STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING AGRICULTURE (JHUM) ON FORESTED ECOSYSTEM

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I certify that the thesis entitled "STUDIES ON THE ECOLOGICAL IMPACT OF SHIFTING AGRICULTURE (JHUM) ON FORESTED ECOSYSTEM" submitted by Mr. Om Parkash 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.

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Place: Shillong

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CONTENTS

PREFACE

This study was undertaken at Burnihat located at an altitude of 100m in the Khasi hills of Meghalaya in order to study the hill agro-ecosystems and more particularly to measure the impact of slash and burn agriculture (locally called 'jhum') which is the predominant agricultural practice in the entire north-eastern hill regions of India.

A number of aspects like hill agro-ecosystem, structure and productivity and energetic efficiency have been studied and form the topic of discussion in chapters 1 and 2. This is followed in chaper 3 by the analysis of vegetation during secondary succession in jhum fallows with respect to its structure, biomass and productivity. Chapter 4 deals with the detailed study of changes in nutrients in soil after burn and during cropping period of one year of jhum. This is placed in the context with the nutrient recovery patterns during forested fallow development upto an age of 50 years. Chapter 5 deals with hydrology and various types of losses of sediment and nutrients from agro-ecosystem. It also deals with the hydrology and the losses from the ecosystem during development of the fallows. Chapter 6 concerns itself with nutrient cycling through the entire process of jhum upto a forested fallow period of 20 years.

The thesis starts with a General Introduction and is concluded with a Chapter on "General Considerations and Conclusions". The conclusions drawn are chiefly based on the present studies. Apart from this general discussion, each Chapter has its own discussion of results and summary. The various chapters have been prepared keeping in view the eventual publication of papers in different journals. All literature cited in the text is brought together at the end.

(iii) The various studies on jhum have been done particularly keeping in mind the impact of the shortening of the jhum cycle from an ecologically more favourable situation of 30 years to as short a period as 4-5 years, as a consequence of reduction in acreage and increase in population pressure. Thus, wherever feasible a 30 year jhum cycle has been compared and contrasted with a 10 and 5 year cycle.

GENERAL INTRODUCTION

Slash and burn agriculture is practised on a wide range of soil types, slashing varied vegetational types, and by people of widely different origin and culture that it shows great variations in the types of crops grown, the length of the cropping and fallow period, and the method of cultivation itself. But the system is universally characterized by (1) partial or complete clearing of the vegetation by cutting and burning (2) cultivation of pure or mixed crops, and (3) the abandonment of the plot to fallow regeneration after the exhaustion of the soil fertility. A short period of cropping generally alternates with a longer period of fallow with exclusive use of human energy for all the steps of the agriculture. It is one of the oldest of all the agricultural systems, which indicates that it must be or has been until recently, more or less in equilibrium with the environment.

It is frequently called as 'slash and burn' agriculture, though the term 'swidden' is preferred by some anthropologist (Ekwall, 1955). The practice is also referred to by a number of local names, among which 'milpa' from Central America, 'chena' from Ceylon, and 'kaingin' from the Philippines are common. In the north-east India and Bangaladesh, the system is called as 'Jhum'. The nomenclature of the system has been thoroughly discussed by Conklin (1957).

Regional differences :

Of the three great continental regions of shifting agriculture in the tropics, Africa is the largest having a great variety of natural conditions and cultural pattern. Its total tropical area of 5.75 million square miles, under forest, woodland and savannah holds a population of 104 million with a density of 18 per square mile (Gourou, 1953). Harroy (1949) and Worthington (1958) discussed slash and burn agriculture against a wider background of the conservation of natural resources of Africa. de Schlippe (1956) described mixed cropping on the border of the Sudan and the Congo practised by the Zande tribe. Here mixed crops including cereals (*Eleusine coracana*, *Zea mays*, *Penisetum typhoides*, *Oryza* sp) pulses (*Vigna unguiculata*, *Phaseolus mungo*, *Phaseolus lunatus*), oil seeds (*Arachis hypogea*, *Sesamum orientale*) and starchy crops (*Manihot utilissima*, *Ipomoea batatas*, *Dioscorea* sp, *Colocasia antiquorum*) are common.

