation losses of water showed a sharp increase in June which was maintained at a slightly lower level during the subsequent months. The losses of water through run-off and percolation are related to the rainfall pattern (Fig.4.1).

Nutrient losses:

The concentration of various nutrients lost during the monsoon through eroded sediment and through run-off

Fig.4.1 Pattern of sediment and water loss during cropping from a hectare of land under jhum and terrace cultivation. Stippled bar, 10 year jhum cycle; open bar, 5 year jhum cycle; hatched bar, terrace cultivation; O- - - - -O , rainfall.

Fig 4.1



18·0
13·5
9·0
4·5
0
Eroded sediment (m.ton)
18
12
6
0
Run-off water (cm)
45
30
15
0
Rainfall (cm)
6
4
2
0
Percolation water (cm)
45
30
15
0
Rainfall (cm)
A
M
J
J
A
S
O

water generally declined during the latter part of the monsoon, both in the case of jhum and terrace agro-ecosystems. The concentration of nutrients lost through percolation water also followed a similar pattern though the concentration of some of the nutrients like No_3-N, organic-N, Po_4-P, K and Ca under jhum increased in June-July compared to April-May. The concentration of all the nutrients remained higher in the sediment and water lost during cropping under a 10 year jhum cycle compared to that under a 5 year cycle except for No_3 - N. The concentration of all the cations in sediment and water was markedly lower under terrace ($P<0.05$) compared to that under jhum. However, No_3-N and Po_4-P losses often was slightly higher under terrace cultivation. Compared to the agriculture systems the nutrient losses from 5 and 10 year fallows were low or in some cases no detectable levels could be observed. In general, in the fallows, the concentration of nutrients in the eroded sediment was much higher than in the run-off and percolated water (Table 4.2).

Table 4.3 presents the losses of No_3-N, organic-N and Po_4-P through sediment and water. While the total loss of these nutrients through sediment and run-off water were significantly higher ($P<0.05$) during cultivation under a 5 year jhum cycle compared to a 10 year cycle, the shortening of the jhum cycle had no significant effect ($p>0.05$) on the percolation loss of No_3-N and Po_4-P. The total loss of No_3-N under jhum and terrace agro-ecosystems was also significantly

Table 4.2. *Concentration(ppm) pattern of various nutrients in sediment, and run-off and percolation water.

Agro-ecosystem/ Jhum fallow	Nutrient	Sediment			Run-off water			Percolation water		
		April-May	June-July	Aug-Sept	April-May	June-July	Aug-Sept	April-May	June-July	Aug-Sept
Jhum agro-ecosystem: 10 Yr cycle	No3-N	2.10	0.55	0.18	0.33	0.32	0.28	0.38	0.39	0.35
	Organic-N	3000	2408	2193	1.27	1.23	0.99	0.21	0.33	0.09
	Po4-P	33	26	22	0.19	0.15	0.11	0.08	0.08	0.07
	K	2363	1496	1120	19.30	15.10	13.00	15.4	23.0	22.80
	Ca	305	273	297	2.30	1.83	1.27	1.30	2.10	1.80
	Mg	231	143	124	0.88	0.45	0.22	1.21	0.88	0.60
Jhum agro-ecosystem: 5 Yr cycle	No3-N	3.00	0.59	0.16	0.37	0.35	0.30	0.32	0.39	0.28
	Organic-N	2938	2329	2168	1.20	1.16	0.80	0.26	0.39	0.13
	Po4-P	23	21	20	0.11	0.16	0.13	0.06	0.08	0.06
	K	2087	1423	1170	18.80	15.60	12.80	13.30	22.10	22.40
	Ca	283	238	249	2.00	1.80	1.30	1.40	1.90	1.90
	Mg	199	130	109	0.81	0.44	ND	1.19	0.88	0.64
Terrace agro-ecosystem	No3-N	3.24	0.47	0.18	0.52	0.36	0.23	0.51	0.41	0.30
	Organic-N	4098	3905	3114	ND	ND	ND	0.33	0.25	0.05
	Po4-P	24	15	13	0.23	0.21	0.18	0.11	0.06	0.10
	K	760	733	719	8.80	6.40	6.00	7.90	5.60	3.50
	Ca	154	155	138	2.30	1.80	1.70	2.60	2.20	2.10
	Mg	94	68	63.8	ND	ND	ND	ND	ND	ND
1 yr Jhum fallow	No3-N	3.31	0.55	0.11	0.32	0.30	0.25	0.29	0.30	0.28
	Organic-N	2559	2345	1439	ND	ND	ND	ND	ND	ND
	Po4-P	6.75	3.25	2.25	ND	ND	ND	ND	ND	ND
	K	1228	980	881	7	5.13	5	ND	ND	ND
	Ca	205	146	109	0.96	0.74	0.51	0.7	0.98	0.69
	Mg	115	90	70	ND	ND	ND	ND	ND	ND

(contd....)

Table 4.3. Nitrogen and phosphorus loss (Kg ha^{-1} yr^{-1}) through sediment, run-off and percolation water.

Category of loss	Nutrient	Agro-ecosystem under jhum: 10 yr cycle (mean±SE)	Agro-ecosystem under jhum: 5 yr cycle (mean ± SE)	Jhum fallows of different age: 1 yr (mean± SE)	Jhum fallows of different age: 5 yr (Mean ± SE)	Jhum fallows of different age: 10 yr (mean ± SE)	Terrace agro-ecosystem (Mean± SE)
Sediment	No3-N	0.054±0.008	0.087±0.012 (0.056±0.005)	0.018±0.003	0.007±0.002	0.003±0.001	0.063±0.005 (0.049±0.004)
	Organic-N	128.442±0.248	172.767±0.384 (176.191±0.343)	17.990±0.087	5.859±0.068	1.634±0.055	135.479±0.133 (155.262±0.162)
	Po4-P	1.372±0.039	2.004±0.048 (1.686±0.049)	0.038±0.003	0.023±0.002	ND	0.574±0.049 (0.762±0.047)
Run-off water	No3-N	1.710±0.020	2.260±0.023 (2.638±0.024)	1.342±0.017	0.962±0.014	0.497±0.011	2.132±0.029 (2.181±0.022)
	Organic-N	6.477±0.027	6.682±0.020 (7.354±0.030)	ND	ND	ND	ND (ND)
	Po4-P	0.851±0.010	0.815±0.009 (1.047±0.009)	ND	ND	0.039±0.003	1.065±0.010 (1.040±0.011)
Percolation water	No3-N	0.459±0.046	0.476±0.042 (0.380±0.026)	0.544±0.028	0.908±0.026	0.218±0.019	0.621±0.028 (0.488±0.022)
	Organic-N	0.039±0.008	0.355±0.003 (0.286±0.004)	ND	ND	ND	0.344±0.002 (0.194±0.007)
	Po4-P	0.095±0.012	0.099±0.017 (0.058±0.015)	ND	ND	ND	0.149±0.009 (0.075±0.007)

Values within the parentheses indicates the total loss during the sencond year of cropping.

ND= Not detectable.

higher ($P<0.01$) through run-off, followed by that though percolation water and was least through eroded sediment. Organic-N and PO_4-P losses were significantly higher($P<0.01$) through eroded sediment followed by run-off and percolation water. The values for losses during the second year of cultivation given in parentheses for a 5 year jhum cycle often show that the loss of nutrient during the second year of cropping may be significantly higher or lower ($P<0.05$) depending upon the nutrient and the type of loss NO_3-N loss through run-off water under terrace cultivation however, was not significantly different during the second year of cropping. While the total NO_3-N loss in the sediment and percolation water under terrace agro-ecosystem was not significantly different from that under jhum, this loss in the run-off water under terrace was significantly reduced ($P<0.05$) by 5.7% in the first year and 17.3% in the second year compared to that under a 5 year jhum cycle.

Organic-N loss through sediment and through water during both the years of cropping was significantly reduced ($P<0.01$) under terrace cultivation than under a 5 year jhum cycle. In fact, in the terrace agro-ecosystem the run-off loss of organic-N was not detectable at all. While the losses of PO_4-P in eroded sediment decreased significantly ($P<0.01$) under terrace compared to that under a short jhum cycle of 5 year, the reverse case was observed for run-off loss ($P<0.01$) and the difference was not significant for percolation losses.

In general, the loss of all the nutrients in the jhum fallows of 1,5 and 10 years gradually decreased with increase in its age, and this was markedly low compared to the jhum agro-ecosystem. The only exception to this was NO_3-N where the loss of this nutrient through percolation increased in a 5 year jhum fallow compared to the agro-ecosystems(Table4.3).

While cultivation under a 5 year jhum cycle resulted in greater cationic loss through sediment and run-off water compared to that under a 10 year cycle, the percolation losses of these were not significantly different ($p > 0.05$) except for Mg the loss of which was high under a 10 year cycle ($p < 0.05$). Both under terrace and jhum agro-ecosystem, the loss of K was much higher than that of other cations. In general , the losses of cations through the eroded sediment was significantly higher ($p < 0.01$) than that in the run-off and percolation waters. The cation lost from the jhum agroecosystems was significantly higher ($p < 0.01$) compared to the terrace agro-ecosystem. However, the loss of Ca through percolation was more ($p < 0.01$) in terrace compared to jhum agro-ecosystems. While in the agroecosystem under 5 year jhum cycle the various types of losses of cations during the second year of cropping may increase or decrease, under terrace agro-ecosystem the nutrient loss was higher during the second year except for percolation loss where a reverse trend was observed(Table 4.4).

The nutrient lost from the different fallows was significantly low compared to jhum agro-ecosystems. This

Table 4.4 Cation loss (Kg ha^{-1} Yr^{-1}) through sediment, run-off and percolation.

Category of loss	Nutrient	Agro-ecosystems under jhum: 10 yr Cycle (mean±SE)	Agro-ecosystems under jhum: 5 yr Cycle (mean± SE)	Jhum fallows of different age: 1yr (mean±SE)	Jhum fallows of different age: 5 yr (mean±SE)	Jhum fallows of different age: 10 yr (mean± SE)	Terrace agro-ecosystem (mean± SE)
Sediment	K	86.109±0.205	110.636±0.221 (101.826±0.237)	8.882±0.050	1.157±0.029	1.067±0.011	27.316±0.073 (28.819±0.065)
	Ca	14.650±0.113	16.488±0.128 (17.313±0.132)	1.320±0.036	0.537±0.027	0.112±0.13	4.794±0.037 (6.478±0.042)
	Mg	8.627±0.042	9.789±0.040 (9.118±0.048)	0.829±0.026	0.215±0.016	0.102±0.12	2.561±0.023 (3.283±0.028)
Run-off water	K	88.163±0.228	104.621±0.353 (109.633±0.360)	25.962±0.103	19.550±0.072	2.318±0.055	33.068±0.167 (46.695±0.173)
	Ca	10.263±0.079	10.576±0.084 (12 .725±0.121)	3.576±0.037	2.164±0.029	0.261±0.011	9.809±0.027 (11.365±0.108)
	Mg	3.075±0.033	3.616±0.030 (1.979±0.022)	ND	ND	ND	ND (ND)
Percolation water	K	25.820±0.203	25.363±0.349 (20.743±0.314)	ND	ND	ND	8.109±0.052 (6.454±0.064)
	Ca	2.259±0.033	2.282±0.027 (1.787±0.023)	1. 684±0.034	2.100±0.018	0.460±0.011	3.485±0.027 (2.614±0.022)
	Mg	1.082±0.022	1.001±0.013 (0.593±0.011)	ND	ND	ND	ND (ND)

Values within the parentheses indicates the total loss during the second year of cropping.

ND= Not detectable.

decrease in loss under a 10 year fallow compared to that under an agro-ecosystem of 5 year jhum cycle was to the order of a maximum of about 1/140 for Mg, 1/70 for K and 1/35 for Ca (Table 4.4).

DISCUSSION

Slash and burn agriculture involving cutting down of branches of sparsely distributed tree species and slashing of herb and shrub community in areas at higher elevation in Meghalaya before burning and cropping for a year or more results in drastic changes on the hydrology and nutrient cycling processes involving considerable losses from the system. Nutrients are removed along with sediment through run-off and percolation water. These losses are maximum during the cropping phase but as the fallows develop with natural regeneration of vegetation the losses tend to be gradually reduced.

The observed sizeable increase in sediment and water loss during the early part of the monsoon from the agro-ecosystems under jhum cultivation can be attributed chiefly as due to lack of crop cover. These losses decreased gradually in the latter months of the monsoon, due to the development of an effective crop cover and also due to the decrease in the intensity of rainfall. The steep rise in the sediment loss during September is closely related to soil disturbance during the harvest of the tuber crops. In the agro-ecosystem under a short jhum cycle of 5 year the loss of sediment was more than that under a 10 year cycle which may be related to the poor physical characteristics of the soil due to shorter jhum cycle and thinner crop cover during the time of cultivation. This is confirmed from the results of the second year of cropping under a 5 year jhum cycle (Mishra and Ramakrishnan, 1981). During the second year of cropping the run-off loss of water increased while percolation loss decreased which could be related to the sealing of the soil pores by the fine particles suspended in the run-off water (Lowdermilk, 1930; Auten, 1934; Weaver and Harmon, 1935).

In a single pulse, fire releases the nutrients particularly the cations in the slash material so much so that its availability exceeds the retention capacity of the jhum agro-ecosystems. Hence, much of the nutrients are lost through sediment and run-off and percolation water before they could be incorporated into the plant biomass. The large amount of cations released after the burn increases the soil pH which in turn may promote nitrification(Granhall and Hendricksson, 1969). This along with increased concentration of the bicarbonate ions results in increase in anions which are balanced by the free cations so that the rate of nutrient loss through water may increase (Borman et al., 1968; Lewis Jr., 1974). The greater loss of potassium through percolation water compared to the percolation loss of divalent cations under the

Jhum confirms the findings of some others (Allen, 1964; Lloyd, 1971) where it was shown that potassium was much more readily dissolved than calcium and magnesium ions following a burn. Heavy erosion loss of the nutrients was chiefly due to higher concentration of nutrients in the eroded sediment. In the latter months of the monsoon, the nutrient losses was checked to some extent by an effictive vegetation cover of crops and associated weeds. In general, the concentration of various nutrients in the sediment and water lost from the agro-ecosystem under a 10 year jhum cycle was higher compared to a 5 year cycle. This may be due to the low nutrient status of the soil, lesser quantity of the slash burnt and also qualitative differences in the nutrient content of the slash in the agro-ecosystem under a 5 year jhum cycle compared to that under a 10 year cycle. However, the total quantity of nutrient lost from the agro-ecosystem was generally higher under a 5 year jhum cycle compared to a 10 year cycle which may also be related to poor physical quality of the soil in the former case and the lesser vigour of the crop cover. This is more evident for the loss of nutrient through sediment and run-off water than for the loss due to percolation. During second year of cropping under a 5 year cycle the losses increase further which further strengthens the argument given above. The reduction in nutrient loss through percolation in the second year of cropping may be related to lesser volume of percolation water discussed earlier.

It is quite reasonable to suppose that the reduction in sediment, water and nutrient losses rates from the agro-ecosystems after the jhum cultivation depends on how quickly the vegetal cover is reestablished. Soil system of the north-eastern hill India possess a variety of strategy such as rapid growth and expansion of stumps, rhizomes and root sprouts, and germination of buried and transperted seeds for the fast development of a good plant cover. Under a forested ecosystem, much of the rainfall reaching the forest floor is first intercepted by the canopy cover and branches of the forest species and then by the litter layer on the soil surface. This actually reduces the hitting force of the rain-drops and thereby the erosion is minimized (Lowdermilk, 1930; Rowe, 1955; Langbein and schumm, 1958). With development of the fallow, the sediment and loss of run-off water drastically reduced. The increase in percolation loss of water in a 1 year fallow compared to that under the agro-ecosystem may be due to better physical structure of the soil and also due to a decline in the run-off losses. Percolation loss reached its peak in a 5 year fallow to decline again in an older 10 year fallow. This decline in the latter case may be related to increased evapo-transpiration/absorption by the vegetal cover. With fallow development, the concentration and total amount of nutrients also decreased drastically so much so that some of the element like organic-N, PO_4-P, K and Mg could not be detected at all in the run-off/percolation water. This is in general agreement with the results obtained for jhum under lower elevation of Meghalaya (Toky and Ramakrishnan, unpublished) expept that the reduction there is more marked than that reported here due to faster development of vegetal cover due to higher temperature and humidity.

The fast accumulation of various nutrients in the plant biomass depletes them in the soil mineral pool and this also accounts for reduction in nutrient loss across the eco-systems boundaries reported here(went and Stark, 1968; Odum, 1969;Jordan et al., 1972; Valentine, 1976). The increased leachability of the nitrate ions in a 5 year old fallow dominated by Imperata cylindrica and Eupatorium adenophorum compared with jhum agro-ecosystems seems to be contrary to the finding of some of the earlier studies that suggest that acidifying grass vegetation dominated by I.cylindrica may repress the nitrification process (Nye and Greenland, 1960). This also is contrary to the results obtained by one of us (Toky and Ramakrishnan, unpunlished) for lower elevations in Meghalaya.

Eventhough the sediment loss under terrace cultivation was reduced by 38.3% compared to that occurred in the first year of cultivation under a 5 year jhum cycle, during the second year terrace cultivation the loss got accelerated by 25.1% more compared to the sediment loss during the first year. Further, eventhough the percolation loss was more under terrace cultivation which is related to the highly porous nature of the soil, the total water loss due to both run-off and percolation was reduced by 9.8% in the first year and 20.2% in the second year compared to that under a 5 year jhum cycle. Beside this, the nutrient losses were also reduced by 24.1% -92.2% depending upon the nutrient compared to the loss from jhum under a 5 year cycle. The reduction in percolation water in the second year of terrace cultivation compared to that under first year of terrace cultivation and the consequent reduction in the nutrient losses from this agriculture system may be accounted as due to clogging of the pores of the soil discussed earlier. Inspite all this, there is evidence of a significant decrease in crop yield in the subsequent years of terrace cultivation (Mishra and Ramakrishnan, unpublished) which may be related to soil fertility reduction and increased weed problem (Mishra and Ramakrishnan, Unpublished). For this reason the farmer often discard the terraced fields after about six years of cultivation as the land becomes uneconomical to maintain. If the total loss of nutrients like N and K are calculated as a percentage of the total input of these through inorganic fertilizer, this would work out to 56% for N and 27.7% for K. This loss would further increase in the second year of cultivation due to decline in the physical characteristics of the soil, this working out to 64% of N and 332% for K. Thus, terracing does not seem to be a viable alternative to jhum though the latter as practised in the present form with a reduced cycle of about 5 years also do not seem to be sustainable on ecological and economic considerations..

SUMMARY

The hydrology, and pattern of sediment and nutrient losses through water that may occur under 'slash and burn' agriculture (Jhum) at the time of cropping as well as during the subsequent fallow development was studied at higher elevations of Meghalaya in the north-eastern India and compared with terrace cultivation. A comparison of an agro-ecosystem under a 10 year jhum cycle with that under a 5 year cycle suggests that the losses of sediment and water and also nutrients like nitrogen and phosphorus are more under the latter, though cationic losses show a reverse trend. All type of losses were markedly reduced during fallow development during secondary succession. Terrace cultivation resulted in a general reduction of water and nutrient losses. However, these losses tended to increase after continuous cropping year after year. While jhum cannot be sustained with a reduced cycle as is the case in the present times, terracing does not seem to offer an alternative to this.

CHAPTER — 5

SOIL FERTILITY CHANGES DURING AND AFTER SLASH AND BURN AGRICULTURE(JHUM) AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH EASTERN INDIA.

INTRODUCTION

'Slash and burn' agriculture (locally known as Jhum) extensively practised by local tribes in the north-eastern hill region of India involves clearing of a patch of forest by slash and burn, growing of a mixture of crops for a year or two and then reverting the land back to natural forest regeneration. After a few years the same piece of land is again cropped. This time lapse before cultivation of the same site is called a jhum cycle. When this cycle was fairly long (more than 10 years), this system of agriculture was in harmony with nature. However, under the present conditions of increased population densities and reduced acreage, the jhum cycle has been reduced to as short as 4-5 years which has drastically reduced crop yield, increased rate of losses of soil, water and nutrients with the consequent infertility of the soil and aggravated the weed problem in this area (Ramakrishnan et al., 1980; Mishra and Ramakrishnan, 1981; Toky and Rakakrishnan, 1981; Ramakrishnan and Mishra, 1981).

The present study is an attempt to understand changes in the nutrient status of the soil pool during jhum cultivation under three different jhum cycle of 15, 10 and 5 years (15 and 10 year cycle are very rare, while 5 year cycle is more common in this region) and the recovery pattern during fallow development up to a period of 15 years. This study is significant firstly because it will provide clues as to why the crop yield decreases drastically under shorter jhum cycle of 5 years compared to compratively long jhum cycles of 10 or 15 years. This study is also hoped to achieve an understanding of optimum jhum cycle which would ensure satisfactory recovery of the soil fertility with least damage to the soil system. Such an analysis has been compared and contrasted with terrace cultivation which has been tried to some extent as an alternative to jhum.

STUDY AREA AND DESCRIPTION OF THE SYSTEM

This study was done at Shillong (25.34°N and 91.56°E) in the Khasi hills of Meghalaya, at an elevation of 1500 meters where 'slash and burn' agriculture is practised by the local Khasi tribe. The area supports sub-tropical montane evergreen pine forests with Pinus kesiya as the dominant species. The terrain is hilly with steep slopes (the average angle ranging from 30°- 40°). The soil cover is thin as the process of erosion outstrips weathering and is podsolic with a pH range of 4-6. The climate is monsoonic with 90% of the annual average rainfall (1843 mm) occurring during the monsoon period from May to September. The average maximum temperature during this season is 23.7°C and the average minimum temperature is 16.3°C. The humidity remains very high during this period (84.1%). Winter is cold with occassional showers, extending from November to February with an average maximum temperature of 16.8°C and a minimum temperature of 7.6°C. Frosts are very common during December-January. The brief summer which is warm and dry extends from March to April (the maximum temperature is 23°C and the minimum is 12.3°C) and is accompained with strong wind.

