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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Bidyut Kumar Mishra

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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 $\frac{1}{2}$ 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 dropped 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 Petén, 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 weeded 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 input 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 foodstuff 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; Nicolás, 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 K'ankab 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).

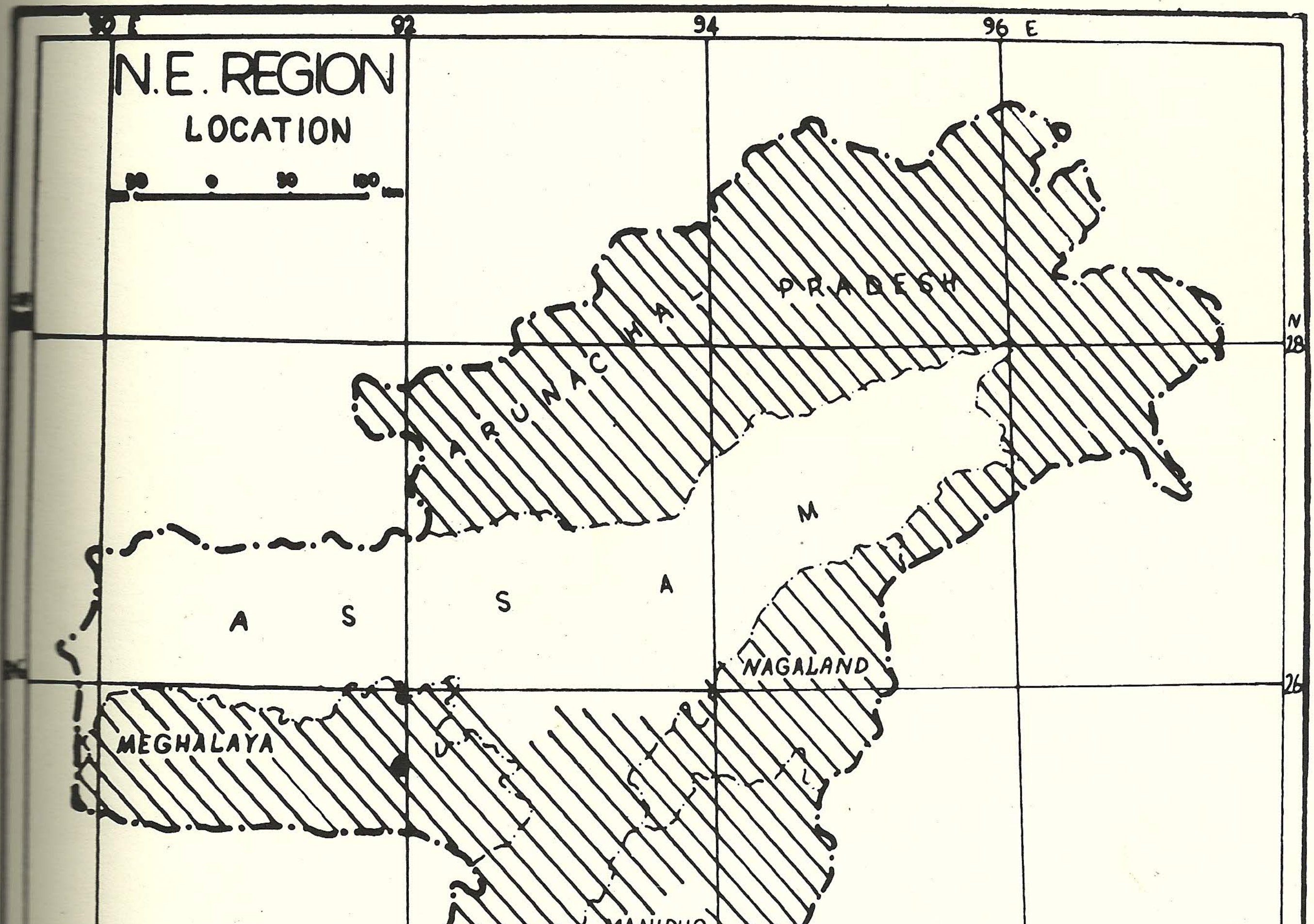
The present work:

'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^{O}N, 91.56^{O}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
ARUNACHAL PRADESH
ASSAM
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MANIPUR
TRIPURA
MIZORAM
LOCATION OF STUDY AREA
INDIA
90 E
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