Nye & Greenland (1960) gave a detail account of the system in evergreen and semi-deciduous forests in Africa. During the dry season a patch of forest is felled, dry biomass is burnt and a mixture of crops is sown by dibbling. During the growth of the crop or slightly after it has been harvested starchy crops like Cassava (Manihot utilissima), Cocoyam (Colocasia antiquorum) or Xanthosoma sagittifolium) and bananas (Musa sp) are planted. Weeding is done twice or thrice during the cropping period. The dense mass of the developing secondary forest is soon dominated by light loving species among which Musanga cecropioides (the Umbrella tree), Trema guinensa and Macaranga barteri are often predominant after the fields are left to regeneration of fallows. According to them, regrowth of the vegetation is rapid and three years of cropping alternating with eight years of fallow often appear to maintain fertility in the semi-deciduous forests, and 1-2 years of cropping is followed by about 10 years of fallow period in evergreen forests.

Under savannah in Africa, the soil has to be more thoroughly cleared than in a forest to get rid of roots and rhizomes of grasses. In contrast to forest the land is without cover during the dry season and it is exposed to the early rains for at least four weeks before a fair cover is formed. The intensity of the weeds is also high particularly if Imperata cylindrica is present. When the field is abandoned it is dominated by Pennisetum sp and Imperata cylindrica if the weeding is not proper. In a year or two the tall perennial grass Andropogon gayanus appears and when in about 10 years this attains dominance, the land is considered fit to clear again.

Tropical America which has an area of 5 million square miles, has received far less scientific study. Like Africa, the system is practised both in forest and savannah regions. Cook (1921) described 'milpa' system of growing maize in Central America and concluded that 'milpa' agriculture is a stable system if the intervals between successive clearing of the same land are very long and the forest has time to restore the land to its original condition. Carneiro (1960) studied Kuikuru Indians of Central Brazil, who subsist largely by the slash and burn agriculture of manioc (Manihot sp). He demonstrated mathematically that under a system of shifting agriculture the Kuikuru have been able to remain permanently settled and they do not have to relocate their villages periodically because of soil exhaustion. Watters (1971) describes 'conuco' agriculture in Venezuela. Cropping is primarily for subsistence and the chief crops are invariably maize and black beans. Inter-cropping is common, with a variety of annual crops and also semi-permanent ones (Yucca or 'quinchoncho'). Formerly stable 'conuco' system is now in a state of break down and shortening of fallows (4-5 years) is the main cause for the breakdown.

The tropics of Asia are unlike those of Africa and America in that the density of population is ten times more as compared to other parts of the world. However, most of the population lives on alluvial soils of the plains. Dobby (1950) estimated that one third of the total area used for cultivation in south-east Asia is under shifting agriculture. However, this system is practised only in forest lands and supports a density of 16 individuals per square mile. Much of these forests receive a rainfall of more than 200 cm. Conklin (1957) describes the 'Hanunoo' system in the Philippines. Forests are felled in the dry months, and after burning and clearing a mixture of crops sometimes nearly 40-50 are sown in the same plot with a system of successive harvesting.

Mey (1978) studied shifting agriculture ('Jhum') in Chittagong hill tracts of Bangaladesh. The seeds of the hill fields consist of 60-80% of paddy, the rest is cotton, corn and vegetables like pulses and gourds, sesamum and chillies. The yields of the 'jhum' plots are very low due to shortening of the jhum cycle and the general economic situation of the farmers is bad.

Rappaport (1971) gave a detailed account of 'swidden' agriculture of the Tsembaga in the central highlands of Papua New Guinea. In making a garden the Tsembaga prefer to clear secondary forests rather than primary forests. A fence is made to keep the pigs, both feral and domestic out of the garden. Trunks of the felled trees are utilized for this purpose. The Tsembaga can name at least 264 varieties of edible plants, representing some 30 species. The staples are taro (Colocasia esculenta) and sweet potato. Other starchy vegetables such as yams, cassavas and bananas are of lesser importance. Sweet potatoes and cassavas are used as pig feed as well as for human consumption. Beans, peas, maize and sugarcane are also grown, along with a number of leafy vegetables like Hibiscus sp. The Tsembaga recognize the importance of the regenerating trees; they call them collectively 'duk mi', or "mother of gardens" and do not destroy them during weeding. Swine husbandry is linked with the swiddening and both these provide the 'Tsembaga' with, on the one hand, an adequate daily energy ration and, on the other, an emergency source of protein.