In its typical form, jhum in the entire north-eastern India consists of clearing the entire forest and burning of the dried plant biomass before growing a mixture of crops on the hilly slopes for one or two years (Toky and Ramakrishnan, 1981). However, in the higher elevations of the Khasi hills of Meghalaya, jhum pattern is significantly different from its typical type in that normally only the lower branches of the sparsely distributed trees are slashed instead of the whole tree. Further, unlike at lower elevations where the slash is burnt _in situ_ and the seeds are dibbled directly into the soil-ash complex, in the present case the slash is placed in parallel rows running along the slope covered over by a thin layer of soil forming the elevated seed beds(ridges) with alternating gaps (furrows) and subjected to a slow burn. The seeds are planted, in the present case, only on the ridges. While fertilizer is not used in the typical jhum, at the higher elevation both organic (pig dung and compost) and inorganic (NPK-1:1:1) fertilizers are used in various proportions depending upon the type of jhum cycle at a given site (Mishra and Ramakrishnan, 1981).

Cropping is done for one year only under 10 or 15 year cycle, but under a 5 year cycle cropping may be done for a year or two. In the recent past, terrace cultivation which necessiates heavey fertilizer inout has been tried as an alternative to jhum. A detailed account of land use and cropping pattern are discussed elsewhere (Mishra and Ramakrishnan, 1981).

METHODS OF STUDY

Sites under jhum and terrace cultivation were selected at Shillong taking care to ensure similar aspects (south facing slopes) and topographic conditions. For the studies pertaining to jhum, deforested sites under 15,10 and 5 year cycle were identified within the same area on the basis of local records. In each site soil was sampled at 10 random points from a depth of 0-40 cm, at intervals of 0-7 cm,7-14cm, 14-28 cm and 28-40 cm of the profile. Soil sampling was done on the five different occassions in the sites under 15 and 10 year jhum cycle: (i) after slashing of the vegetation and just one day before burning, (ii) immediately (1 day) after burning, (iii) 30 days after burning during early monsoon, (iv) 100 days after burning during the mid-monsoon,and(v) 365 days after burning at the end of cropping when the land was just left a fallow. All these samolings were also done under a 5 year jhum cycle except that a sampling was also done at the end of 730 days (after two years of cropping). In the site under terrace cultivation, soil was sampled once before the onset of monsoon before seeds were sown followed by 30,100, 365 and 730 days from the time of first sampling.

Sites under 1,5,10 and 15 year jhum fallows were also identified on the basis of local records, within this area with comparable aspects and topographic situation. These fallows were developed in sites under a 15 year jhum cycle. Sampling was done only once (in March) and is also based on 10 random collections through a depth of 0-40 cm of the soil profile as discussed earlier.

Available phosphorus was estimated on fresh samples. The samples were air dried, ground, screened through 0.2 mm sieve and stored in jars for analysis. The samples were analysed by standard procedures (Allen, 1974). Thus phosphorus was estimated colorimetrically by the molybdenumblue method. The soil carbon was estimated by the Walkey-Black method and total nitrogen was analysed by the micro-kjehldahl method. Calcium and magnesium were determined by EDTA titration method and potassium by the flame-emission method. The soil extraction for cations was done with IN Ammonium acetate at pH 7. The soil pH was determined in a soil-water suspension of 1:5 ratio using a pH meter. The soil bulk density determinations were made using a core sampler and the values were used for subsequent conversion of analytical data to field weight per unit area.

RESULTS

Soil changes during cropping

pH:

The pH values given for ridges and furrows separately on jhum sites (Table 5.1) show that this is generally higher on the ridges compared to the furrews, at all depths. Only in some cases the values are almost the same for these two situations. pH in all the sites declined with increase in soil depth. Immediately after the burn, pH increased ($P<0.01$) under all jhum cycles and this increase was more obvious in the surface layers of the soil profile. Further, this increase in surface soil pH after the burn was more marked under a 15 year cycle compared to 10 and 5 year cycles. During cultivation, the pH declined markedly($P<0.05$) starting from 30 days after the burn up to 365 days and this also was pronounced in the surface layer of the soil. 730 days after cropping, under a 5 year jhum cycle, the pH was even lesser ($P<0.05$) than that after 365 days. The pH of the soil under terrace cultivation increased slightly($P<0.05$) after 100 days of cropping only at a depth of 0-14 cm but declined afterwards reaching a level as the original one present at the beginning. At lower depths, however, pH did not change with passage of time. Under terrace system too, pH declined with increase in soil depth.

Carbon:

The concentration of soil carbon was significantly higher($P<0.01$) at all depths under longer jhum cycles of 10 and 15 years compared to that under a 5 year cycle. At all sites carbon concentration was significantly low ($P<0.01$) at a 28-40 cm depth compared to the profile above. Burning of the slash on the ridges caused a significant reduction ($P<0.05$) in the carbon concentration in the soil at 0-7 cm and 14-28 cm depths and more markedly ($P<0.01$) at a depth of 7-14 cm only under 10 and 15 year jhum cycles. Under a 5 year cycle no significant difference was observed ($P>0.05$) for the surface layer of the soil before and after the burn. Here significant reduction was noted($P<0.05$) only at 7-14 cm depth subsequent to the burn. While ridges and furrows did not show any difference at the pre-burn stage, after the burn carbon concentration was significantly higher ($P<0.05$) in the furrows than on the ridges, except for most of the samples from 28-40 cm depth under 10 and 5 year cycles. The percentage of carbon under terrace system decreased significantly ($P<0.01$) only at a depth of 28-40 cm at a given time. Further at the end of 730 days, carbon level declined sharply ($P<0.01$) at all depths. Soon after the burn, carbon concentration declined up to 100 days at all depths; at 0-14 cm depth alone it was significantly reduced ($P<0.05$) after 100 days (Table 5.2).

At the pre-burn stage, carbon content was significantly higher ($P<0.05$) under 10 year cycle followed by 15 and 5 year cycles. This trend was maintained after the burn also. Under all jhum cycles, the decline in carbon content was marked a day after the burn ($P < 0.01$) and further continued to decline up to 365 days. Thus fluctuation was more pronounced in the surface layers of the soil. Under a 5 year cycle the carbon content at 730 days was not different from that after 365 days ($P > 0.05$). A similar pattern was also observed under terrace cultivation except that the observations pertain to the cropping period only (Fig.5.1).

Nitrogen:

Nitrogen concentration was generally higher in the surface layers of the soil and declined with depth both on ridges and furrows. While the nitrogen concentration in the soil on the ridges under a 15 year jhum cycle was close to that under a 10 year cycle, it was significantly low ($P < 0.05$) under a 5 year cycle. After the burn, the nitrogen concentration at a depth of 0-14 cm declined sharply in the case of 15 and 10 year cycle; under a 5 year cycle this reduction was confined to 0-7 cm depth only. On the ridges, the nitrogen concentration further declined up to 100 days at a depth of 0-14 cm under all jhum cycles and then improved subsequently while in the deeper layers it declined gradually upto 365/730 days. In the furrows too, the nitrogen concentration was similar under 15 and 10 year jhum cycle where as it was low under a 5 year cycle. Nitrogen concentration did not fluctuate with time in the furrows. The nitrogen concentration in the soil pool of the terrace system was found very close to that of a 5 year jhum cycle (Table 5.2).

Fig.5.1 Changes in total quantity of carbon(within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

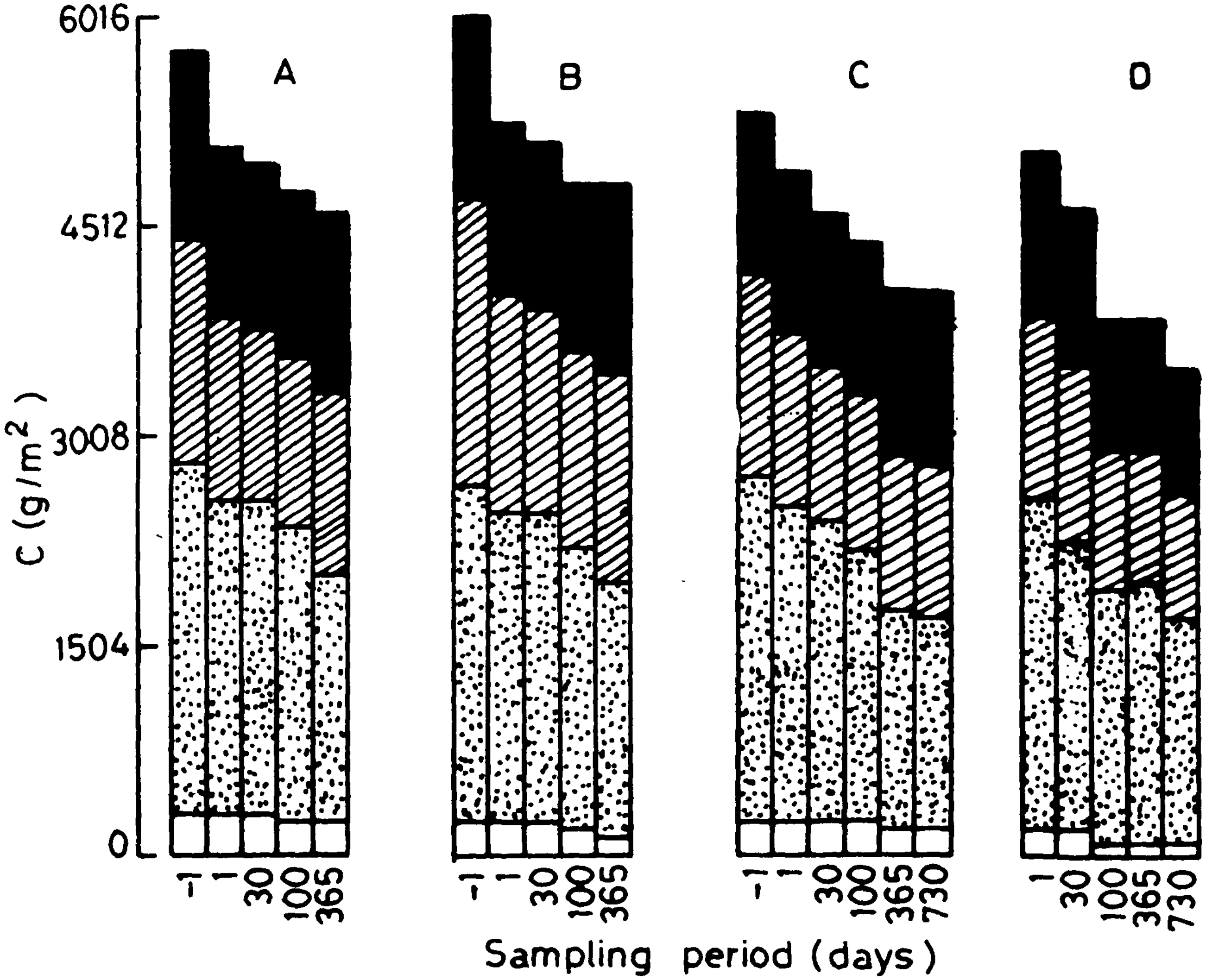

6016
4512
3008
1504
0
C (g/m²)
A
B
C
D
-1
1
30
100
365
730
Sampling period (days)

FIG 5.1

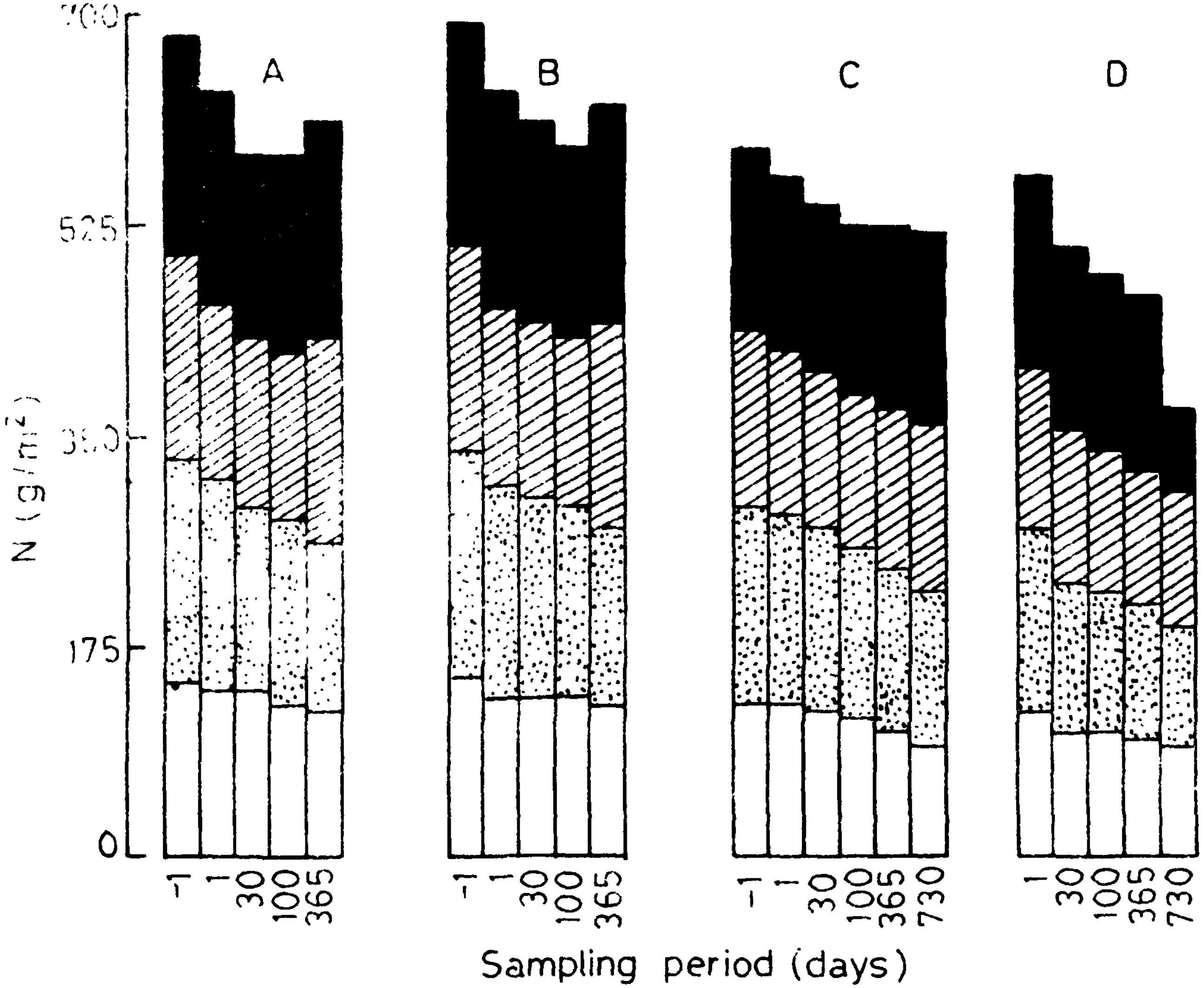
While the total amount of nitrogen b fore burning in the soil pool upto a depth of 40 cm was not significantly different under 15 and 10 year jhum cycles ($P > 0.05$), this was markedly low ($\angle 0.01$) under 5 year cycle. Soon after the burn, it was reduced by 6%, 9.4% and 4.2% in the case of 15,10 and 5 year jhum cycles respectively. After 100 days of jhum, the nitrogen content was reduced by 15-17% of the initial level under 15 and 10 year jhum cycles. At the end of 365 days about 38% of the nitrogen lost during the initial 100 days of cropping under 15 and 10 year cycles was recovered. Under a 5 year cycle, however, the nitrogen content declined up to a period of 100 days and then stablized at this level. At the end of 730 days under a 5 year cycle, this level of nitrogen was maintained. Under all jhum cycles, the fluctuation in nitrogen content was pronounced in the surface layers of the soil only. During cropping under terrace system, the nitrogen content in the soil pool decreased significantly ($P \angle 0.01$) upto 730 days so that about 35% of the nitrogen was lost from the soil pool (Fig.5.2).

Available phosphorus:

At the pre-burn stage, the available phosphrus concentration in the soil pool up to a depth of 40 cm was significantly higher ($P \angle 0.05$) under 15 year jhum cycle compared to 10 and 5 year cycles with least values under the latter, both on ridges and furrows. In all cases, phosphorus

Fig.5.2 Changes in total quantity of nitrogen (within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

FIG 5.2

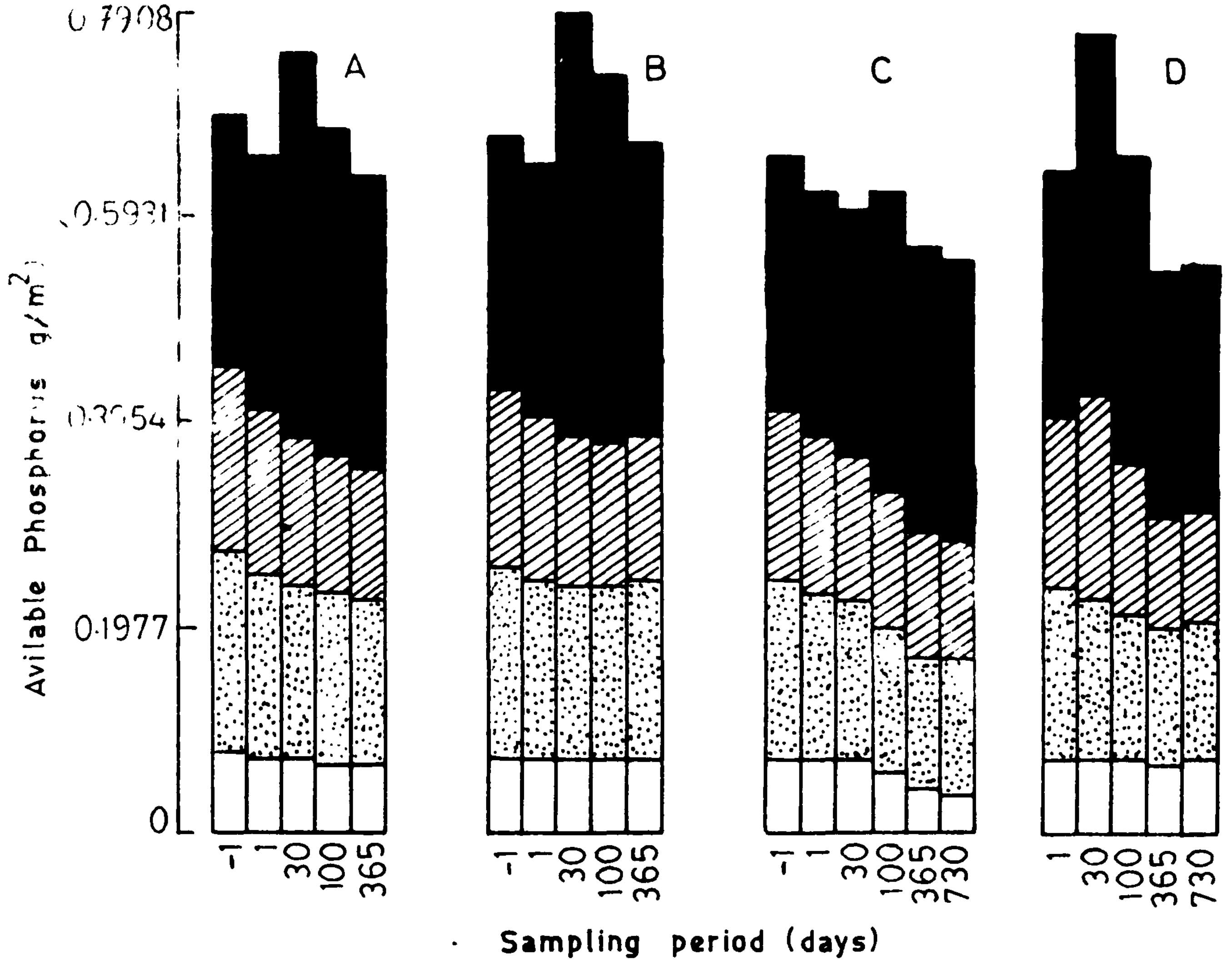

700
525
350
175
0
N (g/m²)
A
B
C
D
-1
1
30
100
365
730
Sampling period (days)

concentration declined with increase in depth of the soil. The concentration on the ridges increased only significantly ($P < 0.05$) 1 day after the burn but improved significantly ($P < 0.01$) 30 days after cropping, followed by a decline upto 365/730 days under all cycles. The change in phosphorus concentration with time was not very marked in the furrows. Further, both on the ridges and furrows, difference in concentration with time was more pronounced in the surface layers of the soil. Under terrace system also the concentration of phosphorus increased after 30 days of cropping followed by a decline subsequently which was more pronounced in the surface layers of the soil only. Here too, the concentration declined with depth of the soil (Table 5.2).

Phosphorus content in the soil pool under different jhum cycles declined significantly ($P < 0.05$) soon after the burn with a marked recovery after 30 days under 15 and 10 year cycles and after 100 days under 5 year cycle followed by a gradual decline during subsequent time period. Under all the cycles, phosphorus level fluctuated sharply in the surface layers of the soil only. In general; phosphorus content was significantly lower ($P < 0.05$) under a 5 year jhum cycle than under 15 and 10 year cycles. During cropping under terrace system, phosphorus content increased sharply after 30 days followed by a significant decline at the end of 365 days (< 0.01) (Fig.5.3).