In the north-eastern hill tracts of India, this practice is a source of support for 1.6 million tribal population. It is widely spread in Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura and some parts of Assam over an area of 0.426 million hectares (Mukerjee, 1975). This practice locally called as 'Jhum' consists of cutting down the forests of various successional stages on the hill slopes in the months of December and January, allowing the slash to dry for a few months and burning the slash before sowing mixed crops of about 8-13 species. The land is utilized for one or two years and then left as fallow to regenerating forest. The Jhum cycle (the fallow period before the land is again cleared) is often short ranging from 4-5 years but longer cycles from 10-30 years are also rarely available. Short cycles have adversely affected the yield of crops, the quality of the environment both in terms of soil fertility and vegetation cover.

At higher elevation (above 800 m) of Meghalaya, the practice differs from the typical form at lower elevations, in many respects. Here the vegetation type is chiefly of Pinus kesiya. At the time of clearing the forest, only a partial felling is done in which only branches of the trees are felled and placed on the ridges of the prepared land which has ridges and furrows. Soil is put over the slash and a light burning is done and pure crop of potato, sweet potato, rice or maize is grown over the ridges sometimes there is mixing of these crops also. 2-3 crops of potato are taken in one year. The fields are used for 2-3 years and left as fallow for 5-10 years. Due to low soil fertility, some organic manure and fertilizer are added to the ridges.

Agro-ecosystem :

Under slash and burn agriculture the fertility in the soil declines rapidly with successive seasons of cropping and this results in decrease in the yields of the crops. In humid forest regions the yield declines faster than in dry forests and savannah regions. Tondeur (1956) reported that in the forested regions of the Belgian Congo during the second cycle of rotation of rice, groundnuts and cassava declined 76%, 86% and 33% respectively compared to the first cycle. Nye & Stephens (1962), on the basis of fertilizer trial in forest regions of Ghana showed that during the continuous cropping for 8 years in the absence of fertilizers, the yield declined sharply but in the savannah zones of Ghana, on the average yields in the absence of fertilizers declined slowly. The yield of a second crop of maize in north Guatemala is often reduced to one half compared to the first crop (Popenoe, 1959). At Yambio Experiment Station, southern Sudan, yields of cotton, groundnuts and eleusine dropped sharply after 3 year's cropping (Anthony & Willimott, 1956).

Weeds are the major cause of declining yield under slash and burn agriculture in many parts of the world and include _Eupatorium odoratum_ in Thailand (Zinke _et al_, 1978) and _Imperata cylindrica_ in Sarawak (Freeman, 1955). Cutting _et al._ (1959) reported that the yield of maize in Nyasaland was 4284 kg/ha when weeded four weeks after germination, but attained only 3217 kg/ha when weeded six weeks after germination. Emerson (1953), describes the influence of weeds on the 'milpa' system in tropical America, in which successive crops of maize, mixed with beans, are grown. The second crop yields less than the first, probably because it is more weedy and therefore farmers like to clear a fresh land than to continue cropping on the old plot. Conklin (1957) estimated that a Hanunoo farmer in the Philippines spends 300 man-hours per hectare in weeding the first year land cleared from primary forest and 600 man-hours on land cleared from secondary forest about 20 years old. In the south-east Asia, the forest often gives way to areas dominated by lalang (Imperata cylindrica var. major and such areas are useless for cultivation (Conklin, 1957; Bedard, 1958). In Africa and America, the corresponding grasses Imperata cylindrica var. africana and Imperata braziliensis are not so agressive and are rapidly replaced by other savannah species if left abandoned (Nye & Greenland, 1960).

The shortening of the jhum cycle, in recent times, has increased the weed problem. Another reason for decline in yield of the crops under shorter cycles is the depletion of the soil of organic matter and deterioration of the soil physical conditions like water-holding capacity, cationic exchange capacity and microbial and faunal activities in the soil (Watters, 1971).