Fig.5.3 Changes in total quantity of available phosphorus (within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

FIG 5.3


0.7908
0.5931
0.3954
0.1977
0
Avilable Phosphorus g/m²
A
B
C
D
-1
1
30
100
365
730
Sampling period (days)

Exchangeable cations:

At the pre-burn stage no significant difference ($P > 0.05$) of the cations were observed between the three jhum cycle, on the ridges and in the furrows. However, a day after the burn significantly higher levels of cations were observed under all the cycles on the ridges only and this was more pronounced in surface layers of soil only up to a depth of 14 cm/28 cm. During subsequent days of cropping the concentration of cations on the ridges declined gradually upto 365/730 days. During the post-burn period, concentration of cations on the ridges was higher under 15 year jhum cycle and least under a 5 year cycle. During cropping under terrace system cations declined significantly ($P < 0.01$) with passage of time. Under all situations cation concentration also declined with increase in depth (Table 5.3).

The level of all the cations increased sharply soon after burn ($P < 0.01$), under all jhum cycles, this being more pronounced under longer jhum cycles. During the cropping period there was a drastic decline ($P < 0.01$) in the amount after 30 days followed by a gradual decline ($P < 0.01$) during the subsequent period. Generally, during the post-burn period, the amount of cations was found to be maximum under a 15 year cycle and least under a 5 year cycle. Potassium level at the end of the 365 days after cropping was higher ($P < 0.01$) in the soil pool compared to the pre-burn period under 10 and 15 year cycles and was significantly lower

Table 5.3 Changes in concentration of the cations (mg/100 g soil) during cropping.

Cations	Sampling time (days)	Jhum cycle (yr) 15				10				5				Terrace			
		Soil depth (cm)				Soil depth (cm)				Soil depth (cm)				Soil depth (cm)			
		0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40
Potassium	-1	13(13)	9(9)	6(6)	5(5)	11(11)	7(7)	5(5)	5(5)	12(12)	7(7)	6(6)	6(6)	-	-	-	-
	1	61(13)	39(9)	9(6)	7(5)	56(11)	34(7)	7(5)	7(5)	51(12)	32(7)	7(6)	6(6)	13	10	7	5
	30	29(11)	22(11)	10(6)	6(5)	32(9)	20(7)	9(5)	7(5)	27(8)	17(7)	6(6)	5(6)	11	7	5	7
	100	21(8)	17(7)	18(7)	9(5)	22(7)	16(6)	13(5)	11(3)	16(6)	10(9)	5(6)	5(4)	7	6	9	9
	365	15(6)	10(5)	14(5)	13(3)	13(6)	14(4)	11(5)	16(5)	11(4)	7(6)	3(4)	7(3)	5	3	5	5
	730	-	-	-	-	-	-	-	-	8(4)	5(4)	3(3)	9(2)	3	5	5	5
Calcium	-1	10(10)	11(11)	7(7)	3(3)	12(12)	10(10)	6(6)	4(4)	9(9)	8(8)	8(8)	3(3)	-	-	-	-
	1	32(10)	27(11)	19(7)	5(3)	28(12)	20(10)	15(6)	6(4)	21(9)	17(8)	13(8)	6(3)	13	11	6	5
	30	23(10)	16(11)	11(7)	4(3)	19(12)	18(10)	13(6)	6(4)	16(9)	15(8)	13(8)	6(3)	12	9	5	5
	100	19(10)	11(11)	8(7)	3(3)	16(12)	14(10)	11(6)	4(4)	8(6)	6(6)	5(8)	6(3)	8	7	5	4
	365	15(8)	9(11)	5(7)	2(3)	13(8)	12(10)	9(6)	3(4)	5(3)	4(5)	5(8)	5(3)	7	6	4	2
	730	-	-	-		-	-	-	-	3(3)	2(3)	5(8)	4(3)	5	4	3	2
Magnesium	-1	8(8)	7(7)	7(7)	5(5)	10(10)	6(6)	4(4)	2(2)	9(9)	6(6)	5(5)	3(3)	-	-	-	-
	1	23(8)	16(7)	9(7)	7(5)	21(10)	19(6)	9(4)	3(2)	20(9)	16(6)	8(5)	3(3)	10	7	5	3
	30	14(8)	10(7)	7(7)	5(5)	13(10)	12(6)	8(4)	3(2)	15(9)	13(6)	7(5)	3(3)	7	6	4	3
	100	9(7)	9(7)	6(7)	5(5)	11(8)	10(6)	7(4)	4(2)	11(9)	9(6)	6(5)	3(3)	4	4	4	3
	365	7(7)	7(5)	5(7)	5(5)	7(7)	6(6)	5(4)	5(2)	8(7)	6(6)	4(5)	2(3)	2	3	3	2
	730	-	-	-	-	-	-	-	-	6(6)	4(6)	3(5)	2(3)	ND	3	4	2

Value in parentheses refer to the changed chemical characterics under furrows of the jhum site.

($p < 0.01$) under a 5 year cycle . For calcium and magnesium, a significant decline ($p < 0.01$) in the level of these nutrients at the end of 365/730 days compared to the pre-burn stage could be observed only under a 5 year jhum cycle. The fluctuations in the level of these cations was marked in surface soil layers only. In general, under terrace system the cation level in the soil was significantly lower ($p < 0.01$) at the end of 365/730 days of cropping compared to the initial level (Fig.5.4,5.5, 5.6).

Recovery pattern during fallow development.

Soil pH in the surface layers of the soil declined with fallow development, the fluctuation was not marked in the deeper layers of the profile. Percentage of carbon in the soil declined initially up to 5 years of fallow development and then recovered in older fallows in the surface layer of the soil only where as in deeper layers a gradual increase in carbon was noted beyond 1 year fallow period. Nitrogen and phosphorus concentration throughout the soil profile, in general, declined in the initial stages of fallow development and then improved later. Cations in the soil showed a marked drop after one year of fallow development fallowed by recovery in the surface layers only around 5 to 10 years. The cation concentration in deeper layers of the profile was not very much affected (Table 5.4).

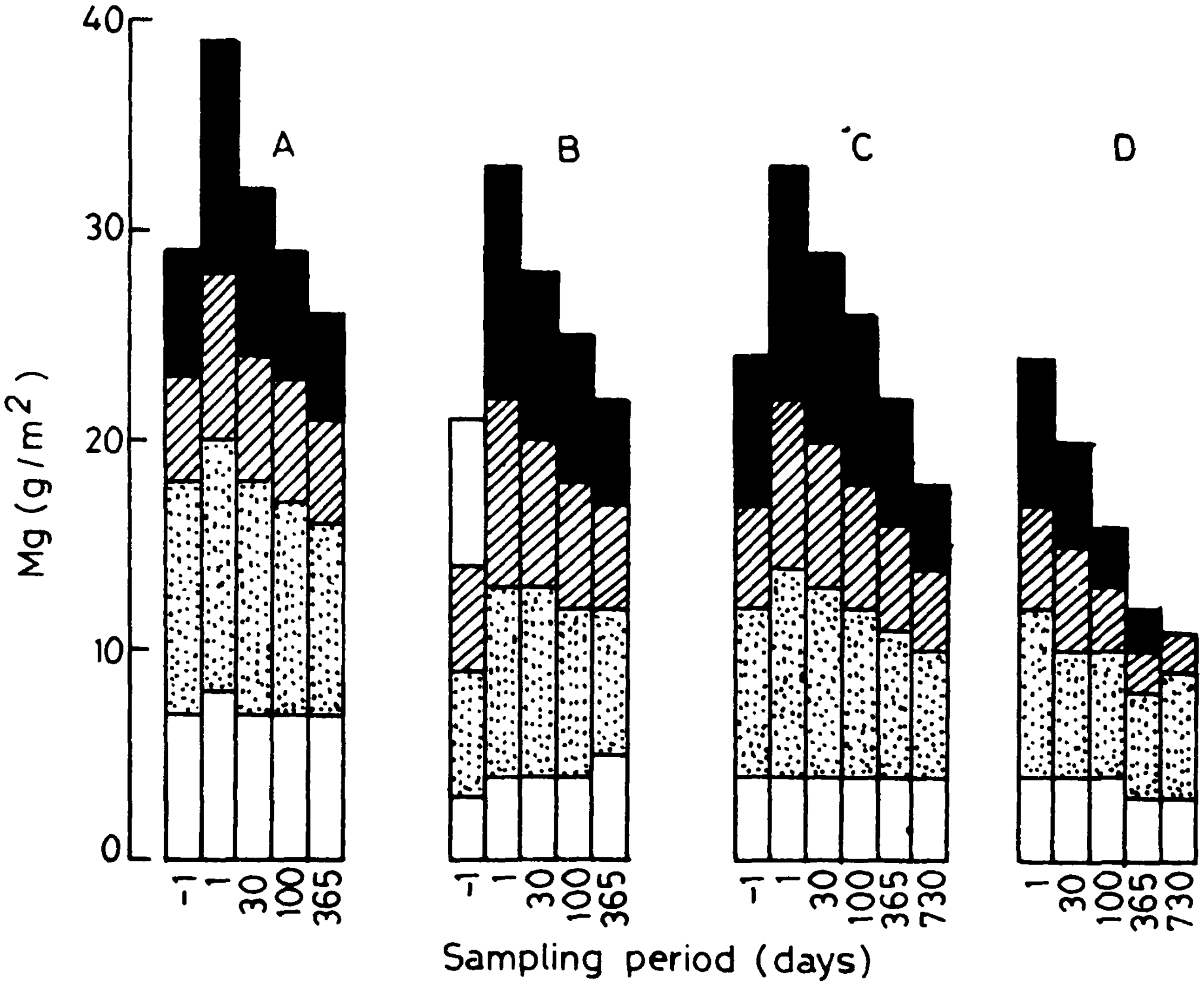


FIG 5.6

Fig.5.6 Changes in total quantity of magnesium (within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

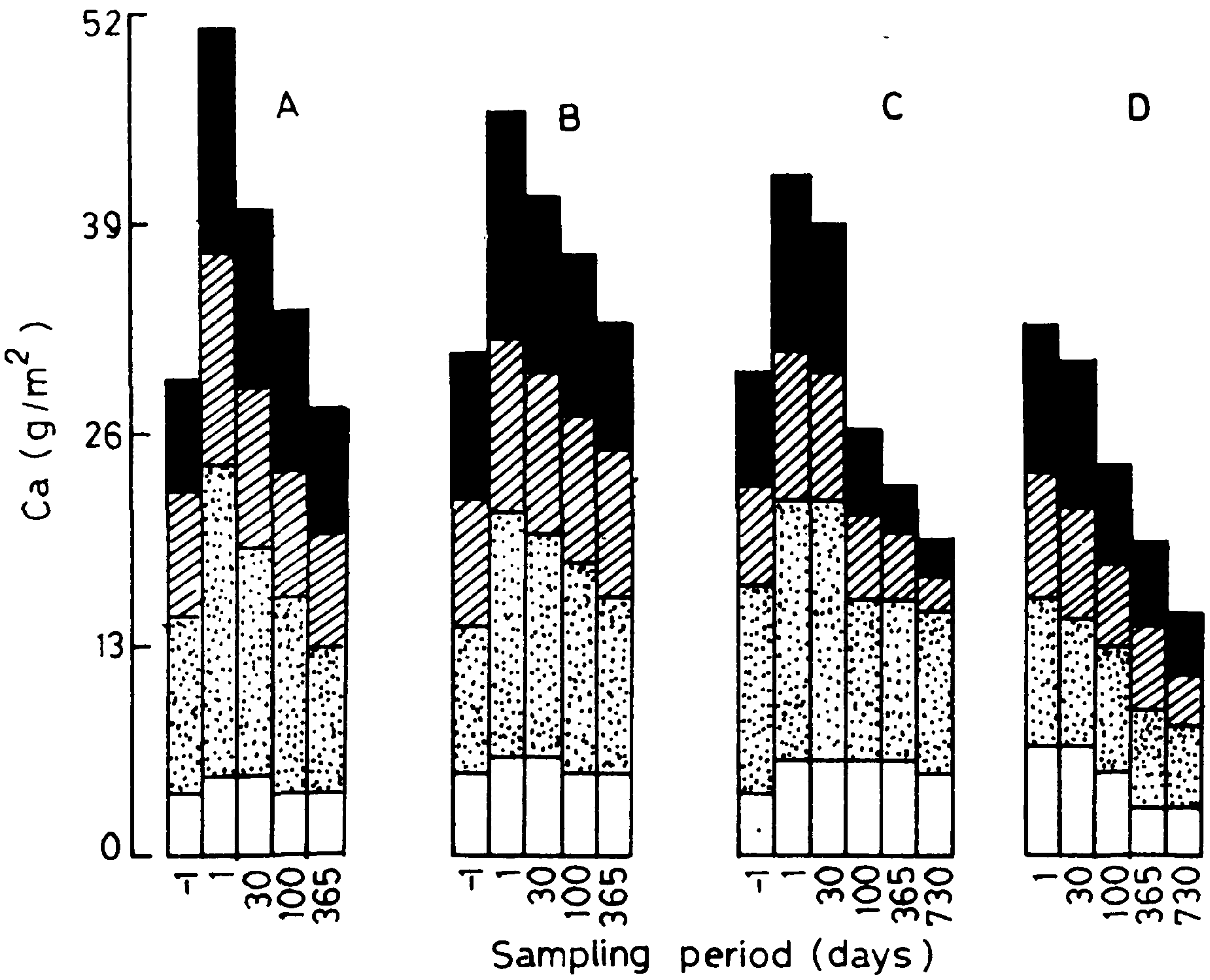
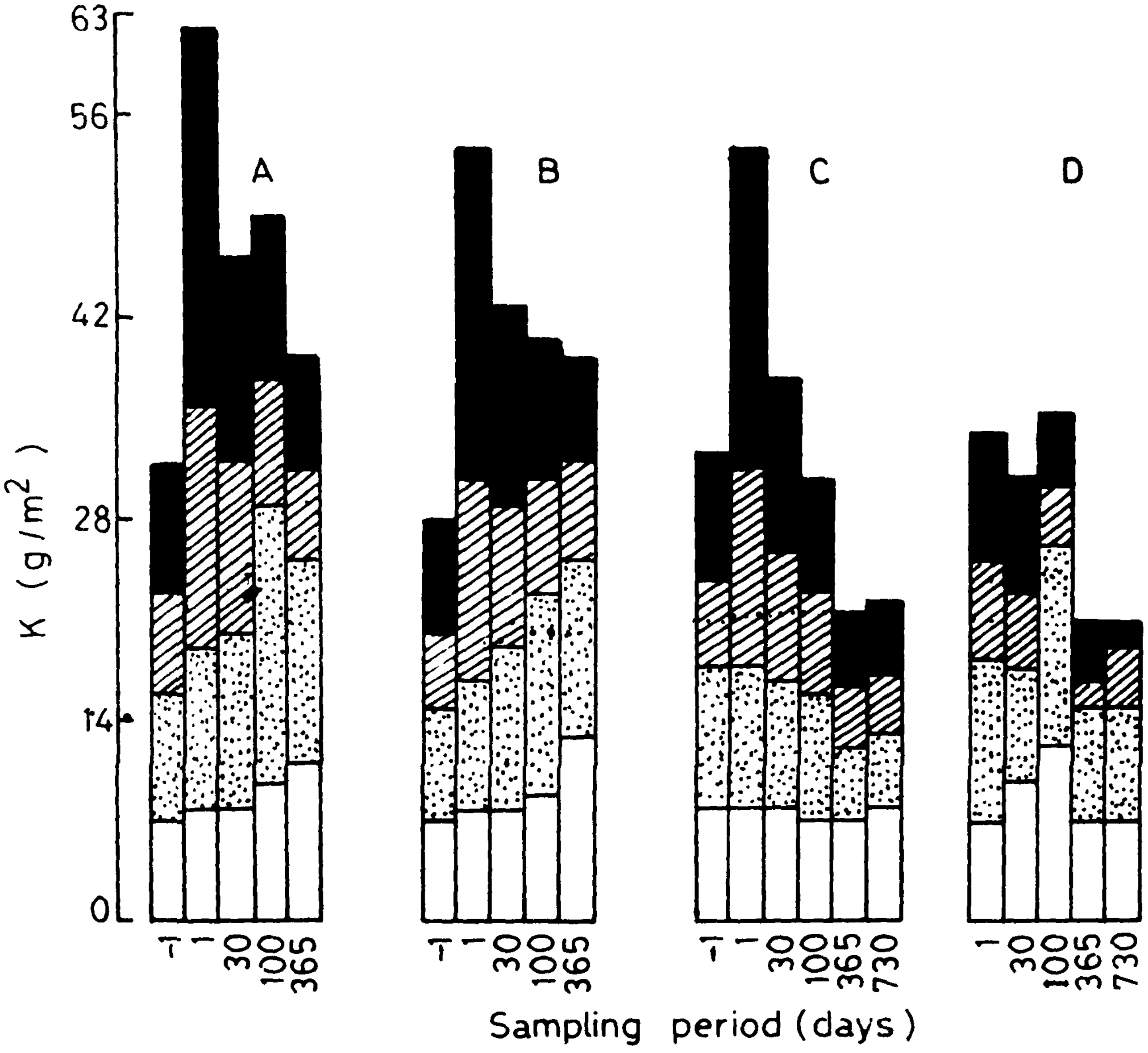


FIG 5.5

Fig.5.5 Changes in total quantity of calcium (within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.



K (g/m2)
63
56
42
28
14
0
A
B
C
D
-1
1
30
100
365
730
Sampling period (days)

FIG 5.4

Fig.5.4 Changes in total quantity of potassium (within a soil profile of 40 cm depth) during the various stages of jhum and terrace cultivation. A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil.

Table 5.4. Changes in physico -chemical characteristics during fallow development after jhum.

Age of jhum fallow (Yr)															
1				5				10				15			
Soil depth(cm)				Soil depth(cm)				Soil depth (cm)				Soil depth (cm)			
0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40	0-7	7-14	14-28	28-40
5.4(5.4)	5.1(5.1)	5.2(5.2)	5.0(5.1)	5.5(5.5)	5.2(5.1)	5.1(5.1)	5.1(5.0	5.3	5.1	5.1	5.0	5.1	5.0	5.0	4.9
1.79 (1.83)	1.18 (1.31)	0.81 (0.84)	0.07 (0.07)	1.65 (1.65)	1.81 (1.81)	1.49 (1.49)	0.14 (0.14)	1.85	2.65	1.55	0.17	1.93	2.10	1.60	0.22
0.217 (0.221)	0.200 (0.205)	0.069 (0.069)	0.047 (0.046)	0.216 (0.221)	0.190 (0.194)	0.105 (0.105)	0.091 (0.093)	0.260	0.218	0.122	0.111	0.257	0.215	0.121	0.111
3.55 (3.48)	1.09 (1.05)	1.13 (1.[illegible])	0.50 (0.51)	3.33 (3.31)	2.11 (2.10)	1.09 (1.10)	0.50 (0.50)	3.41	2.25	1.16	0.62	3.44	2.29	1.22	0.57
6(5)	5(5)	5(5)	4(4)	11(9)	7(6)	6(5)	5(5)	11	6	5	5	13	9	6	5
10(11)	8(8)	6(6)	4(4)	9(11)	8(7)	8(8)	5(5)	12	11	6	5	11	11	8	5
6(7)	6(8)	4(4)	3(3)	9(9)	6(6)	6(6)	3(3)	10	5	4	3	8	7	7	6

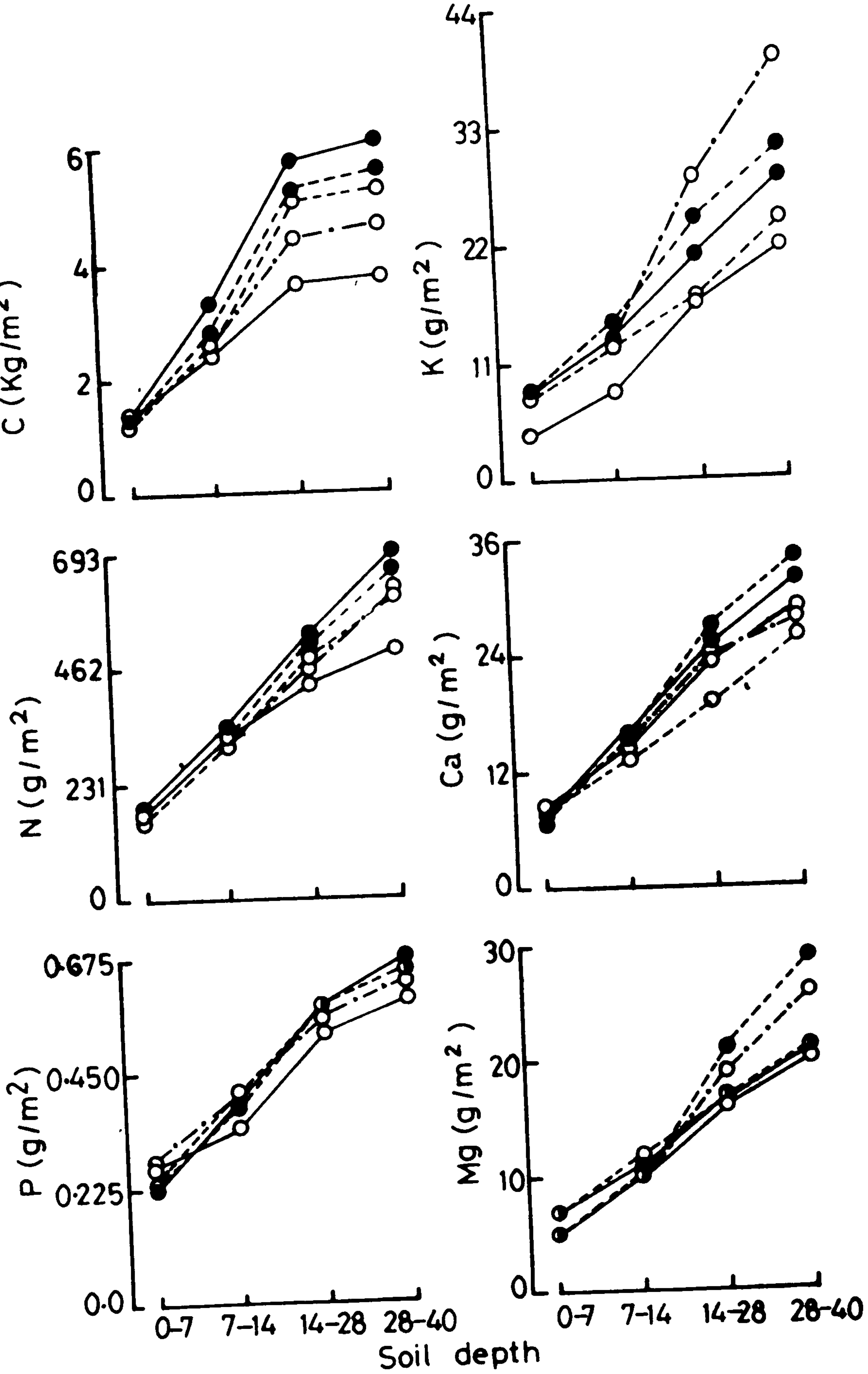
In general, the cumulative values for carbon, nitrogen and phosphorus followed a similar trend in the recovery pattern of nutrients during fallow development. To start with, the level of all these three elements was low in a 0 year fallow after 1 year of cropping which further declined after 1 year of fallow development. In 5 and 10 year fallows the recovery of these elements was marked though in a 15 year fallow. it slightly declined. In the case of cations, the nutrient capital in a 0 year fallow was comparatively higher and was maximum in the case of potassium followed by magnesium. In a 1 year fallow there was a drastic decline in the case of potassium and magnesium where as it occurred only in a 5 year fallow for calcium. In 10 and 15 year fallows, steady nutrient revovery was observed for all the three cations (Fig.5.7).