In north-eastern India there is a great confusion regarding the yields of crops from hill agro-ecosystems. The Agro-economic Research Centre, Jorhat, Assam, conducted surveys on jhum yield of rice and concluded that the average yield of 800-900 kg/ha in Garo hills, Mizoram and Arunachal Pradesh is comparable to the average yield of 1145 kg/ha/yr for the country as a whole for 1971-1972. On the other hand, the rice yield under jhum in Tripura was reported to be around 1200 kg/ha/yr (Misra, 1976). In a recent survey of the socio-economy of shifting agriculture, Aurora et al (1977) concluded that the yields of rice under jhum and dry land cultivation on terraces are not significantly different under comparable situations. A study of Burnihat (Sahu, 1978) on rice yield gave yearly outputs under valley cultivation of 3428 kg/ha, under terrace cultivation 738 kg/ha and with jhum of 853 kg/ha. According to a report of the Indian Council of Agricultural Research (Borthakur et al, 1978) the yield under jhum is very low (190 kg/ha) compared to terrace cultivation (1860 kg/ha). Unfortunately none of these studies specify the fertilizer inputs under terrace cultivation nor do they indicate the jhum pattern, the cycle of which determines the yield. None of these study either specify whether yields from other crops are included in the final figure.

In recent times, there has been a renewed interest in the energetic efficiency of slash and burn agriculture due to energy shortage in the present times. Data on the energetics of slash and burn agriculture is rather scarce. Rappaport (1971) provides relatively complete information on the energy expenditure of the Tsembaga people of new Guinea highlands. According to him, the farmers obtained an average of 16 food calories for each calorie of human energy employed during farming which may go upto 20 under more favourable conditions. Modern agriculture is highly unstable and has many environmental repercussions; it is highly inefficient from an energy point of view as 5-10 calories of fuel energy is required to produce a single calorie of food energy (Steinhart & Steinhart, 1974). From the energy point of view, shifting agriculture seems to be the best evolved system for forested areas in tropics and sub-tropics (Conklin, 1957; Nye & Greenland, 1960). Ramboo (1978) taking the energy data of Rappaport (1971) calculates that if the fire energy is included as an input then the output/input ratio may drop to 0.11 which is in comparable range of efficiency of modern agriculture. During the calculations he has, however, ignored many products of the fallow which form a great source of energy to the farmers.

<u>Forested fallows</u> :

When the cultivated land is abandoned, its vegetation passes through several secondary successional communities, but rarely reaches the climatic climax before the land is again cleared. Richards (1952) made a fine survey of secondary successions in the moist evergreen forests of Africa. The first phase of the succession is dominated by weeds which are short lived and are replaced by shrubs and later on by trees. Young secondary forests tend to be even aged and are often dominated by a single species; the first dominants may form a single generation community which dies without reproducing itself and is followed by communities with other dominants. In Nigeria and much of the Congo Basin, for example, the secondary succession is often dominated by the Umbrella tree (*Musanga cecropioides*). This is a fast growing shade intolerant species with a high potassium content that dies out after about 20 years and is unable to regenerate in its own shade. Detailed studies of the early stages of succession after slash and burn agriculture have been made in south-west Ghana by Ahn (1958). Clayton (1958) studied the succession on the abandoned farmland around Ibadan in western Nigeria and reported a wide range of vegetation over a relatively small area. In all these cases, the details of the successional pattern depend on the degree of cropping and exhaustion of the land, and the type of the soil.

Savannah in Africa consists of ecologically dominant stratum of more or less xeromorphic herbaceous species, of which grasses and sedges are the principal components; fire-resistant shrubs, trees and palms are sometimes also present. The density of the woody growth varies greatly according to the intensity of cultivation, the method of clearing and the severity of the annual burn (Nye & Greenland, 1960).

A variety of reproductive and growth strategies are adopted by successional species, among which stump, root and rhizome sprouts and invasion through seeds are common. Salisbury (1942), Hayashi & Numata (1968) and Raynal & Bazzaz (1975) discussed the role of high seed production in early stages of succession. The early species may be considered as most closely approaching a purely exploitive strategy, which enable them to become dominant in abandoned fields temperarily enriched with nutrients and radiant energy (Grime, 1974; Harper & White, 1974; Marks, 1974). The species that follow in the later phases of succession have fewer and larger seeds and a long vegetative phase (Harper & White, 1974; Bormann & Likens, 1979) and could be considered representative of the conservation strategies.