DISCUSSION

'Slash and burn' agriculture involving slashing of the underbrush along with the lower branches of the sparsely distributed pine trees and burning the dried slash along the ridges before growing a mixture of crops on the hilly slopes at the higher elevations of Meghalaya, brings about a number of changes in the physico-chemical properties of the soil. Burning of the plant biomass in a forested ecosystem is known to alter the availability of at least a few nutrients important for plant growth (Ahlgren and Ahlgren,

Fig.5.7 Changes in cumulative quantity of various nutrients (within a soil profile of 40 cm depth) during the various stages of fallow development. O–·–·–O, '0' year; O——O, 1 year; O- - -O, 5 year; ●——●, 10 year; ●- - -●, 15 year jhum fallow.

FIG 5.7



C (Kg/m²)
0
2
4
6
K (g/m²)
0
11
22
33
44
N (g/m²)
0
231
462
693
Ca (g/m²)
0
12
24
36
P (g/m²)
0.0
0.225
0.450
0.675
Mg (g/m²)
0
10
20
30
0-7
7-14
14-28
28-40
Soil depth

1960); it may also affect the amount of water passing through the soil sub-system, dissolved substances and the particulate matter lost from the top soil (Ramakrishnan et al.,1980; Mishra and Ramakrishnan, unpublished). These changes are dependant on the intensity of burning imposed on a given site.

One of the effects of the burn was increased pH of the soil, an observation already well documented (Ahlgren and Ahlgren, 1960; Ramakrishnan and Toky, 1981). This is accounted as due to increase in calcium and other cations liborated after fire. During cultivation and subsequent fallow development, pH declined sharply. This may be partly due to erosion and leaching losses of cations, absorption by the crops and the fallow vegetation, and the acidity caused by decomposing pine litter alongwith others.

The marked decrease in carbon content under 10 and 15 year jhum cycles may be explained as due to comparatively high intensity burn than under 5 year jhum cycle where the fuel load is obviously low. Though the burning damages soil microbial populations, their recovery to pre-burn levels and even higher occurs almost immediately (Fuller et al., 1955; Meiklejohn, 1955; Firsova, 1964; Ahlgren and Ahlgren, 1965). Such an increased microbial activity alongwith improved soil temperature condition could possibly result in increased breakdown and utlization of the organic matter in the burned sites. This accentuated by greater losses of organic matter due to increased surface run-off (Mishra and Ramakrishnan, unpublished) could cause decrease of carbon content during the cropping period. This depletion continued even to the first year of fallow development. After this initial depletion of organic matter, recovery occurred due to: (i) return of litter from decomposing weedy species and pine litter derived from sparsely distributed trees of this species, and (ii) the generally slow rate of pine needle decomposition accentuated by low temperature conditions of higher elevations (Madge, 1966). Generally high level of carbon under longer jhum cycles of 10 and 15 years suggests that this could be supported compared to a 5 year cycle. Coulter (1950), Reed (1951), and Birch and Friend (1956) have also made similar observations and concluded that under favourable cropping and fallow period humus level in the soil could be maintained at relatively higher levels in order to sustain slash and burn agriculture.

Nitrogen under jhum declined sharply after the burn (Hoffman, 1966; Wells, 1971; White et al., 1973) and this could be attributed to the conversion of organic nitrogen to volatile forms during the pyrolysis(Allen, 1964; Knight, 1966; Debell and Ralston, 1970). The degree of volatalization is dependent on the intensity of the burn and therefore under a 5 year jhum cycle the post-burn decline is minimal compared to longer cycles with greater fuel load. Nitrogen recovery occurred after 100 days of cropping under 10 and 15 year jhum cycles only, which may be related to increased nitrification (Ahlgren, 1960; Ahlgren and Ahlgren, 1965; Wells 1971; Jorgensen and Wells, 1971; Biswell, 1972) after the burn partly due to changed pH and micro-environmental conditions and also due to release of allelopathic suppression by the removal of the vegetational cover as suggested by Smith et al.(1968), and Rice (1974).

Though there are no obvious mechanisms for volatilization of phosphorus, Lloyd (1971) has reported a massive loss of this element due to burning, while Allen(1964) and Viro (1974) found no significant effect due to fire. After the burn in the jhum sites, the quantity of available phosphrous declined in the soil more markedly in the surface layers. This loss may partly be due to volatalization (?) and more because of losses due to erosion, run-off and leaching which was estimated to be to the tune of 1.7 kg ha^{-1} during the first 3 months of the cropping season during the monsoon. This was followed by recovery during the cropping period. This recovery may be related to the addition of organic manure to the soil during the cropping period and also decomposing plant litter derived from weeds ploughed into the soil. The subsequent decline in phosphorus level in the soil pool may be due to rapid absorption by the fast growing crops and further depletion by the developing vegetation in the initial stages.

During jhum, large quantities of cations are released in a single pulse after the burn (Nye and Greenland, 1960;

Zinke et al., 1978) and their availability exceeds the retention capacity of the ecosystem. Hence a large proportion of this is lost before they could be incorporated into the plant biomass (Mishra and Ramakrishnan, unpublished). The larger quantity of cations released in sites under 15 and 10 year jhum cycles is due to more slash that was burnt compared to that under a 5 year cycle. This alongwith more marked depletion of cations after cropping for one year under a 5 year cycle would again make a short cycle unfavourable (Nye and Greenland 1960). The recovery pattern for the cations during fallow development indicated marked depletion in the first year followed by a gradual improvement reaching a maximum under a 15 year fallow where the level often exceeds that under a 0 year fallow as in the case of calcium and magnesium. This initial depletion is due to rapid utilization by developing vegetation and the fact that this recovery is not up to the initial level suggests that shorter cycles would result in rapid depletion of soil nutrients after successive jhum.

Under terrace cultivation, nutrient depletion is very rapid during the cropping period and in all cases the level of nutrients attained after one/two years of cropping is invariably lower than the values attained even under 5 year cycle of jhum. This is inspite of addition of the organic and inorganic fertilizers which suggests that the efficiency of utilization of nutrients is extremely low under this practise. Earlier results obtained by us (Ramakrishnan et al., 1980) suggest that losses due to leaching could be as heavy as through surface run-off even on a slope due to highly porous nature of the soil profile and this only could get accentuated after terracing when run-off losses are checked.

A comparison of the nutrient status under jhum at lower elevations of this region (Ramakrishnan and Toky, 1981) with the present study indicates that the level of all the elements during the first year of cropping is often many times higher in the former. This is partly related to slash and burn of the entire forest at lower elevations in contrast to partial slashing at higher elevations. Further the wide variety of broad leaved species including trees at lower elevations would probably contribute to higher nutrient levels compared to that under high elevation jhum where the only important tree species is <u>Pinus kesiya</u> (that too only a few selected branches are slashed). The nutrient recovery in the present case is also comparatively slow, partly due to low temperature conditions which permit only slower decomposition of litter which gets accentuated because of pine needle, a comparatively difficult material for decomposition, being one of the chief components of the organic matter added to the soil during fallow development. The inefficiency of a 5 year jhum cycle at higher elevation is also evident from the generally low nutrient status of these soils during jhum. Apart from rapid depletion of nutrients due to continuous imposition of a short cycle, soil physical characteristics could also be adversely affected. This along with rapid loss of soil and nutrients under high rainfall situation as prevails in the region has resulted in deseartification (Ramakrishnan, 1980) of vast tracts of land.

SUMMARY

The soil fertility as affected by 'Slash and burn' agriculture (Jhum) at higher elevations of Meghalaya in the north-eastern India was investigated, comparing and contrasting 15 year, 10 year and 5 year jhum cycles. pH of the surface soil increased after the burn and gradually decreased during cropping and subsequent fallow development. Nutrients like carbon and nitrogen are volatalized due to burn and declined atleast in the initial phase of cropping. However, nitrogen recovery started during the later phase of cropping. Available phosphorus followed a more or less similar pattern as nitrogen. On the other hand, cations improved markedly after the burn and was depleted during cropping. In general, nutrients level under a 5 year jhum cycle was significantly lower than under 10 and 15 year cycles. The recovery pattern during fallow development had an initial phase of depletion upto about 5 years followed by recovery. This suggests against a short jhum cycle of 5 years as is more prevalent in the region. The generally lower nutrient status under terrace system after cropping even when compared to a 5 year jhum cycle suggests in-practicability of this system without heavy input of fertilizers.

CHAPTER — 6

POPULATION DYNAMICS OF *EUPATORIUM ADENOPHORUM* SPRENG. DURING SECONDARY SUCCESSION AFTER SLASH AND BURN AGRICULTURE(JHUM) AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.

INTRODUCTION

The perennial weed Eupatorium adenophorum Spreng., is a great menace in many parts of the world by causing damage to plantations and forest species, reducing the carrying capacity of grazing lands, restricting the movement of stock and machinery, affecting crop yield and rendering many areas useless for cultivation (Auld & Martin, 1975; Ramakrishnan et al.,1980). It is a native of Mexico and was first reported in India in the beginning of this century and during the last few decades it has established itself as a serous weed at higher elevations of the north-eastern India. This weed is an early colonizer on fallows naturally regenerating after 'Slash and burn' agriculture (locally called Jhum). The practice of jhum involves slashing the herb and shrub species of the vegetation and also the lower branches of sparsely distributed pine trees (Pinus kesiya) in the month of December and burning the slashs in the following March after which the land is cultivated for a year or two before it is abandoned for natural regeneration of vegetation.

Biological control of this weed has been tried with some measure of success in Hawaii (Bess & Haramoto, 1959) and in Australia (Haseler, 1966; Auld, 1969 a) using a Tephritid gall fly (Procecidochares utilis Stone). However, this method has not been effective in India as this fly is susceptible to some native parasites (Gupta, 1977). Heavy herbicidal requirement and hilly terrain pose major impediments for chemical control. The prime purpose of the present study was , therefore, to measure the relative performance of this species in terms of fecundity and survivorship in plant communtties present in jhum fallows of different age and to assess factors determining natural regulation of population size, at higher elevations of Meghalaya.

GROWTH CHARACTERISTICS OF E.ADENOPHORUM

E. adenophorum (Asteraceae) is a bushy perennial herb, 1-2 m high and is an important weed soon after jhum. Roots are mostly confined to the top layer of the soil(up to a maximum depth of 40 cm) with adventitious roots arising from the base of the stem. New shoots may arise as sprouts from the base during the monsoon with simultaneous depth of some of them occurring throughout the year. These shoots, therefore, were considered as separate individuals. Seedling regeneration also occurs during the early part of the monsoon. The active vegetative growth phase is during June to October. During winter, growth is retarded and may even be adversely affected due to frost. Flowering starts in November and the mature seeds are disperesed by March - April. This species possesses many characteristics for its success as an early colonizer. Apart from the production of a large number of seeds which are light and wind dispersed, it is also capable of some degree of vegetative propagation due to sprouts arising from the base of the plant. Seedling could also tolerate some shading up to 10% of daylight (Auld & Martin, 1975) apart from its faster growth rate. Aromatic and acrid chemicals present in the plant body makes it unpalatable to cattle.

STUDY AREA AND CLIMATE

This study was done at Shillong(25.34°N,91.56° E) in the Khasi hills of Meghalaya, placed at an elevation of 1500 meteres where jhum is extensively practised by the local Khasi tribe. The climate here is seasonal with most of the average rainfall of 1843 mm occurring during the monsoon period from May to September. The average maximum temperature during this season is 23.7°C and the average minimum temperature is 16.3°C. The humidity remains very high during this period (84.1%). Winter is cold with occasional showers, extending from November to February with an average minimum temperature of 7.6°C. During December and February, frosts are very common and the temperature often goes below 0°C. The brief summer is warm and dry extending from March to April and is accompanied with strong winds. The entire area is characterised by pine forests with <u>Pinus kesiya</u> as the dominant species. The terrain is hilly with steep slopes, the angle average being 30°- 40°. The soil is of podsolic type .The soil cover is thin as erosion outstrips the weathering process.

METHODS OF STUDY

Five jhum fallows (after jhum cultivation done for one year) of different age, i.e., 1,3,6,10 and 15 years were identified around Shillong taking care to ensure similar topographic and exposure conditions. The age of the fallows and the consistency in land management at the time of jhum cultivation was ensured on the basis of records available with the village headman. Density, frequency and cover of the different plant species in different jhum fallows were measured uding $1m^2$ quadrats in the case of herbacous species and 100 m^2 quadrats for shrubs and trees. Relative frequency, relative density and relative cover were estimated for the vegetation on the basis of 30 quadrats in each site and the importance value index (IVI) is t the sum of all these three parameters. The IVI values could, therefore, be a theoretical maximum of 300 and is indicative of the dominance of a given species in the community (Mishra, 1968; Kershaw, 1973).

Demographic studies were done in permanent quadrats of $1m^2$ with three replicates in each of the jhum fallows. Each sprouts arising from the base of the plant was considered as an individual for the purpose of this study. The fate of the seedling, plants more than a year old and new vegetative sprouts recruited during the study period was followed over a period of one year from April 1979 to April 1980. The plants already present at the start of the experiment were considered as more than a year old. The seedlings of two cohorts coming up in May and June were marked using two different colours of paints by putting a dot over the cotyledonary leaves in order to differentiate them. Vegetative shoot sprouts of current year and that more than a year old were tagged, separately and observed.

The number of capitula per m^2 was estimated by counting the total number of capitula produced by all the plants in a quadrat of $1m^2$ and is an average of three replicates. Calculations on the number of seeds per capitula was based on 30 observations in each fallow. The seed output per m^2 was then calculated for each of the fallow by multiplying the total number of capitula. The number of seeds per fertile plant was calculated on the basis of the number of fertile plants and the seed output per m^2.

RESULTS

Vegetation analysis:

Slash and burn agriculture (Jhum) at higher elevations differs from that at lower elevations(Ramakrishnan et al., 1980) in that only the lower branches of the trees alongwith undergrowth shrubs and herbs are slashed instead of the entire forest. *Pinus kesiya* is, therefore, already present right from the beginning of secondary succession but sparsely scattered. Secondary succession, therefore, starts with a few old trees of pine already present at the beginning of secondary succession.

The importance value indices (IVI) for plant species growing in different jhum fallows are given in Table 6.1. In a 1 year fallow a number of weedy species like *Eupatorium adenophorum*, *Erigeron linifolius*, *Hypochaeris radicata*, *Imperata cylindrica*, *Oxalis latifolia*, etc. are abundant. In 3-6 year fallows

Table 6.1. Importance value indices (IVI) of associated plant species in different jhum fallows.

Species	Age of the jhum fallow (year)				
	1	3	6	10	15
Artemisia vulgaris Linn.	-	-	-	5.46	4.8
Prunella vulgaris Linn.	-	4.1	-	-	-
Buddleia asiatica Lour.	-	-	-	3.86	4.57
Chrysanthemum cinerarifolium (Trev.)Vis.	4.76	-	-	-	-
Cosmos bipinnatus Cav.	-	7.9	-	-	-
Crotalaria mysorensis Roth.	-	-	3.3	4.14	3.7
Dichranip-teris linearis Burm.f.	-	13.58	22.56	8.08	4.1
Eleagnus latifolia Linn.	-	-	-	7.57	5.35
Erigeron linifolius Willd.	65.61	-	-	-	-
Eupatorium adenophorum Spreng.	43.89	45.92	52.97	7.0	2.1
Galium mollugo Linn.	-	1.75	-	-	-
Galium rotundifolium Linn.	-	2.78	4.46	-	-
Gnaphalium hypoleucum DC.	17.17	-	-	-	-
Gnaphalium luteoalbun Linn.	14.72	7.3	-	-	-
Gaultheria fragrantissima Wall.	-	-	3.99	3.28	4.73
Hypericum japonicum Thunb.	-	1.23	-	-	-
Hypochaeris radicata Linn.	33.91	25.3	13.15	-	-
Imperata cylindrica P.Beauv.	42.2	74.5	42.51	-	-
Indigofera dosua Ham.	-	-	-	2.29	2.7
Inula cappa DC.	-	2.99	-	-	-
Lantana camara Linn.	-	1.28	4.8	4.5	-
Lindera pulcherrima Benth.	-	-	-	5.67	8.36
Myrica esculenta Buch-Ham.	-	2.6	2.1	6.64	8.0

(Contd...)

Species	Age of the jhum fallow (year)				
	1	3	6	10	15
Neillia thyrsiflora D.Don.	-	1.5	-	-	-
Ophiopogon intermedius D.Don.	-	-	7.44	8.13	8.11
Osbeckia crinita Benth.	5.32	15.8	22.73	17.67	-
Oxalis latifolia HBK.	27.48	-	-	-	-
Panicum khasianum Munro.	-	1.5	-	-	-
Pieris ovalifolia(Wall.)Drude.	-	-	-	4.45	4.89
Pinus kesiya Royle.(seedling)	-	3.87	18.0	11.22	12.57
Pinus kesiya Royle.(tree)	11.76	17.78	36.4	46.3	47.2
Plectranthus coetsa Ham.	-	4.0	-	-	-
Plantago major Linn.	14.23	17.83	-	-	-
Pouzolzia hirta Hassk.	-	-	21.55	-	-
Pteridium aquilinum(L.)Kuhn ex Decken.	17.68	4.15	2.11	9.78	3.9
Quercus griffithii HK.f.	-	2.84	5.2	6.54	11.37
Rhus semialata Lour.	-	-	-	4.35	4.73
Rubus ellipticus Sm.	-	5.77	6.65	6.02	4.1
Rubus micropetalus Gard.	-	2.68	4.1	14.2	13.7
Scleria terrestris(Linn.)Fass.	-	-	3.3	-	-
Sehima wallichii Choisy.	-	-	-	-	4.51
Sida cordifolia Linn.	-	-	5.34	6.1	-
Smilax aspera Linn.	-	-	4.69	5.16	7.3
Sporobolus diander Beauv.	-	12.67	-	-	-
Viola distans Wall.	-	-	12.65	-	-

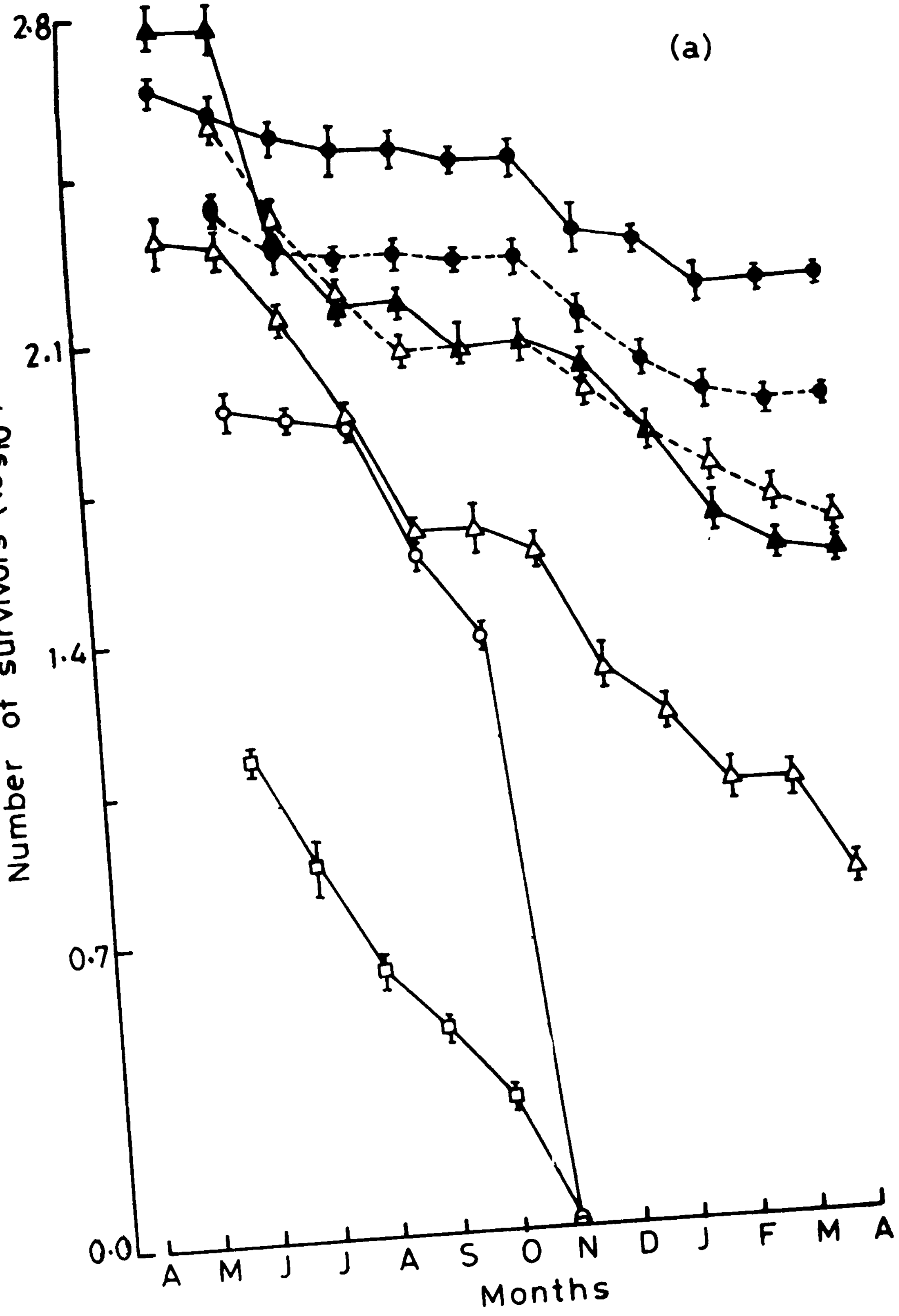
Erigeron linifolius and Oxalis latifolia are absent and the rest of the weed species maintain their dominance in the community. Apart from these, ferns like Dichranopteris linearis and Pteridium aquilinum are also important components in these early successional communities alongwith Osbeckia crinita. The weedy species are gradually replaced by rapidly regenerating Pinus kesiya tree, besides other broad leaved tree saplings of Cehima wallichii, Quercus griffithii and shrubs like Rubus micropetalus and Rubus ellipticus.

Surviorship:

The seedling population in different jhum fallows experienced varied degrees of mortality (Fig.6.1a). In a 1 year fallow all seedlings come up after the first rain in the month of May. However, in 3 and 6 years fallows seedlings appear at two different times in May and June and these two are designated as cohort 1 and 2 respectively. In older fallows of 10 and 15 years only one cohort appeared in June. Mortality of seedlings were high in younger fallows of 1 and 3 years and about 75% to 80% mortality of seedlings occurred during the first 6 months between May and October. Mortality in cohort 1 was higher than in cohort 2 in a 3 year fallow though the reverse was the case in a 6 year fallow. Seedling survival was maximum in a 6 year fallow. 100% mortality occurred in 10 and 15 year fallows by November.

Fig.6.1 Survivorship curves of _E. adenophorum_ (a) seedlings. Closed triangle, 1 year fallow; open triangle, 3 year fallow; closed circle, 6 year fallow; open circle, 10 year fallow; open square, 15 year fallow; Solid line, cohort 1; broken line, cohort 2. Vertical bars indicates standard errors of means.

FIG6.1


(a)
2·8
2.1
1·4
0·7
0·0
Number of survivors (log10)
A
M
J
J
A
S
O
N
D
J
F
M
A
Months

Considering the plants more than a year old (Fig. 6.1b), over 48% mortality occurred in fallow of 6,10 and 15 years; no mortality occurred in 1 and 3 year fallows. Mortality of plants here was most severe during the winter months of December-February.When sprouts originating during the study period was considered (Fig.6.1C) (less than a year old), 3 year fallow showed no mortality at all where as percentage mortality increased markedly in older fallows with increase in age of the fallow. However, recruitment of sprouts into the population was maximum in a 10 year fallow.

Population flux:

Table 6.2 presents the population flux of E.adenophorum in different jhum fallows. It may be noted here that sprouting of shoots of equal size occur from the base of the plant; simultaneously a few of these sprouts may also die. The values outside parentheses represent both sprout and seedling regeneration considered together, whereas seedling flux alone is shown in parentheses.

There was a net population increase both through vegetative and sexual reproduction in this species in 1,3 and 6 year fallows, this increase being more pronounced in the older fallows. In 10 and 15 year fallows, however, there was a net loss in the population size. While the plants originally present at the beginning of the study period did not show any mortality in 1 and 3 year fallows, 48% or more of these died in 6-15 year fallows. Annual

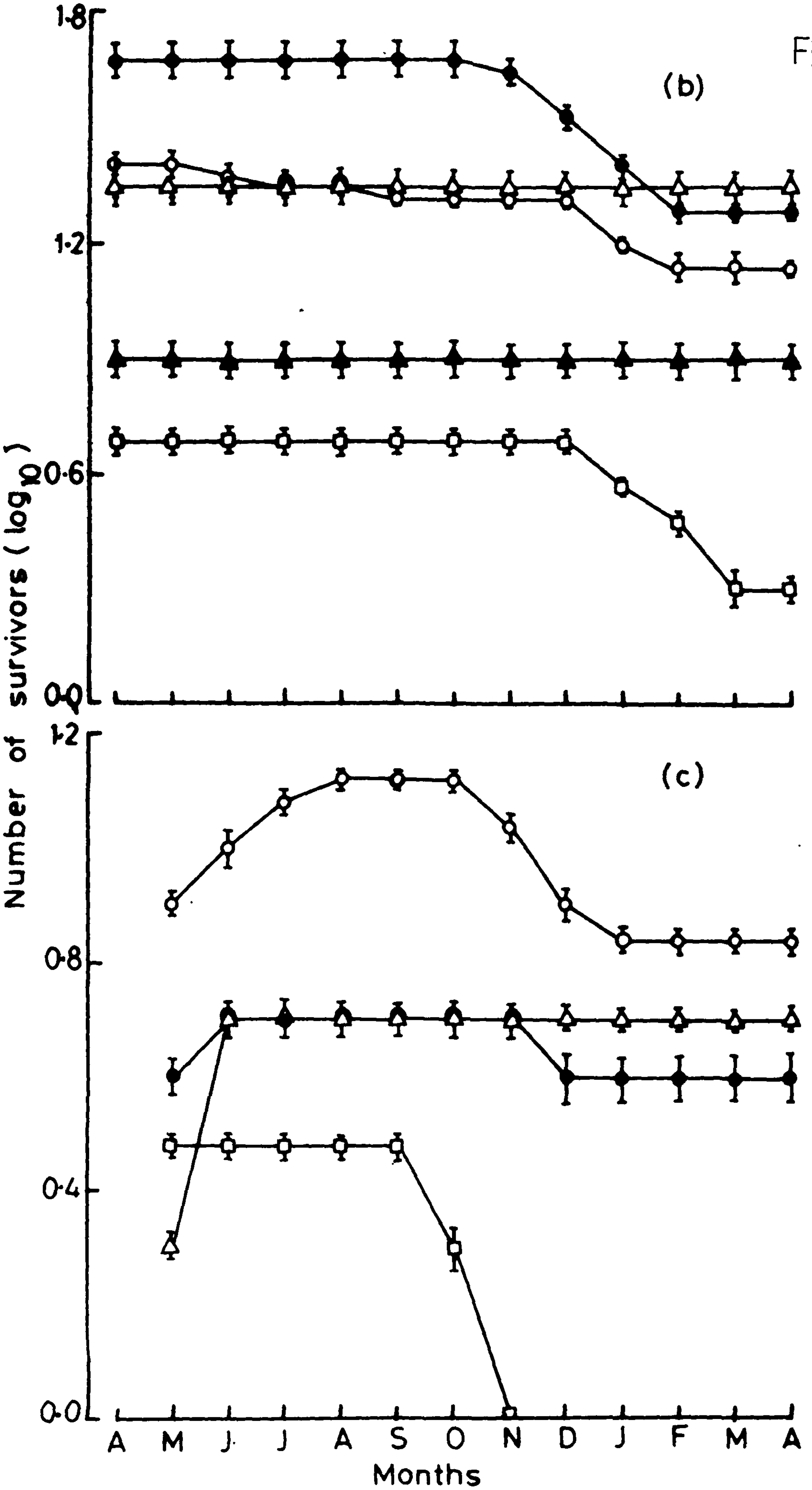
Table 6.2 Population flux of E. adenophorum in different jhum fallows.

	Age of the jhum fallow (year)				
	1	3	6	10	15
(a) No. of Plant/seedling per m^2, April 1979	8.0(0.0)	23.0(0.0)	47.0(0.0)	26.0(0.0)	5.0(0.0)
(b) No. of Plant/seedling per m^2, April 1980	41.0(33.0)	74.0(46.0)	238.0(214.0)	20.6(0.0)	3.0(0.0)
(c) Net population change (b-a)	+33.0(+33.0)	+51.0(+46.0)	+191.0(+214.0)	-5.4(0.0)	-2.0(0.0)
(d) Rate of increase(b÷a)	5.12(∞)	3.22(∞)	5.06(∞)	0.79(0.0)	0.6(0.0)
(e) No. of plant/seedling per m^2 arrived between April 1979 and April 1980	576.0(576.0)	565.0(560.0)	683.0(678.0)	96.0(83.0)	16.0(13.0)
(f) No. of plant/seedling per m^2 died between April 1979 and April 1980	543.0(543.0)	514.0(514.0)	492.0(464.0)	101.4(83.0)	18.0(13.0)
(g) Plants/seedlings present April 1979, alive by April 1980	8.0(-)	23.0(-)	20.0(-)	13.6(-)	2.0(-)
(h) Percentage survival of plant/seedling in 'a' (g÷a) x 100	100.0(-)	100.0(-)	42.55(-)	52.3(-)	40.0(-)
(i) Total plant/seedling recorded during the study period, April 1979-April, 1980	584.0(576.0)	588.0(560.0)	730.0(678.0)	122.0(83.0)	21.0(13.0)
(j) Percentage annual mortality of all individual (f ÷ i) x 100	92.98(94.27)	87.41(91.78)	67.4(68.43)	83.11(100.0)	85.71(100.0)

Values in parentheses indicate population flux of seedlings.

Fig.6.1 Survivorship curves of *E. adenophorum* (b) sprouts more than a year old and (c) sprouts originating during the study period. Closed triangle, 1 year fallow; open triangle, 3 year fallow; closed circle, 6 year fallow; open circle 10 year fallow; open square, 15 year fallow. Vertical bars indicates standard errors of means.

FIG6.1


(b)
(c)
1·8
1·2
0·6
0·0
1·2
0·8
0·4
0·0
Number of survivors (log10)
A
M
J
J
A
S
O
N
D
J
F
M
A
Months

mortality of seedlings and established plant put together decreased with the age of the fallow upto 6 years reaching the lowest in this fallow but showed a sharp increase in 10 and 15 year fallows. The rate of increase of new recruits was also higher in fallows upto 6 years compared to older fallows, the number of plants recruited during the year being sharply reduced in 10 and 15 year fallows.

When the population flux of seedlings alone was considered, recruitment was maximum in a 6 year fallow closely followed by 1 and 3 year fallows. Seedling recruitment declined sharply in 10 and 15 year fallows. A net increase of 33, 46 and 214 individuals occurred in the case of 1,3 and 6 year fallows respectively. Of the few seedlings that arrived in 10 and 15 year fallows all died during the year. Seedling mortality was minimum in a 6 year fallow with over 30% survival whereas in 1 and 3 year fallows the survival was less than 10%.

Reproductive potential:

In the younger fallows of 1 and 3 years, all the plants were fertile but with increase in the age of the fallow more individuals were not reproductive. Thus from 46% plants that were not reproductive in a 6 year fallow, it went upto 90% and 100% respective in 10 and 15 year fallows. Similarly in a given reproductive plant the number of non-reproductive branches were totally absent as in a 1 year fallow or was very low as in a 3 year fallow. The number of non-reproductive branches progressively increased reaching a maximum of 66.8% in a 10 year fallow. In a 15 year fallow, however, flowering was totally absent. While the seeds/capitula was a more stable character for all the fallows, the number of capitula/m^2 was maximum in a 3 year fallow followed by a 6 year fallow and was least in 10 year fallow. Seeds/fertile plant was maximum in a 6 year where as seeds per m^2 was highest in a 3 year fallow (Table 6.3).

DISCUSSION

After slash and burn agriculture at higher elevations of Meghalaya a number of changes occur in the physical and biological environment. Apart from improving the light availability in the environment due to slashing the vegetation, the temporarily nutrient enriched soil is fast depleted of its nutrients due to run-off and infiltration losses and also due to rapid utilization by the crop and weed species during the first few years (Ramakrishnan et al., 1980). E.adenophorum comes up in such an environment in the initial stages of the fallow development but soon has to survive unde conditions of thick and diversified vegetational cover and consequent poorer availability of light, increased litter on the soil surface, increased evapo-transpiration and altered pH and nutrient status of the soil under more competitive conditions.

Seedling survival was low in a 1 and 3 year fallows but was maximum in a 6 year fallow. Though some seedling recruitment occurred in 10 and 15 year fallows, 100%

Table 6.3 Reproductive characteristics of *E. adenophorum* in different jhum fallows

	Age of the jhum fallow (year)				
	1	3	6	10	15
(a) Plant per m^2 [1]	8.0	28.0	24.0	20.6	3.0
(b) %non-reproductive plant in 'a'	100.0	100.0	54.1	9.7	0.0
(c) %non-reproductive branch in 'b'	0.0	7.0	32.58	66.8	-
(d) Capitula per m^2	536.0	1988	1287	62.0	-
(e) Seed per capitula	63.0	62.0	62.0	61.0	-
(f) Seed per m^2	33768.0	123256.0	79794.0	3782.0	-
(g) Seed per fertile plant	4221.0	4402.0	6138.0	1891.0	-

1 excluding seedlings but including plants that may or may not have attained reproductive stage.

mortality occurred within a few months and this may partly be due to high pine litter accumulation on the soil surface which does not permit root penetration into the mineral soil and partly to increased competition from other species under low light conditions. Seedling mortality was very high in the early stages of growth of the plant though it was a continuous risk throughout the life cycle (Ramakrishnan and Kumar, 1971). Mortality that occurred during the winter months may be related partly to moisture stress(as also emphasized by Arnon, 1958; Ellern, 1974)and partly to frost (Auld, 1969 b) which are critical factors at this time of the year.

Though the percentage survival of sprouts of more than a year old was maximum in 1 and 3 year fallows, the ultimate number of sprouts originating during the study period was maximum in a 10 year fallow. Such a high number of vegetative recruits in a 10 year fallow compared to seedling recruitment which follows a totally different pattern may be due to better competitive ability of sprouts compared to seedlings.

Reproductive potential is a critical feature of a species for maintenance of the population in a given habitat (Harper, 1960; Ramakrishnan, 1972). Just as vegetative reproductive vigour of the plant is drastically reduced in older jhum fallows, so too the sexual reproducive vigour. Thus seed production of the species is adversely affected in older fallows due to increased number of non-reproductive individuals in such a way that no seed production occurred in a 15 year fallow.

Just as E.odoratum is a early successional exotic weed in jhum fallows at lower elevations of north-eastern India up to an altitude of 950 meters (Kushwaha et al., 1981), similarly E.adenophorum is an exotic weed in the jhum fallows at higher elevations (1066-2130 m). This study is significant from the point of view of shortening of the jhum cycle (the time interval after which the same land is slashed and cultivated after a fallow period of natural regeneration of vegetation). An ideal jhum cycle of 20-30 years which was a common feature in the entire region until recent times has been reduced to an extremely short cycle of 4-5 years due to increased population pressure. As seen from this study, E.adenophorum is able to succeed in the secondary successional communities only up to a period of about 6 years. Repeated short jhum cycles of less than 6 years have had the effect of arresting succession at this weed stage so that vast areas of land have been taken over by weeds like the present one along with others like Imperata cylindrica due to gradual depletion of germ plasm of other shrubs and tree species from the vicinity (Ramakrishnan et al., 1980). This in turn has also contributed to the degradation of the environment further reducing the land available for cultivation.

SUMMARY

Eupatorium adenophorum Spreng. is an important weedy colonizer coming up in early successional communities developing after 'Slash and burn' agriculture(Jhum) at higher elevations of the north-eastern hill regions of India. The relative performance of this species in terms of fecundity and survivorship in successional plant communities has been worked out. A net population increase of this species occured through both vegetative and sexual reproduction in early successional fallows up to 6 years old, this being most pronounced in a 6 year fallow. High seedling mortality occurred in 1 and 3 year fallows, whereas mortality was low in a 6 year fallow; 100% mortality occurred in older fallows. Seedling mortality was maximal during the monsoon though some mortality occurred during the winter too which may partly be due to drought and partly due to frost. Mortality of vegetative sprouts also followed a more or less similar pattern to those of seedlings. Reproductive potential of the weed was drastically reduced with age of the successional communities; in a 15 year fallow all individuals were non-reproductive. Since E.adenophorum is able to succeed only in fallows of less that 6 years, repeated short jhum cycles of 4-5 years have had the effect of arrested succession at the weed stage.

CHAPTER — 7

SECONDARY SUCCESSION SUBSEQUENT TO SLASH AND BURN AGRICULTURE (JHUM) AT HIGHER ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA. I. SPECIES DIVERSITY, BIOMASS AND LITTER PRODUCTION.

INTRODUCTION

'Slash and burn' agriculture (Jhum) at high elevations of Meghalaya in north-eastern India involves slashing of the undergrowth and also of the lower-most branches of sparsely distributed pine trees, burning of the dried slash in a controlled manner by covering it over with a thin layer of soil and subsequent cropping with a mixture of crops for a year or two before the site is abandoned for natural regeneration of fallows (Ramakrishnan et al.,1980; Mishra and Ramakrishnan, 1981). After a gap of few years the same site is again cultivated in the same manner, and this time interval is referred to as a jhum cycle . This cycle has been reduced to a short period of 4-5 years in recent times from a more favourable length of 20-30 years.

The long term success of jhum cultivation depends upon the recovery and maintenance of the soil fertility which in turn is directly dependent upon the structure and composition of the fallow vegetation. The present study aims at an understanding of the process of secondary succession on the fallow lands of up to 15 years of age subsequent to jhum under a 15 year cycle, and the changes in the biomass, litter fall, and productivity of these secondary successional communities. This study is significant because the pattern of secondary succession would determine the pattern of change in nutrient cycling during the different phases of fallow development discussed in chapter 8.

STUDY AREA AND CLIMATE

This study was done at Shillong which is located at higher elevations of the Khasi hills of Meghalaya (1500 meters above the sea level; 25.34°N and 91.56°E). This area supports sub-tropical montane evergreen early successional pine forests with *Pinus kesiya* as the dominant species. Terrain is hilly with steep slopes (average angle ranges from 30°-40°). Soil cover is thin as the process of erosion outstrips weathering and is podsolic with a pH range of 4-6. The climate here is seasonal with average rainfall of 1843 mm comming during the monsoon period extending from May to September. Average maximum temperature at this time is 27 .7°C and the minimum temperature 16.3°C. Winter is cold with a few scattered showers from November to February with a maximum temperature of 16.8°C and a minimum of 7.6°C . Summer is very brief and dry with a maximum temperature of 23°C and a minimum of 12.3°C .

Under a 15 year jhum cycle, the slash is arranged in parallel rows running down the slope covered by a thin layer of soil to form distinct ridges and furrows. The burning of the dried slash is done in March followed by mixed cropping of a number of crops like *Solanum tuberosum*, *Colocasia antiquorum*, *Ipomoea batatus*, *Zea mays*, Cucurbita *maxima*, *Cucumis sativus* and *Phaseolus vulgaris*. The cropping is done for one year before the land is abandoned for fallow development. The detailed description of the agro-ecosystem is given elsewhere (Mishra and Ramakrishnan, 1981).

METHOD OF STUDY

Sites under 1,3,6,10 and 15 year jhum fallows (three replicates) were selected, on the basis of the local records, at Shillong taking care to ensure similar aspects (south facing slopes) and topographic conditions. The fallows selected were developed in sites under a 15 year jhum cycle. Density, frequency and cover of the different plant species in different jhum fallows were measured using I m^2 quadrats in the case of herbaceous species and 100 m^2 quadrats for shrub and tree species. Importance value index (IVI) which is an integrated measure of the relative frequency, relative density and relative basal area of the species, was calculated and are based on 30 quadrats in each site, laid along a transect line running down the slope (Mishra, 1968; Kershaw, 1973). Species diversity was calculated using the formula given by Margalef (1968) as:

$$\bar{H} = - \sum \left[\left(\frac{ni}{N}\right) . \log_e \left(\frac{ni}{N}\right) \right]$$

where, H=Shannon index of general diversity, ni = Importance value index of each species and N = Total Importance value of all the species. The Dominance index of the community was calculated on the basis of the formula of Simpson(1949) as:

$$C = \Sigma \left(\frac{ni}{N}\right)^2$$

where, C = Index of dominance, ni = Importance value index of each species and N = Total Importance value of all the species. In all studies the original pine trees were considered separately.