Detailed studies on succession, in temperate regions, have shown that following dominance by a few species early in the seres, there is an overall increase in species number with time. Numerous studies of the tropical successional vegetation (Kenoyer, 1929; Ross, 1954; Sarukhán, 1964; Kellman, 1970; Lawson et al, 1970) suggest that while the overall species richness is greater in tropical successional communities, the rate of increase in species richness is not basically different from that of temperate communities. Another important but least understood aspect of successional communities is the relationship between diversity, energy flow and age of the community. There seems to be considerable confusion related to diversity, productivity and stability. A general model of community structure and function has been developed (Margalef, 1958a, b, 1961, 1969; Woodwell & Smith, 1969) with two basic approaches to evaluate stability: (i) the persistence of certain species combinations through time and (ii) the ability of the community to resist environmental perturbations. However, a few of the generally accepted hypotheses have been experimentally tested (Odum, 1969).

Soil fertility :

The long term success of slash and burn agriculture depends upon the recovery and maintenance of soil fertility. If the nutrient lost or displaced during the short period of cultivation are approximately balanced by those replaced during the fallow period, the system could continue indefinitely. The maintenance of soil fertility in hot, humid and high rainfall areas is a serious problem and is more severe in situations when the cycle becomes short, due to poor recovery of soil fertility and increased intensity of weed competition. This in turn results in reduced crop yield under short jhum cycles (Nye & Greenland, 1960; Watters, 1971).

When the forests are cleared and the debris is burnt, all the cations are released on the surface soil as ash. Heavy losses of carbon, nitrogen and sulphur occur due to volatilization during the burn (Nye & Greenland, 1960; De Las Sales & Fölster, 1976). For phosphorus there are no obvious mechanisms of volatilization but the matter has not been closely studied. Lloyd (1971) reported high loss of total phosphorus due to burning but Allen (1964) and Viro (1974) reported no losses on account of this. Large proportion of the ash liberated after the burn is blown-off by the wind.

After the burn and during cropping period loss of organic matter from the soil due to decomposition is likely to be faster due to higher insulation and also due to rapid surface run-off. Joachim & Kandiah (1948), Nye & Greenland (1960), Zinke et al (1978) and Jha et al (1979) reported a net loss of carbon after a year of cropping. Juo & Lal (1977) estimated a requirement of 16 ton/ha/yr of dry plant material to be added to the soil under slash and burn agriculture in order to maintain soil organic matter in the surface soil at a level comparable to soil under secondary forest, as the rate of decomposition is faster under continuous cropping. The depletion of organic matter depends upon the intensity of cropping, type of the fallow vegetation and the ratio of the cropping to the fallow period. With optimum cropping (1-2 years) and fallow period (8-10 years), the humus in the soil could be maintained at a relatively high level even after many years of shifting agriculture (Coulter, 1950; Birch & Friend, 1956; Nye & Greenland, 1964). Similar to carbon, there is also a net loss of nitrogen after cropping compared to that before burn. Nitrification after the burn is shown to be accelerated due to high microbial activity, due to rise in pH and temperature of the surface soil (Griffith, 1949; Moore & Jaiyebo, 1963; Ahlgren & Ahlgren, 1965). The increase in nitrification after the burn has also been attributed to the removal of chemical inhibitors (Reed, 1951; Smith *et al*, 1968; Rice, 1974).

Nye & Greenland (1960) have reviewed a large number of fertilizer trials carried out in many parts of Africa with the main crops grown by shifting cultivators and have shown that on forest soil, whether oxysols or ochrosols, responses to nitrogen have been small after fallows lasting ten years or more, but large on land more intensively cropped with only short fallows. The effect of phosphate fertilization varied with soil type, but in many places small responses have been obtained in first year of cropping and larger responses in subsequent years. Response to potash has very commonly been obtained after short fallows or on land that has been cropped for a number of years.

Deforestation has a major impact on both the amount and relative proportions of water, dissolved substances and particulate matter lost from the system. Moreover, the total concentration of cations in the soil solution depends upon the total concentration of anions. A high level of nitrate ion due to increased 'biological activity' (Ahlgren & Ahlgren, 1965; Wells, 1971) after burning balances a corresponding concentration of nutrient cations in the soil solution and therefore heavy losses through water occurs (Bormann et al. 1968; Lewis Jr., 1974).