For litter production studies in different jhum fallows, litter traps of Im^2 size were employed at 10 random points in each site. The litter samples were collected at regular intervals from these traps and classified into leaves/ needles, twigs and cones, and further sub-divided into specific categories. Samples were then dried at $80^{o}C$ and weighed.

Estimation of the standing biomass of the different jhum fallows was done by using harvest technique and on the basis of allometric regressions (Newbould, 1967). The above ground biomass of herbs and shurbs, alongwith the tree saplings were found out after harvesting the vegetation from 30 quadrats of I m^2 size in each site along a transect running down the slope. The samples were dried at 80C and expressed in terms of their dry weight. Estimation of the standing biomass of the tree species are based on the regression equations given in the Table 7.1. In all the cases, biomass sampling was done in the month of October-November, a time when all the plants were at their peak of vegetative growth. The annual increase in biomass for each of the jhum fallow was found out by dividing the difference between the standing biomass of two consecutive fallow with the time difference in years. Estimation of the annual net primary production of each fallow was done by adding the total amount of litter produced over a one year period to the annual increase in the standing biomass. For all these studies, the old pine trees which were not cut down before cropping (Mishra and Ramakrishnan, 1981) were considered both by including them as well excluding them in computation.

Table 7.1. Allometric regression equations between DBH and dry weight of different components of dominant tree species grown in a 15 year jhum fallow.

Tree species	Bole	Branches	Leaf/needle	Cones
Lindera pulcherrima	Y=-9.256+2.572 x r= 0.928	Y=-3.809+0.929 x r= 0.811	Y=0.073+0.275x r=0.921	-
Pinus kesiya[1]	Y=4.523+2.250 x r=0.952	Y=3.950+2.420 x r=0.990	Y=4.569+1.071x r=0.970	Y=0.936+1.695x r=0.945
Quercus griffithii	Y=-9.547+2.744 x r=0.933	Y=-4.912+1.341 x r=0.863	Y=-1.207+0.444 x r= 0.932	-
Sehima wallichii	Y=-8.111+2.243 x r= 0.958	Y=-0.899+0.319 x r= 0.718	Y=-0.016+0.173 x r= 0.700	-

1. after Das & Ramakrishnan, unpublished.

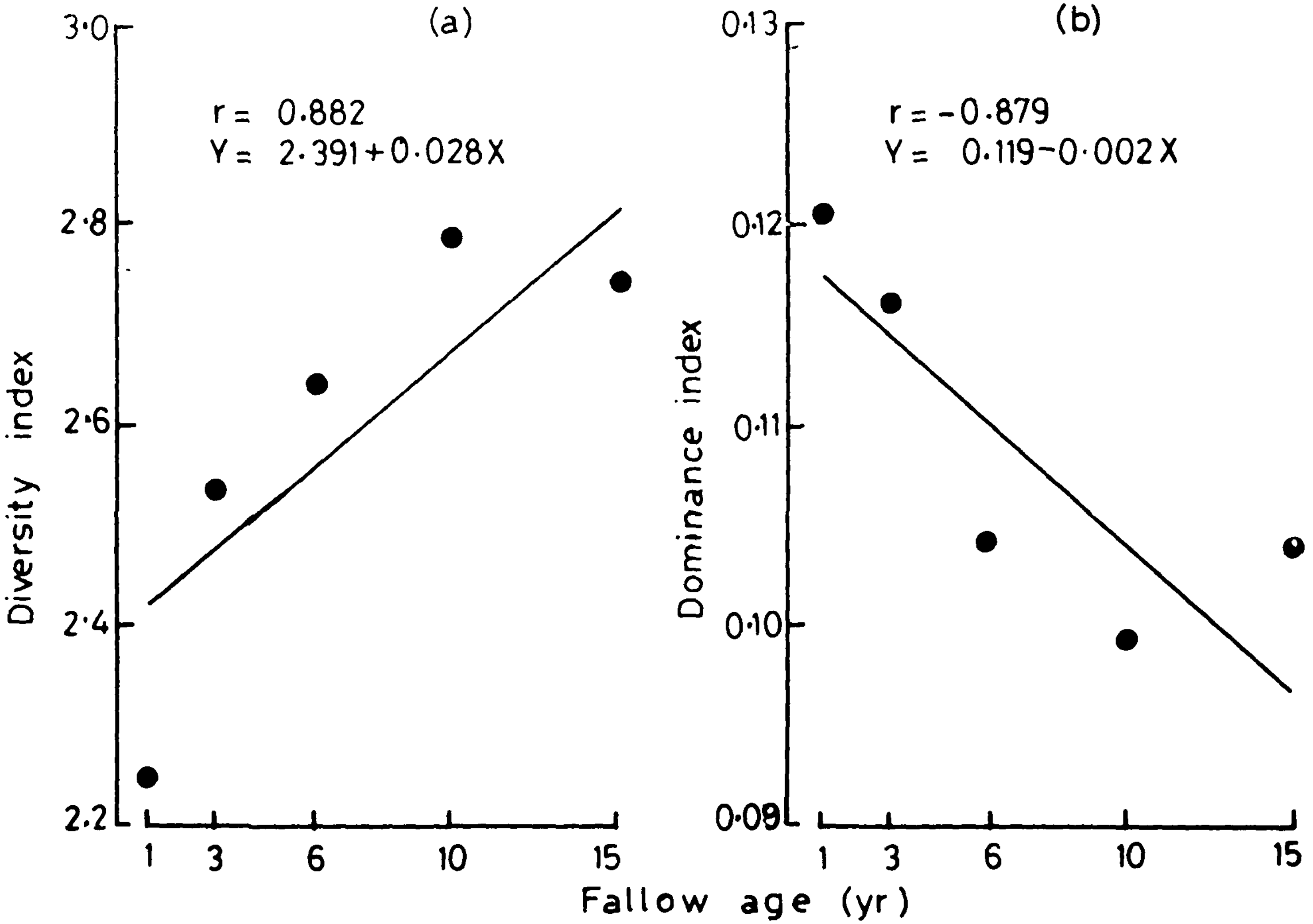
RESULTS

At higher elevations of Meghalaya when the jhum fields are abandoned for natural regeneration of vegetation, the secondary succession starts with a few scattered old pine trees already present in the sites due to the previous land use practice. A number of weedy colonizers like Eupatorium adenophorum, Erigeron linifolius, Hypochaeris radicata, Imperata cylindrica, Oxalis latifolia, etc. are dominant in a 1 year jhum fallow. While Erigeron linifolius and Oxalis latifolia are totally absent in 3-6 year fallows, the dominance in the community is shared by the rest of the weed species. Besides these species, ferns like Dichranopteris linearis and Pteridium aquilinum are also important components in these early successional communities alongwith Osbeckia crinita. In 10 and 15 year fallows, these weedy colonizers are replaced by Pinus kesiya which gains dominance in the community alongwith other broad leaved trees and saplings of Quercus griffithii, Lindera pulcherrima, Schima wallichii, and shrubs like Gaultheria fragrantissima, Rubus micropetalus and Rubus ellipticus (Table 6.1)(Cf. Chapter 6).

Species diversity (Fig. 7.1a) was low in 1 year jhum fallow which increased markedly in older fallows with a significant positive correlation (r=0.882). Conversely, dominance (Fig. 7.1b) was maximum in the early stages of fallow development and declined with the increase in the fallow age (r=-0.879).

Fig.7.1 Changes in diversity (a) and dominance (b) pattern in different jhum fallows.

FIG 7.1


(a)
r = 0.882
Y = 2·391+0·028X
Diversity index
3·0
2·8
2·6
2·4
2·2
1
3
6
10
15
(b)
r = -0·879
Y = 0·119-0·002X
Dominance index
0·13
0·12
0·11
0·10
0·09
1
3
6
10
15
Fallow age (yr)

Litter production:

A major fraction of the litter in the jhum fallows was due to Pinus kesiya alone, though the different dicot species together accounted for maximum litter production. Leaves/needles accounted for 59-90% of the total litter collected in the different jhum fallows; pine needles alone accounted for about 9-36% of the total leaf litter produced in these fallows. Pine twig and cone formed another major part of the litter biomass in 10 and 15 year jhum fallows. While total pine litter and litter of all dicot species increased sharply with the increase in the fallow age with significant positive correlation (r=0.950), the litter from monocot grass species did not show any significant correlation with the age of the fallow (r=0.219). However, there was an increase of the monocot litter up to a period of 6 years of the fallow development and it declined sharply in the older fallows of 10 and 15 years. In a 6 year fallow, Eupatorium adenophorum formed nearly 75% of the total dicot litter and Imperata cylindrica formed 84% of the total litter from the monocot species (Table 7.2).

Total litter produced by various plant communities in different jhum fallows increased significantly with the age of the fallow (r=0.912) reaching a maximum of 6.138 mt ha^{-1} yr^{-1} in the case of a 15 year fallow. The total litter produced was also significantly related (r=0.912) with the standing biomass of the communities (Fig.7.2 a,b).

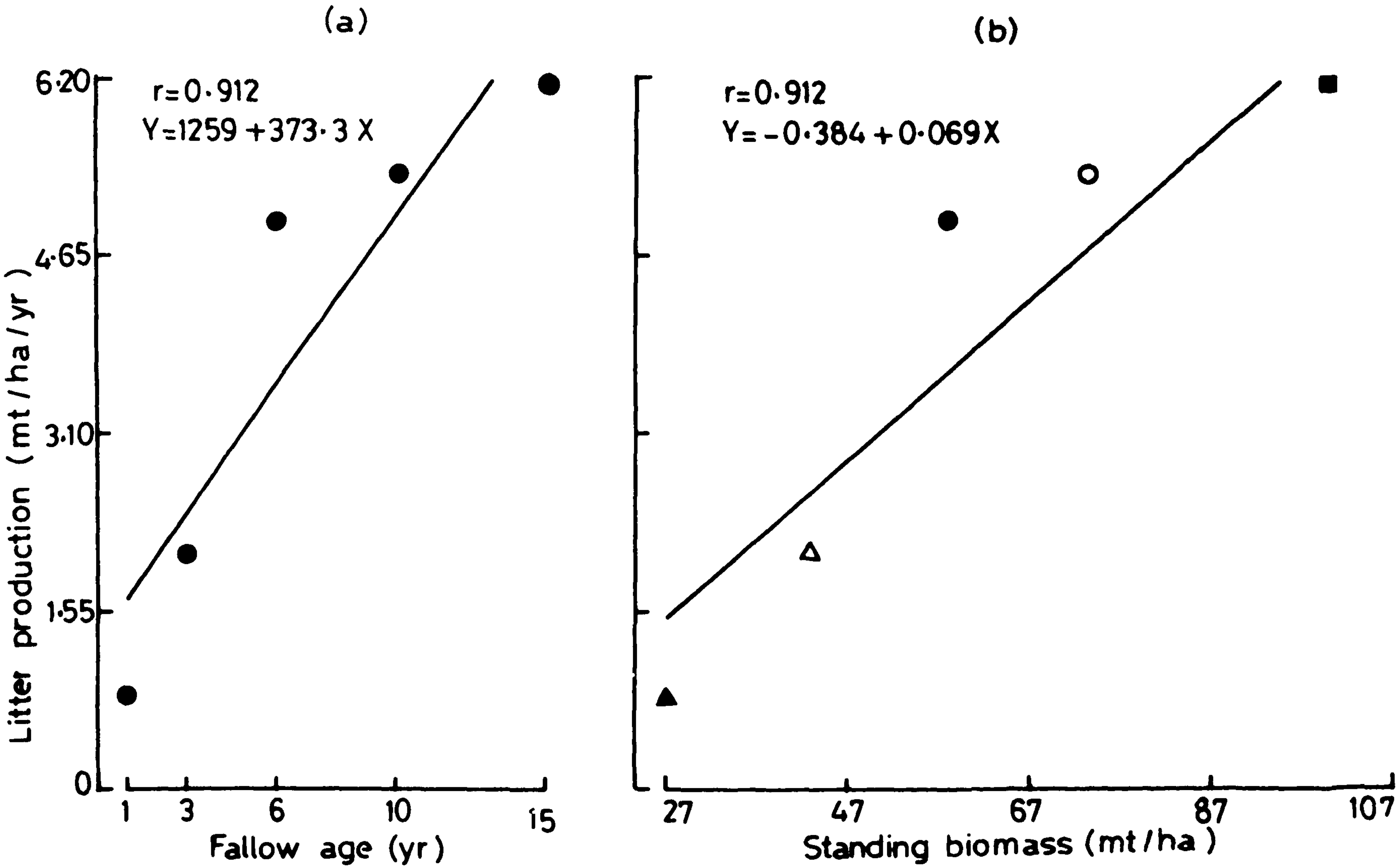
Table 7.2 Litter production(with S E values) in different jhum fallows(kg ha^{-1} yr^{-1}).

Litter category	Age of the jhum fallow (Yr)				
	1	3	6	10	15
Pine total:	204.8±6.05 (72.2)	293.5±8.46 (48.6)	1672.6±7.36 (33.7)	2184.7±10.05 (40.7)	2621.5±9.75 (42.7)
Needle	123.1	137.7	735.6	1098.1	1313.4
Twig	81.7	115.8	694.3	738.5	896.6
Cone	-	40.0	242.7	348.1	411.5
Dicot total:	417.3±3.91 (18.5)	1173.3±7.49 (34.3)	2322.5±13.79 (46.7)	2768.3±18.84 (51.6)	3294.6±20.5 (53.7)
Leaf	417.3	761.7	1433.2	1854.0	2111.4
Twig	-	411.6	889.3	914.3	1183.2
Monocot total:	211.0±2.0 (9.3)	583.7±3.44 (17.1)	975.8±4.38 (19.6)	416.2±4.51 (7.7)	221.7±2.27 (3.6)
Total : (including old pines)	833.1±12.0	2050.5±19.4	4970.9±25.5	5369.2±33.4	6137.8±32.5
Total : (excluding old pines).	628.3±5.9	1834.5±14.2	4713.3±19.7	5030.1±22.7	5763.8±20.7

Values in parentheses refer to the percentage of the total litter production.

Fig.7.2 Litter production in relation to fallow age (a) and standing biomass (b) of the jhum fallows (▲ , 1 year fallow; △ , 3 year fallow; ● , 6 year fallow; ○ , 10 year fallow; ■ , 15 year fallow).

FIG 7. 2



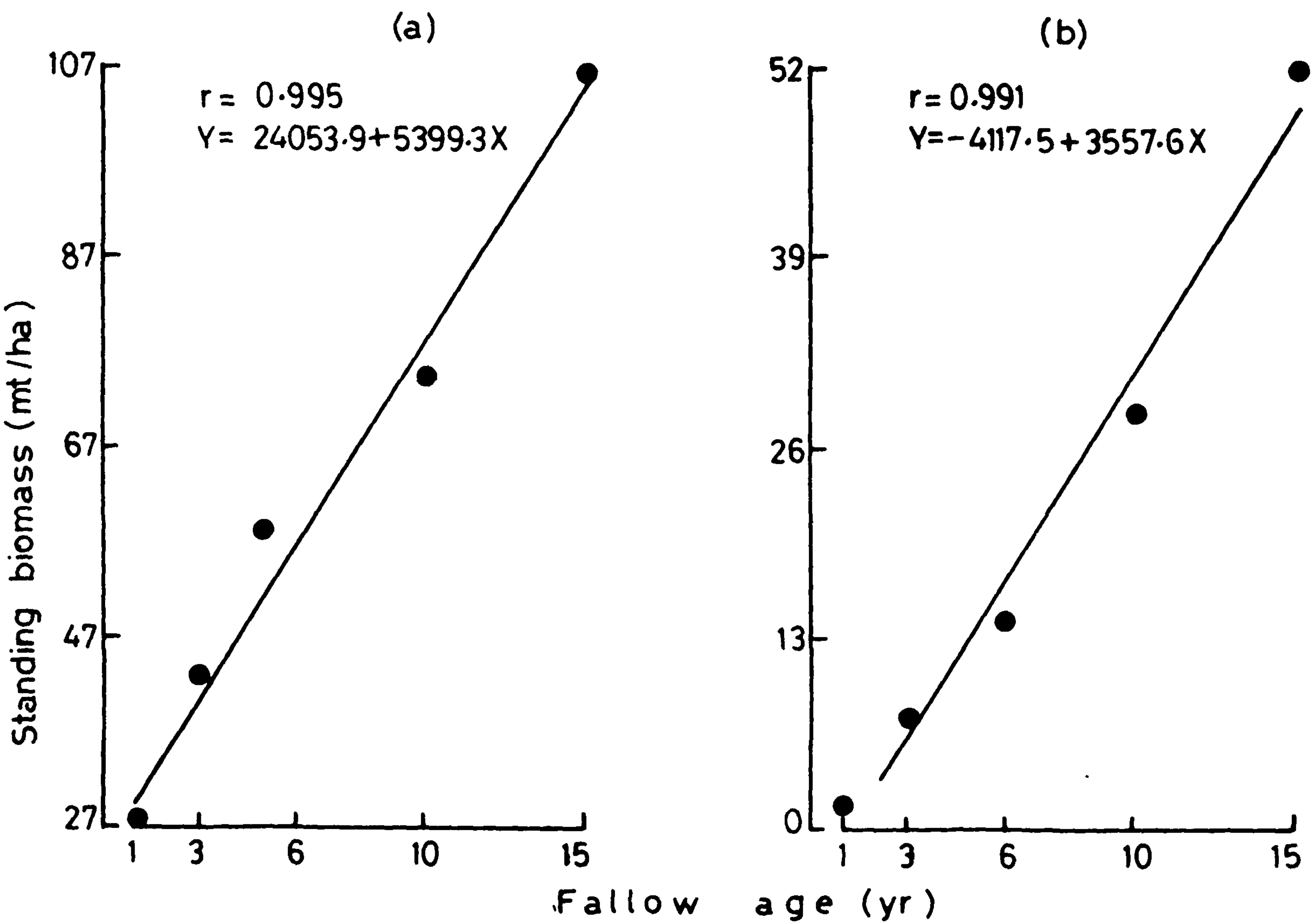
(a)
(b)
r=0·912
Y=1259 +373·3 X
r=0·912
Y=-0·384+0·069X
Litter production (mt/ha/yr)
6·20
4·65
3·10
1·55
0
1
3
6
10
15
Fallow age (yr)
27
47
67
87
107
Standing biomass (mt/ha)

Standing biomass:

The standing biomass increased significantly with increase in the fallow age (r=0.995) reaching a maximum of 98.967 mt ha^{-1} in a 15 year jhum fallow and 51.949 mt ha^{-1} in the same fallow if the sparsely distributed old pine trees are not considered in the calculation (Fig.7.3 a,b). Biomass contributed by the pine trees was nearly 83-94% of the total biomass, if the old and current pine trees are considered together. If the biomass contribution due to the sparse pine trees which were already present at the beginning of the secondary succession is not considered, the current pines alone accounted for 29% of the total biomass in a 3 year jhum fallow, which increased markedly in older fallows reaching about 67% in the case of a 15 year fallow. While the biomass of sparse old pines, current pines and all the dicot shrubs and tree saplings increased linearly with increase in the fallow age(r=0.356,r=0.988 and r=0.986 respectively), that of the herbs showed a negetive correlation (r=-0.512) with the age. Biomass of the herbs increased up to a period of 6 years of fallow development with a sharp fall in 10 and 15 year jhum fallows. Biomass contribution through the leaves/ needle was 4-7% only of the total, and if the needle biomass of the sparse old pines are not considered this was 19-27% in the younger fallows of 1-6 year which declined to about 5-7% in 10 and 15 year fallow (Table 7.3).

Fig.7.3 Standing biomass as a function of the fallow age (a, standing biomass including old pines; b, standing biomass excluding old pines).

FIG7.3



(a)
r = 0·995
Y= 24053·9+5399·3X
(b)
r= 0.991
Y=-4117·5+3557·6X
Standing biomass (mt/ha)
107
87
67
47
27
52
39
26
13
0
1
3
6
10
15
Fallow age (yr)

Table 7.3. Standing biomass (with SE values) in different jhum fallows ($kg\ ha^{-1}$)

Category	Age of the jhum fallow (Yr)				
	1	3	6	10	15
Old pine total:	256.22 ±188.22	35667 ±167.68	44107 ±257.41	45360 ±231.27	47018 ±248.69
Bole	18384	28073	34375	35067	36199
Live branch	4517	4717	6720	7028	7345
Dead branch	1580	1674	1780	1767	1832
Needle	941	985	1007	1261	1385
Cone	200	218	225	237	257
Current pine total.	-	2169±71.5	5470±63.6	18475±98.0	34679±117.2
Bole	-	968	2808	12958	24738
Live branch	-	423	1403	3122	6136
Dead branch	-	-	-	1048	2201
Needle	-	778	1177	1239	1318
Cone	-	-	82	108	286
Dicot shrub & tree saplings total:	-	1356.1 ± 57.53	2594.7 ±36.3	10159 ±77.5	17238 ± 83.23
Bole	-	1320	2522	7379	12167
Branch	-	-	-	1909	3999
Leaf	-	36.1	72.7	871	1072
Herb total:	1589 ±41.7	3859 ±29.7	6256 ±45.61	52.4 ±1.1	31.8 ±1.3
Bole & branch	1262	2716	4805	41.1	24.5
Leaf	327	1143	1451	11.3	7.3
Total:	27211±229.9	43051.1 ±326.4	58427.7 ±402.9	74046.4 ±407.9	98966.8±450.4
	(1589±41.7)	(7384.1 ±158.7)	(14320.7 ±145.5)	(28686.4 ±176.6)	(51948.8 ±201.7)

Values in parentheses refer to the standing biomass excluding the old pines.

No significant correlation was found between fallow age and the rate of accumulation of the standing biomass if the old pines are included (r=0.102), though a significant positive correlation (r=0.928) was found when the old sparse pines are excluded from the calculation. If the old pines are included, the rate of biomass accumulation increased 5 times in a 3 year jhum fallow compared to that in a 1 year fallow, which decreased in older fallows. If these old pines are excluded, the rate of biomass accumulation increased with increase in age of the fallow. Net primary production also followed a similar trend as biomass accumulation. The biomass accumulation ratio increased linearly (r=0.989) with the increase of the fallow age reaching a maximum in a 15 year fallow, when the old pines are excluded (Table 7.4). Net primary productivity showed a strong positive correlation with age of the fallow only when the old pines are excluded from the calculation (Fig.7.4).

A positive correlation(r=0.912) between diversity index and net community productivity was noted only if productivity of old pines are excluded from the calculation. Such a correlation does not exist when old pines are included in the calculation (Fig.7.5 a,b).

DISCUSSION

Secondary succession over large tracts of land left abandoned for natural regeneration of vegetation after jhum provides the means of rehabilitating soil fertility for

Table 7.4. Changes in rate of accumulation of biomass, litterfall and net primary productivity in different jhum fallows.

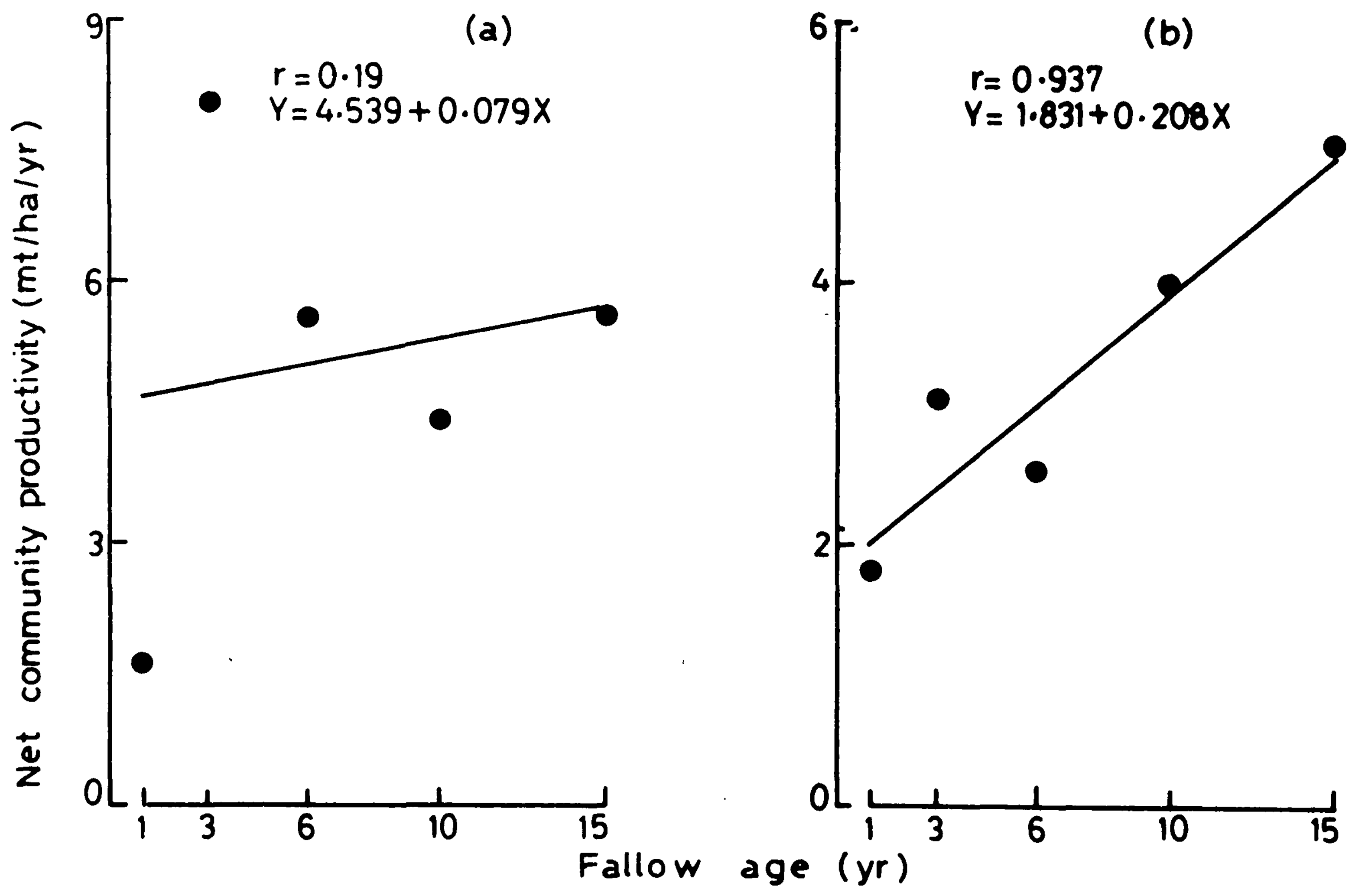
	Age of the jhum fallow (yr)				
	1	3	6	10	15
Accumulation in standing biomas(mt ha^{-1} yr^{-1})(A)	1.681* (1.589)	7.920 (2.898)	5.126 (2.312)	3.965 (3.591)	4.984 (4.652
Release as litter fall (mt ha^{-1} yr^{-1}) (B)	0.083 (0.205)	0.205 (0.216)	0.497 (0.258)	0.537 (0.339)	0.614 (0.374
Net primary productivity (mt ha^{-1} yr^{-1}) (A + B)	1.764 (1.794)	8.125 (3.114)	5.623 (2.570)	4.442 (3.930)	5.598 (5.026
Biomass accumulation ratio(standing biomass/ NPP)	15.42 (0.89)	5.23 (2.37)	10.39 (5.57)	16.70 (7.30)	17.68 (10.34

*Standing biomass of old pines in a '0' year fallow worked out to 25.53 mt ha^{-1}

Values in parentheses refer to the figure excluding old pines.

Fig.7.4 Changes in the net primary productivity in different jhum fallows (a, net community productivity including the old pines; b, net community productivity excluding the old pines).

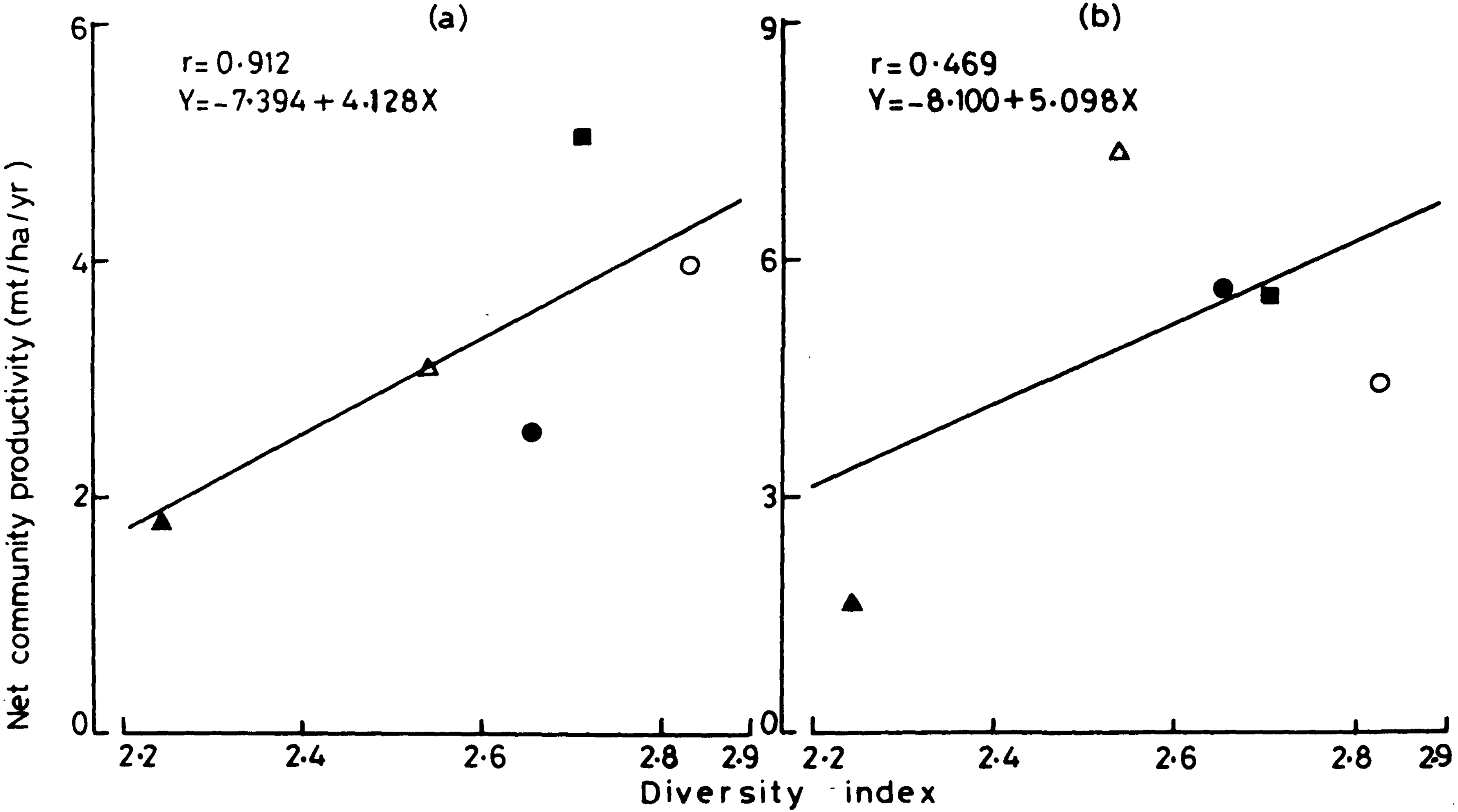
FIG 7.4



(a)
r = 0·19
Y = 4·539 + 0·079X
(b)
r = 0·937
Y = 1·831 + 0·208X
Net community productivity (mt/ha/yr)
9
6
3
0
4
2
1
3
6
10
15
Fallow age (yr)

Fig.7.5 Relationship between net community productivity and species diversity in different jhum fallows (a, excluding the old pines; b, including the old pines). 1 year fallow, ▲ ; 3 year fallow, △ ; 6 year fallow, ● ; 10 year fallow, ○ ; 15 year fallow, ■

FIG 7.5



(a)
r= 0·912
Y=-7·394 + 4·128X
(b)
r=0·469
Y=-8·100+5·098X
Net community productivity (mt/ha/yr)
Diversity index
6
4
2
0
9
6
3
0
2·2
2·4
2·6
2·8
2·9

renewed cropping. Unlike at lower elevations of Meghalaya where regeneration through root and stump sprouts are more frequent (Toky and Ramakrishnan, unpublished) that through these means at higher elevations are limited to a very few species like Myrica esculenta. Other strategies are related to stored and transported seeds and also regeneration through underground rhizomes.

Eupatorium adenophorum, a highly competative weed species in open sites comes in early fallows. Apart from the production of a large number of seeds which are light and wind dispersed, this weed is also capable of some degree of vegetative propagation due to sprouts arising from the base of the plant (Ramakrishnan and Mishra, 1981). seedlings can also withstand some degree of shading upto 10% of day light (Auld and Martin, 1975). The importance of heavy seed production for early colonizing species has been discussed by many workers like Salisbury(1942), Hayashi and Numata (1968), and Raynal and Bazzaz (1973). According to them the species with light and highly mobile seeds very often invade highly disturbed areas, while species with heavier seeds often animal disseminated invade the community at a later stage of succession.

Imperata cylindrica, on the other hand, also an early colonizer has fire resistant under ground rhizomes which are difficult to eradicate during cropping. This alongwith the heavy production of light and wind transported seeds under heavy disturbance (Saxena and Ramakrishnan, unpublished) help this species to succeed as an early colonizer in the young jhum fallows. Thus the early phase of succession is dominated by only those species which possess an exploitive strategy (Harper and white, 1974; Grime, 1974, Marks, 1974). These species are able to succeed only in fallows of less than 6 year age and their relative performance in terms of fecundity and survivorship decreased drastically in older fallows (Ramakrishnan and Mishra, 1981).

The species diversity was low in the early jhum fallows which increased significantly in older fallows. This supports the finding of earlier workers that the early successional seres are often dominated by a few species which increased gradually as the succession proceeded (Ross, 1954; Oosting, 1956; Odum, 1969). Conversely, the dominance decreased as the community grew old with a rapid shift of this in the early stages of fallow development (Richards, 1952; Marks, 1974). While fallows up to about 6 years were dominated by weedy species, due to seedling and sprout regeneration, shade intolerant shrubs and trees take over in older fallows. However, the rate at which community development occurs in terms of species diversity is much more pronounced at lower elevations (Toky and Ramakrishnan, unpublished) due to more favourable temperature conditions.

Quantities of litter produced in older jhum fallows reached levels typical of secondary forests of tropics and sub-tropics. Ewel (1976) reported values ranging from 4.6-10.0 mt ha^{-1} yr^{-1} in secondary successional communiti s 1-14 year old in Guatemala. Higher values of litter production for secondary forests are 8.3-14.4 mt ha^{-1} yr^{-1} in Malaya as was reported by Mitchell (cited by Bray and Gorhan, 1964). However, the amount of biomass accumulation in different jhum fallows was less than those reported by the earlier workers in the secondary forests of tropics and sub-tropics(Nye and Greenland, 1960; Golley et al., 1969).

When the contribution due to the sparsely distributed pine trees which were already present at the beginning of secondary succession was not considered, in the present study, the rate of biomass accumulation and the net community productivity significantly increas d during secondary successi n reaching a maximum of 4.652 mt ha^{-1} yr^{-1} and 5.026 mt ha^{-1} yr^{-1} respectively in a 15 year fallow. While this trend is in agreement with that of other workers, the biomass accumulation values reported for tropical forests by them are higher (Bartholomew, Mayer and Laudelot, 1953). Similar to the increase in net primary production with fallow age observed here, the studies of Holt and Woodwell (quoted by Whittaker, 1975) at New York during secondary succession in an Oak-pine forest also shows a similar trend though the studies of Mellinger and Mc Naughton(1975) showed a decline in net primary production during old field secondary succession in central New York.

Biomass accumulation ratios have often been used to characterise productivity conditions of forest communities

(Whittaker, 1966; Woodwell and Whittaker, 1968). This ratio for temperate forests did not usually exceed 1:10(zavitkovski and Stevens, 1972); the biomass accumulation ratios for the jhum fallows are comparable to that of many tropical forests as seen from the data given by Whittaker (1975).

Though litterature on the diversity and its relationship with successional stages and in turn with productivity and stability is vast, there seems to be considerable confusion regarding these relationships. While Odum (1969), and Woodwell and Smith (1969) are of opinion that the species diversity brings functional stability of an ecosystem, May (1973) reported that an increase in diversity destabilizes the interacting systems. Mc Naughton(1967), and Mellinger and McNaughton(1975), however, have reported that secondary succession was accompanied by increased biological diversity and reduced dominance. These workers have also reported a positive correlation between diversity and stability in an ecosystem. The generality of this relation was questioned by Singh and Mishra (1969) who proposed that for seral grasslands the species diversity increased production efficiency of the ecosystem, while decrease in dominance made the system more stable. In the present case, however, during secondary succession on the jhum fallows there was a significant increase (r=0.882) in the diversity as the fallow grew older with a simultaneous decrease (r=-0.879) in dominance. This was accompanied by an increase in the net community productivity.

SUMMARY

The pattern of secondary succession and the subsequent changes in biomass, productivity and litter fall on the fallow lands developed after 'Slash and burn' agriculture (Jhum), up to a period of 15 years, is considered in this study. Early phases of succession up to a 6 years period had weedy colonizers like Eupatorium adenophorum and Imperata cylindrica as important species which are replaced in the older fallows of 10 and 15 years where Pinus kesiya alongwith a few broad leaved tree species come up. The secondary succession was accompanied by increased species diversity, reduced dominance and an increase in the net community productivity. Standing biomass and litter production increased linearly with the age of the jhum fallow. The significance of these results are discussed.

CHAPTER — 8

SECONDARY SUCCESSION SUBSEQUENT TO SLASH AND BURN AGRICULTURE(JHUM)AT HIGH ELEVATIONS OF MEGHALAYA IN NORTH-EASTERN INDIA.II. NUTRIENT CYCLING.

INTRODUCTION

Slash and burn agriculture on steep hill slopes, locally called Jhum, involving slashing of the natural vegetation and burning before mixed cropping for one or two years (Mishra and Ramakrishnan, 1981) would bring about drastic short-term changes in the nutrient stock in the soil due to the burn, utilization by crops and losses through water. Recovery of fertility after cropping would occur during fallow development during secondary succession. Besides, understanding the soil fertility recovery pattern, an overall understanding of the nutrient cycling through various stages of secondary succession is essential for evolving proper land use. The present study aims at an analysis of the nutrient cycling in fallow of 1,3,6,10 and 15 years age developing after jhum at higher elevations (1500 m) of Meghalaya, at Shillong (25.34°N,91.56°E).

METHODS OF STUDY

Description of the study area, soil, vegetation, climate and land use pattern are given in Chapter 7. Estimation of the nutrient pool in the standing biomass and litter compartment was based on the data collected in Part I of this study (cf.Chapter 7). In all the estimations here, old pine trees present during cropping (Mishra and Ramakrishnan, 1981) are included.

Nutrient analysis was separately done for the different plant parts of the major and minor species in the community. The litter analysis of composite mixtures of monocots, dicots and pine (<u>Pinus kesiya</u>) were done after separating them into different plant parts. Plant samples were oven dried at 80^{o}C, ground, screened through 0.2 mm sieve and stored in polythene jars for analysis.

At each site, 10 random soil sampling was done in October through a depth of 0-40 cm. After analysing the available phosphorus on fresh soils, the samples were air dried, ground, passed through 0.2 mm sieve and stored in polythene jars, for subsequent analysis. Soil and plant analysis were done following standard procedures of Allen (1974). For soil cation analysis, extraction was done using I N Ammonium acetate at pH 7. Extraction for available soil phosphorus was done using 0.03 N Ammonium fluoride in 0.025 N hydro-chloric acid. Cations estimation in plant was done after dry ashing and dissolving the ash in dilute hydrochloric acid. Nitrogen was estimated by the micro-Kjehldahl method. Phosphorus was estimated colorimetrically by the molybdenum-blue method. Magnesium and calcium were estimated by the EDTA titration method, while potassium was estimated by the flame emission method.

Biomass and litter values obtained in the earlier study (Part I) were used for computation of the total chemical inventory of the vegetation compartment. The soil bulk density determinations were made using a core sampler and the values were used for subsequent conversion of the analytical data to field weight per unit area of the soil pool.

Enrichment ratio for each jhum fallow was calculated as the ratio of element stock in the vegetation compartment to the elemental uptake by it (Woodwell et al.,1975). For vegetation and soil compartment,fractional annual turnover was calculated by dividing the quantity that leaves the compartment by the standing state of that particular element and expressed as percentage (Reiners and Reiners, 1970).

RESULTS

Nutrients stored in the standing biomass of the different categories of plants, except herbs, increased significantly ($P < 0.05$) with the increase in the age of the fallow upto a period of 15 years with maximum accumulation for nitrogen, potassium and calcium. The high levels of different nutrients for pine in the fallow is due to the already existing older pine trees which are not totally slashed during jhum. In the herbaceous compartment, while the nutrient pool increased upto 6 year fallow, a drastic reduction was observed in 10 and 15 year fallows. Pine alone contributed about 78.5% of the total nutrients that was held in the vegetation compartment in a 1 year jhum fallow. This contribution by pine declined in older fallows to 57% in a 15 year fallow due to a gradual increase in contribution by dicot tree sapling and shrubs (Table 8.1)

The rate of nutrient accumulation increased markedly in the first 3 years of fallow development; decreased slightly between 3-6 years but more sharply between 6-10 years after which it improved reaching almost the same rate as during the initial stages of regeneration. However, this fluctuation in the pattern was less marked for calcium compared to other nutrients. Of all the nutrients, nitrogen and potassium had the highest rate of accumulation (Table 8.2).

Pine alone contributed for a good proportion of the annual return of nutrients through litter fall. However, litter from dicot tree saplings and shrubs accounted for maximum return to the system. While the nutrient return through these two categories of plants increased with increase in the age of the fallow reaching a maximum in a 15 year fallow (except for phosphorus and calcium both of which reached peak values in a 10 year fallow), the nutrient return through monocot litter reached its peak in a 6 year fallow with a sharp decline in older fallows. When the total quantity of nutrients returned through litter fall was considered, return of nitrogen, potassium and magnesium followed a similar pattern in that their amount increased upto 15 years of fallow development. Return of calcium and

Table 8.1 Nutrient content (kg ha^{-1}) in different components of the standing biomass in different jhum fallows

Category	Nutrient	Age of the jhum fallow(yr)				
		1	3	6	10	15
Pine total	N	45.888	66.737	88.319	110.492	138.192
	P	5.486	7.833	10.423	13.127	16.560
	K	31.149	45.015	59.613	75.307	95.097
	Ca	31.464	50.557	66.542	84.552	107.063
	Mg	13.684	22.682	28.931	34.860	40.836
Dicot tree saplings and shrubs total	N	-	5.610	10.734	42.028	71.314
	P	-	0.659	1.261	4.937	8.378
	K	-	7.987	15.283	59.837	101.532
	Ca	-	6.564	12.558	49.169	83.432
	Mg	-	2.726	5.215	20.420	34.648
Herbs total	N	11.345	27.553	44.668	0.374	0.227
	P	1.530	3.716	6.025	0.050	0.030
	K	11.950	29.024	47.051	0.394	0.293
	Ca	4.767	11.577	18.768	0.157	0.095
	Mg	5.477	13.302	21.564	0.181	0.110

Table 8.2 Nutrient accumulation rate (Kg ha^{-1} yr^{-1}) in the standing biomass during the fallow development.