The losses of water, nutrients and sediment are highly reduced when the land is reverted to the fallow. Under fallows in the deciduous and semi-deciduous forest zones, although there will be relatively large amounts of nitrate in the soil, leaching will be restricted both by the uptake of anions by the vegetation, and because the transpiration of a larger proportion of the rainfall will reduce through percolation. In the wetter evergreen forest zone where precipitation is high (over 200 cm), percolation is bound to occur, but leaching losses will be restricted, not only by the absorption of anions by vegetation but also by low nitrate levels in the soil, since nitrification will be limited by high acidity. Losses also depend upon the nutrient status of the soil. Ecosystems with nutrient saturated soils would lose relatively more of their nutrients than those with nutrient depleted soils (Jordan _et al_, 1972). For example, the northern hardwood forests (Likens _et al_, 1977) in which a large proportion of the nutrients is in the soil in exchangeable form would lose a relatively larger quantity out of it than tropical rain forests as in these forests most of the nutrients are tied up in the biomass (Odum, 1971; Jordan _et al_, 1972) and mineral soil has very low nutrient content (Went & Stark, 1968).

The depletion of various nutrients in soil continues in the early successional stages. The transfer of nutrients from sub-soil to top-soil probably does not begin until after the first year or two of fallow; during this initial period the top-soil is further depleted by leaching and by the uptake of nutrients by the regenerating vegetation, which has few active roots in the sub-soil at this stage. Popenoe (1959) showed under regenerating forest fallow in Guatemala that there was an initial depletion of the surface soil, after which the level of cations rose in the top 3 cm, and fell in the layers below, as the vegetation developed. Valentine (1976) also reported rapid depletion of soil with exchangeable cations upto 7 years of the regeneration burn in south-western Australia. Zinke *et al* (1978) also made similar observations with the 'Lua' forest fallow system in Thailand.

Biomass, Productivity and Litterfall :

A sharp increase in the aboveground biomass occurs during secondary succession. According to Lugo (1973) maximum biomass value for tropical forests is approached in about 30 years at a level of 250 m.ton/ha where as in the temperate forest in northern hardwoods of USA, after clear-cutting the living biomass rises to a peak of 490 m.ton/ha in about 170 years only (Bormann & Likens, 1979). While according to Margalef (1968), Odum (1969), Whittaker & Woodwell (1972) a steady-state for biomass immediately follows the attainment of the peak during succession, according to Bormann & Likens (1979) this is reached only after a transition period of more than 100 years. In any case, a steady-state for biomass is reached over a shorter time period in the tropics than in the temperate forests. The rate of accumulation of biomass is faster in the early stages of succession but may decline in the subsequent years. Snedaker (1970) reported maximum rate of increase of biomass of 19.23 m.ton/ha/yr upto 7 years in lowland forests in Izabel, Guetamala. Bartholomew *et al*

(1953) reported a maximum rate of 26.6 m.ton/ha/yr in a new forest of *Musanga cecropioides* upto a period of 5-8 years. However, the rate of biomass accumulation during succession also depends upon the type of vegetation established and other environmental conditions. Tropical forests as a whole, with a mean annual net primary productivity of 21.6 m.ton/ha, exceeds temperate forests, averaging 13.0 m.ton/ha and boreal forests averaging 8.0 m.ton/ha (quoted by Lugo, 1973). Jordan (1971) reported values of 5.4 m.ton/ha/yr for a 3 year old successional forest and 10.3 m.ton/ha/yr for old rain forests in Puerto Rico. In an oak-pine forest in New York, net primary productivity (Holt & Woodwell, quoted by Whittaker, 1975) increased to a fairly stable level in the meadow stage of succession and increased more steeply through the shrub and the young tree stage to 12 m.ton/ha/yr in the oak-pine forest of 44-45 years age. Mellinger & Mc Naughton (1975) showed a contrasting trend where over a 30 year period during succession in old fields in central New York, there was a decrease in average net productivity.