Nutrient Category	Time span (Yr)				
	0-1	1-3	3-6	6-10	10-15
N	11.513	21.333	14.607	2.293	11.368
P	1.546	2.596	1.834	0.101	1.370
K	12.062	19.464	13.307	3.398	12.266
Ca	4.880	16.234	9.723	9.003	11.342
Mg	5.530	9.775	5.667	-	4.027

phosphorus through the litter fall increased upto 10 years with a slight decrease thereafter. Return of nitrogen was the highest followed by calcium in all the jhum fallows (Table 8.3).

The rate of uptake of all nutrients except calcium increased significantly ($P<0.05$) upto 6 years with a decline between 6-10 years of fallow development. Subsequently, there was a marked increase in the rate of uptake of these nutrients. In the case of calcium, however, a sharp increase was noticed between the first 3 years of fallow development after which the rate of uptake of this element showed a slow increase upto 15 years. The uptake rate was consistently high for nitrogen followed by that for potassium or calcium. The enrichment ratio in older fallows beyond 6 years was generally higher than in younger fallows. This pattern was more pronounced in the case of potassium and magenessium (Table 8.4).

The inventory of the nutrients is given in Table 8.5. Nutrients in the standing biomass increased with the increase in the fallow age reaching the highest level in a 15 year fallow. Nitrogen fallowed by potassium and calcium contributed maximum quantity to the total budget in biomass. Quanitity of nutrient returned (except potassium) throggh litter also increased with the fallow age upto 15 years.

The amount of nitrogen in the soil pool (0-40 cm) increased upto a period of 10 years of fallow development

Table 8.3. Annual nutrient return (kg ha^{-1} yr^{-1}) through litter fall in different jhum fallows.

Category	Nutrient	Age of the jhum fallow (yr)				
		1	3	6	10	15
Pine total	N	0.807	1.179	6.676	8.971	10.747
	P	0.116	0.155	0.856	1.211	1.449
	K	0.226	0.297	1.647	2.298	2.751
	Ca	0.972	1.219	6.800	9.149	10.980
	Mg	0.153	0.200	1.119	1.515	1.816
Dicot total	N	4.131	11.534	22.815	27.224	32.380
	P	0.313	0.834	1.644	1.976	0.916
	K	1.002	2.610	5.130	6.187	7.315
	Ca	0.960	2.575	5.075	6.093	2.834
	Mg	0.213	0.590	1.167	1.394	1.657
Monocot total	N	1.772	4.903	8.197	3.496	1.862
	P	0.135	0.374	0.625	0.266	0.142
	K	0.907	2.510	4.196	1.790	0.953
	Ca	0.422	1.167	1.952	0.832	0.442
	Mg	0.188	0.519	0.868	0.370	0.197
Total	N	6.710	17.616	37.688	39.691	44.989
	P	0.564	1.363	3.125	3.453	2.507
	K	2.135	5.417	10.973	10.275	11.019
	Ca	2.354	4.961	13.827	16.074	14.257
	Mg	0.554	1.309	3.154	3.279	3.670

Table 8.4 *Rate of nutrient uptake (kg ha^{-1} yr^{-1}) by the standing biomass during the fallow development.

Nutrient Category	Time span (yr)				
	0-1	1-3	3-6	6-10	10-15
N	13.223 (3.14)	38.949 (2.56)	52.295 (2.75)	41.984 (3.64)	56.357 (3.72)
P	2.110 (3.33)	3.959 (3.08)	4.959 (3.57)	3.554 (5.10)	3.877 (6.44)
K	14.197 (3.04)	24.881 (3.30)	24.280 (5.02)	13.673 (9.91)	23.285 (8.45)
Ca	7.234 (5.00)	21.195 (3.24)	23.550 (4.16)	25.077 (5.34)	25.599 (7.45)
Mg	6.084 (3.15)	11.084 (3.49)	8.821 (6.32)	3.217 (17.24)	7.697 (9.82)

*Annual uptake = Annual increase in nutrients in biomass + Annual nutrient return via litter fall. Values in parentheses refer to the enrichment ratio.

and declined slightly in a 15 year fallow. Available phosphorus increased only slightly in older jhum fallows. Exchangeable cations also followed a similar trend as the available phosphorus with slight improvement in older fallows. The total of these three categories for different elements except nitrogen increased significantly ($P < 0.05$) with the age of the fallow upto 15 years; nitrogen however, peaked to a maximum in a 10 year jhum fallow and declined on either side (Table 8.5).

The annual turnover in the vegetation compartment was higher than that for the soil compartment in the case of nitrogen, calcium and magneesium, while the reverse was the case for phosphorus and potassium(Table 8.6).

DISCUSSION

The amount of nutrient stored in the standing biomass and its release through litter fall increased consistently upto 15 years of fallow development subsequent to jhum. This is understandable because of a linear increase in the standing biomass and litter production in different jhum fallows with increase in the fallow age (Part I in this study). Nutrients stored in the herb compartment peaked in a 6 year fallow with a sharp fall in older fallows. This is also related to the rapid shift of dominance in the community at this stage from the herbs to the fast growing shrub and trees species.

Table 8.5. Total inventory of nutrients (kg ha^{-1} yr^{-1}) for different jhum fallows.

	Nutrient	Age of the jhum fallow (yr)				
		1	3	6	10	15
Standing biomass	N	57.233	99.900	143.721	152.894	209.733
	P	7.016	12.208	17.709	18.114	24.968
	K	43.099	82.026	121.947	135.538	196.368
	Ca	36.231	68.698	97.868	133.878	190.590
	Mg	19.161	38.710	55.710	55.461	75.594
Soil pool (0-40cm)	N	4970	5187	6076	6980	6614
	P	6.00	5.69	6.95	6.75	6.58
	K	218	195	248	282	316
	Ca	290	276	263	322	347
	Mg	213	200	208	211	294
Litter on soil in October	N	0.575	1.507	3.195	3.240	3.745
	P	0.050	0.086	0.265	0.282	0.328
	K	0.181	0.463	0.930	0.833	0.917
	Ca	0.218	0.435	1.168	1.309	1.556
	Mg	0.049	0.113	0.267	0.266	0.306
Total:	N	5027.808	5288.407	6222.916	7136.134	6827.475
	P	13.066	17.989	24.924	25.146	31.876
	K	261.280	277.489	370.877	418.371	513.785
	Ca	326.449	345.133	362.036	457.187	539.146
	Mg	232.210	238.823	263.977	266.727	369.900

Table 8.6. Fractional annual turnover(%) of various nutrients in soil and vegetation compartments in different jhum fallows.

Age of the jhum fallow (yr)	Fractional annual turnover(%) of different nutrient									
	N		P		K		Ca		Mg	
	Soil	Vegetation	Soil	Vegetation	Soil	Vegetation	Soil	Vegetation	Soil	Vegetation
1	0.37	11.72	35.17	8.04	6.51	4.95	2.49	6.50	3.86	2.89
3	0.75	17.18	69.58	11.16	12.76	6.60	7.68	7.22	5.54	3.38
6	0.86	26.22	71.35	17.65	9.79	9.00	8.95	14.13	4.24	5.66
10	0.60	25.96	52.65	19.06	4.85	7.58	7.79	12.00	1.52	5.91
15	0.85	21.45	58.92	10.04	7.37	5.60	7.38	7.48	2.62	4.85

During 3-6 years of fallow development after jhum, the nutrient uptake and accumulation rate by the vegetation compartment was maximum with a subsequent decline between 6-10 years. Similar observations were also made by earlier workers(B rtholomew et al., 1953; Nye and Greeland, 1960). They have shown that the nutrient accumulated more rapidly during the first five years of secondary succession then during the later stages, and concluded that the storage capacity of leaves and twigs get saturated at an early stage; thereafter, the total storage increases more slowly chiefly in the wood and root compartments. The increase in the nutrient absorption and accumulation rates by the vegetation between 10-15 years may be related to the increase in the biomass of the fast growing pine tree (Wells and Jorgensen, 1973).

Nutrients in the soil pool was fast depleted during the early stages of succession due to rapid absorption by the developing vegetation. Release of significant quantities of nutrients into the soil pool started only after about 10 years of fallow development. The enrichment ratio of potassium was invariably high in all the jhum fallows. This is indicative of the conservation of this element in the vegetation which in soil is more susceptible to leaching (Nye and Greenland, 1960). The increase in the enrichment ratio during fallow development has an advantage in that it helps in conserving nutrients in the vegetation, particularly under high rainfall situations where the losses from soil could be very high.

The fractional annual turnover percentage of various nutrients in the soil pool increased upto 6 years of fallow development due to the rapid increase in uptake by the developing vegetation. The reverse trend noticed in the older fallows may be explained as due to enrichment of the soil through litter fall so that the uptake/stock ratio is lesser. In the vegetation compartment, the turnover percentage increased upto about 10 years of fallow development which may be related to the gradual increase in release through litter fall as vegetation develops.

A comparison of the total chemical inventory for different jhum fallows at lower elevations of this region (Toky and Ramakrishnan, unpublished) with the present one indicates much lower values for high elevations. Nutrient recovery at higher elevations was also comparatively slow which may partly be due to low temperature conditions which permit only slower decomposition of litter which gets accentuated because of pine needles, a comparatively difficult material for decomposition. However, the nutrient accomulation rates in the living biomass in the present study are comparable to those obtained for the lower elevation except for potassium. The high rate of potassium accumulation observed at lower elevations is due to the ability of bamboo (Dendrocalamus hamiltonii), an early successional dominant species, to accumulate this nutrient at a rapid rate.

It may be concluded that jhum cultivation with short cycles of 4-5 years, as is more prevalent in the region, would reslut in rapid depletion of the soil nutrients due to uptake by the developing secondary successional community which does not release it through litter until after about 10 years. Continuous imposition of short jhum cycles has resulted in rapid deterioration of the site leading to desertification (Ramakrishnan et al., 1980) which has adversely affected environmental quality.

SUMMARY

The present study deals with nutrient cycling between the plant and soil compartment in secondary successional communities up to 15 years of fallow development subsequent to 'Slash and Burn' agriculture (Jhum) at higher elevations of Meghalaya in North-Eastern India. The total inventory for different elements increased with the age of the fallow up to 15 years of fallow development except in the case of nitrogen where it peaked in a 10 year fallow. Nutrient accumulation and uptake rates were comparatively higher in the early stages of secondary succession which declined between 6-10 years with a significant increase again between 10-15 years of fallow development. Rapid depletion nutrients in the soil pool occurred up to 6 years of fallow development, and release of nutrients into the soil started only after about 10 years. This was reflected in the annual fractional turnover pattern in the soil and vegetation compartments. Therefore, repeated short jhum cycles of 4-5 years as is now more common in the region have adversely affected the environmental quality.

CHAPTER — 9

GENERAL CONSIDERATIONS

1. High elevation jhum differs from the low elevations one in that: (i) the temperature conditions are low with the consequent slower regeneration of the vegetation during fallow development, (ii) the forested area has *Pinus kesiya* as the imoortant component which makes litter degradation more difficult, and (iii) the soil is acidic. As a consequence jhum in its typical form as exists at lower elevations is difficult to sustain. Probably for this reason, a modified version of jhum as discussed earlier is practised by the farmer in order to conserve nutrients more efficiently.

2. Jhum as it was originally practised had a cycle of 20-30 years. However, due to increased population pressure and decreased land available for cultivation due to poor land use practices, the cycle has become a short one of 4-5 years.

3. Such a short jhum cycle of 4-5 years has resulted in arrested succession at the weed stage with species like *Eupatorium adenophorum*, *Imperata cylindrica*, and others. Once this stage of arrested succession is reached the land is considered unfit for cultivation,which in turn reduces the acreage available for cropping.

4. One of the important consequences of the shortening of the jhum cycle has been rapid desertification of the site as is examplified by the situation prevailing

in a high rainfall areas as at Cherrapunji (annual average rainfall is 1150 cm). A situation has come about where there no soil to support any forest cover and there is no vegetation to hold the soil. Such desertified areas are a common feature at higher elevations of North-Eastern India.

5. A rapid depletion of the wild germ plasm has been another consequence of shortened jhum cycles. Among plants, apart from the loss of wild varieties of crop plants, many orchids such as species of <u>Dendrobium</u>, <u>Cymbidium</u> and <u>Vanda</u> are in the list of endangered plant species.

6. Replacement of jhum by sedentary terrace agriculture which necessiates heavy inputs of fertilizer does not seem to be a viable solution to the environmental problem of this region. Apart from deforestation and the cost factor involved, the efficiency of use of fertilizer would be very low in view of high infiltration losses that may occur in spite of checking surface run-off through terracing.

7. Further, any damage to the hill ecosystems of the Himalayas is likely to have grave ecological repercussions not only in the region but also in the northern plains of India through recurrent floods.

8. It is suggested that annual crops should be restricted to the minimum and the economy should be developed with emphasis on plantation and horticultural crops. In fact the area is highly suitable for many temperate fruit trees as well as for oranges. Other plantation crops like coffee has been successful in selected areas.

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APPENDIX

PLATE - 1:

A typical Jhum plot. *Zea mays* is interplanted with *Solanum tuberosum* under pine canopy on the hill slope.

PLATE - 2:

Beginning of the Jhum operation. The undergrowth vegetation alongwith the lower branches of the pine trees has been slashed and is being arranged in parallel rows for drying.

PLATE 1

PLATE 2

PLATE - 3:

One row of slash is magnified. Note that the pine forms a major proportion of it.

PLATE - 4:

Burning of the dried slash.

PLATE 3

PLATE 4

PLATE - 5:

The Jhum field after burining. Note that the soil-ash complex forms distinct ridges with alternate furrows.

PLATE - 6:

Mixed cropping under a 15 year Jhum cycle with *Zea mays*, *Solanum tuberosum* and *Cucurbita maxima* as the major crops.

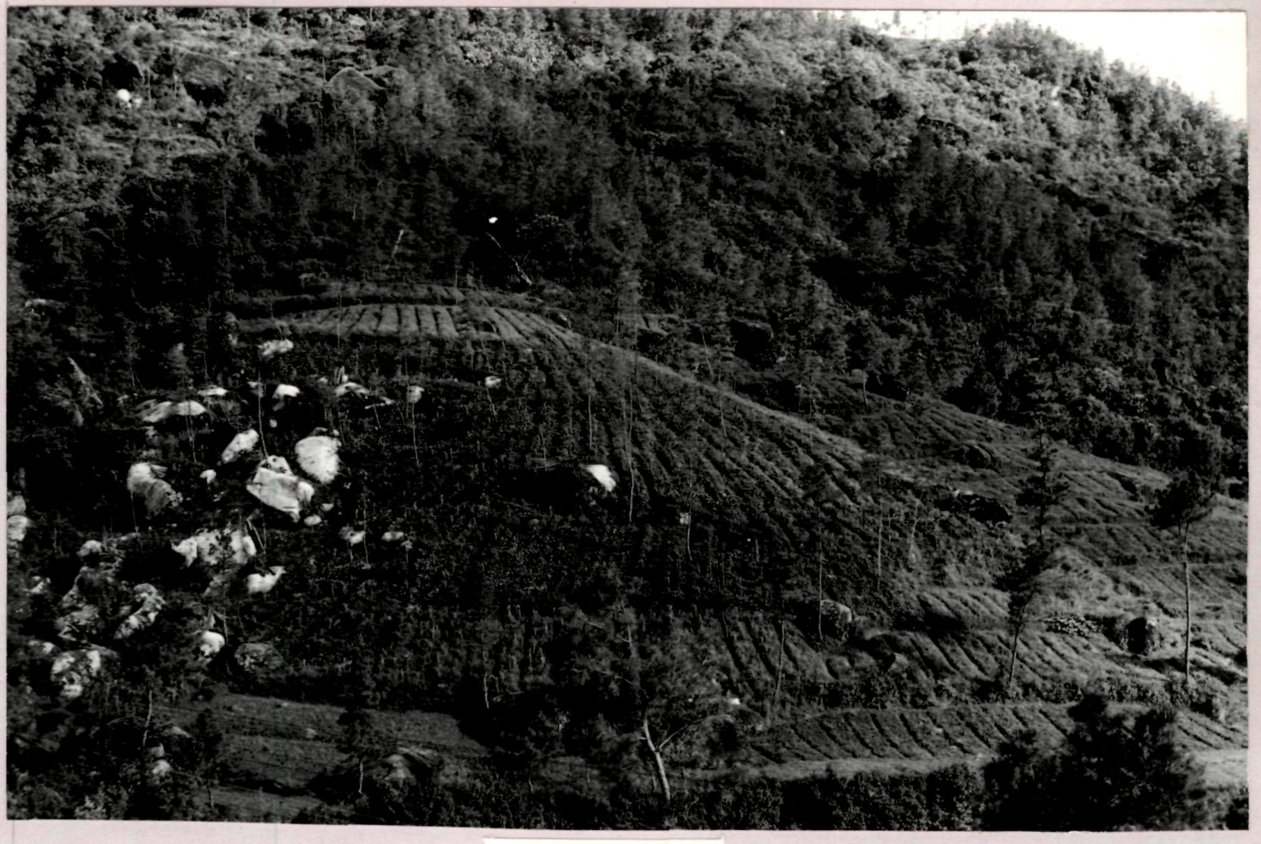

PLATE 5

PLATE 6

PLATE - 7:

A view of mixed cropping under Jhum. Note that Phaseolus vulgaris is planted under the pine tree which provides a support to this climber.

PLATE - 8:

Weeds after the first rain. Galinsoga parviflora, Dicranopteris linearis and Erigeron linifolius are prominent.

PLATE 7

PLATE 8

PLATE - 9:

Maintenance of the field. Note that the soil washed off by heavy rain is being heaped up again on the redges.

PLATE - 10:

Harvesting of *Solanum tuberosum*. *Zea mays* plants are left standing to be harvested after a few weeks.

PLATE 9

PLATE 10

PLATE - 11:

Winter crop of Solanum tuberosum. Note that while some of the Zea mays plants are still left standing which may be harvested for another couple of weeks, the winter crop of S.tuberosum is grown alone on few ridges

PLATE - 12:

Farmers with their harvested crops. Note that very simple tools like spade is used for this operation. For carrying the harvested crops to home, baskets made up of bamboo are used.

PLATE 11

PLATE 12

PLATE - 13:

Imperata cylindrica in a fresh Jhum fallow under a 5 year cycle.

PLATE - 14:

A three years old Jhum fallow. Note that the stand is dominated by weedy species like *Eupatorium adenophorum* and *Imperata cylindrica*.

PLATE 13

PLATE 14

PLATE - 15:

Eupatorium adenophorum in a 6 year Jhum fallow.

PLATE - 16:

A 15 years old Jhum fallow. Besides pine(*Pinus kesiya*), many dicot tree and tree saplings gain dominance at this stage.

PLATE 15

PLATE 16

PUBLICATIONS ARISING OUT OF THE THESIS

PUBLISHED PAPERS:

1. Slash and burn agriculture in North-Eastern India. In: Fire Regimes and Ecosystem Properties(Ed.by H.Mooney, J.M.Bonnicksen, N.L.Christensen, J.E. Lotan & W.A.Reiners). U.S.D.A. For. Ser.Gen.Tech.Report, Washington, D.C.(1980) (In Press).

2. The economic yield and energy efficiency of hill agro-ecosystems at higher elevations of Meghalaya in North-Eastern India. Acta Oecologica/Oecologia Applicata 9(1981) (In Press).

3. Pooulation dynamics of Eupatorium adenophorum Spreng. during secondary succession after Slash and Burn agriculture (Jhum) in North-Eastern India. Weed Res.(1981) (In Press).

4. Energy flow through a village ecosystem with Slash and Burn agriculture in North-Eastern India. Agricultural Systems (1981) (In Press).

PAPERS SUBMITTED FOR PUBLICATION:

1. Sediment, water and nutrient losses under Slash and Burn agriculture (Jhum) at higher elevations of North-Eastern India. Environmental Management.

2. Soil fertility changes during and after Slash and Burn agriculture (Jhum) at higher elevations of North-Eastern India. Environmental Management.

3. Secondary succession subsequent to Slash and Burn agriculture at higher elevations of North-East India.I. .

Species diversity, Biomass and Litter Production. Acta Oecologica/Oecologia Applicata.

4. Secondary succession subsequent to Slash and Burn agriculture at higher elevations of North-East India. II. Nutrient Cycling. Acta Oecologica/Oecologia Applicata.

ABSTRACTS OF PAPER PRESENTED:

1. Shifting cultivation and its impact on forested ecosystems at higher elevations of Meghalaya, with special emphasis on nitrogen budget. Focal Theme Symposium On: Environmental Degradation, Agro-forestry and Conservation of Natural Resources. Indian Science Congress (1980).
2. Energy efficiencies of traditional versus sedentary agroecosystems of the Khasi hills of Meghalaya. Focal Theme Symposium On: Impact of the Development of Science and Technology on Environment. Indian Science Congress (1981).