During development of vegetation, a part of the nutrient is stored in the vegetation and part is returned to the surface soil by rain wash from leaves and twigs, by litter and twig fall, and in the form of dead roots and

and root exudates. The soil humus is increased during fallow period, chiefly as a result of litter. Relatively high value of litter production is found in the secondary successional communities compared to the mature ones (Mitchell, cited by Bray & Gorham, 1964; Ewel, 1976). This is because of the fast rate of development of the community in the early successional stages.

Nutrient cycling :

The information on the chemical content of tropical vegetation has been summarized by Rodin & Bazilevich (1967); studies of the dynamics of mineral cycling include those of Laudelot & Meyer (1954), Greenland & Kowal (1960), Nye (1961), Dommergues (1963), Rozanov & Rozanova (1964), Odum & Pigeon (1970), Odum (1970), Stark (1970) and Golley *et al* (1975). While the information is quite limited, certain patterns are nevertheless suggested by these studies: (i), the uptake and return of nutrients may be greater per year in tropical forests than in other type of vegetation (ii), a larger proportion of the entire chemical inventory of the system is held in the vegetation, (iii), in tropical forests the percentage of the vegetation in green parts, the proportion lost per year as litter, and the rate of decomposition of the litter are greater than in temperate forests, (iv), the rate of uptake is strongly influenced by the rate of evapotranspiration.

The average concentration of elements in the vegetation of tropics is shown to be higher in the second-growth than in the mature forests (Golley et al, 1975) because of their high requirement of nutrients. Potassium is more abundant of all the elements in the early successional forest but calcium tends to be more in mature forests (Bartholomew et al, 1953; Golley et al, 1975).

Mineral cycling probably varies with the nutrient supply to the system, with the time available for the system to develop on the site and also the environmental conditions. The accumulation of nutrients and their release through litterfall increases with the age of the fallow and becomes stabilized in mature forests. The type of soil may also play a great role, as for e.g., the soil in certain Amazonian forests (Stark, 1971 a,b; Klinge & Rodrigues, 1968 a,b) are podsols which contain low quantities of nutrients and have low exchange capacity. As a consequence, concentration of nutrients in plants are much higher than in the soil and the elements released from the litter are rapidly taken up by the plants; the litter is also low in nutrients than in other forests (Klinge & Rodrigues, 1968b).

The Amazon case has led Stark (1971a) to propose a direct nutrient cycling hypothesis which states that on poor Amazon soils nutrients are transported from dead organic matter by mycorrhizal fungi directly to living plant roots without appearing in the soil solution.

Misra (1972) presents data on tropical dry deciduous forests near Varanasi, India. The annual rainfall where this forest grows in India is 70 to 80 cm and distributed in a short period. The turnover of the nutrients in the biomass is rapid (P, 44 years; Ca, 20 years; and N, 70 years). Apparently in this environment availability of water is the major limiting factor to forest production and because of the environmental conditions the amount of nutrients that can be incorporated into the biomass is relatively small and these are conserved by rapid cycling between the biomass and sustrate.

A complete destruction of forests under slash and burn agriculture disrupts the mineral cycling, because the system loses its ability to hold the nutrients. The development of the regulatory functions depend upon the reestablishment of biotic compartment which in turn regulates the uptake of nutrients and water, nutrient storage, decomposition, nitrification, mineralisation and erosion.

Rapid recovery of these ecosystem characteristics are promoted by temperature, moisture, and nutrient conditions favourable to plant growth (Likens <u>et al</u>, 1978).

The present study attempts at detailed analysis of agro-ecosystem structure and function with respect to cropping and yield pattern and also the energetic efficiency of the different slash and burn agriculture cycles (Jhum cycles) at a lower elevation of the Khasi hills of Meghalaya at Burnihat (located at 26.0°N and 91.5°E) 90 km. north of Shillong. 30, 10 and 5 year jhum cycles were compared between themselves as well as with terrace cultivation and valley cultivation of wetland rice.

Immediately prior to burning the slash and through the first year of cropping, the nutrient availability in the soil, the pattern of loss of water, sediment and nutrients through run-off/leaching were also studied. These studies were continued through various stages of development of fallows.

The development of secondary communities was analysed in detail with respect to species composition, biomass accumulation, litterfall and productivity. On the basis of the above studies and on the basis of detailed nutrient analysis of the different compartments of the developing ecosystem, the nutrient cycling pattern was worked out.