STUDIES OF LAND USE AND VILLAGE ECO-SYSTEM FUNCTION IN THE KHASI HILLS OF MEGHALAYA

SUPRAVA PATNAIK
CENTRE FOR ECO-DEVELOPMENT
SCHOOL OF LIFE SCIENCES

SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF
THE DEGREE OF
DOCTOR OF PHILOSOPHY

TO

THE NORTH—EASTERN HILL UNIVERSITY
SHILLONG, INDIA
APRIL—1988

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TO WHOM IT MAY CONCERN

I certify that the thesis entitled ''Studies of Land use and Village Eco-system Function in the Khasi Hills of Meghalaya'' submitted by Miss. Suprava Patnaik, for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by her under my supervision. She has been duly registered and the thesis presented is worthy of being considered for the award of Ph.D. degree. This work has not been submitted for any degree of any other University.

Date : 22 April 1988
Place : New Delhi

(Signature of the Supervisor)

Forwarded
R.R. Mishra
Head
Department of Botany
N.E.H.U.

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PREFACE

Slash and burn agriculture (jhum) is the chief land use of the tribals of north-east India in general and Khasis of Meghalaya in particular. In recent past there were attempts by the Governmental agencies to replace jhum, which is considered to be damaging to forests, by alternative land use systems of which terracing was an important one. Though terrace system of agriculture has largely been rejected by the tribals there are areas around Shillong where the immigrant Nepalis practice terrace agriculture for sometime now. One of the objectives of this study, therefore, has been to evaluate the terrace agroecosystems as practised by the Nepalis at Nayabunglow 30 km north of Shillong and compare it with that of the native Khasi community in the region. While doing so, the study was extended to cover village ecosystem function of these two co-existing communities in the region considering agriculture, animal husbandry and domestic as sub-systems of the village.

The original work presented in thesis is divided into five chapters each one dealing with an aspect related to the study done at Nayabunglow. The thesis starts with a general introduction and concludes with a concluding section. The literature cited are all placed at the end of the thesis. The organization of the chapters themselves are done in such a way as to facilitate their publication into separate papers, eventually therefore, a certain degree of overlap could not be avoided at places.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Of all the vegetational types of the world, tropical rain-forests constitute an important heritage for posterity and have both academic and applicational values (Gomez-Pompa *et al.*, 1972; Raven, 1981). Apart from the facts that there are still a considerable proportion of biota which are yet to be identified and catalogued from the humid tropics, and that we know so little about the ecosystem function of tropical rain-forests, the rich germ-plasm reserve which they harbour could form the basis for future development of food plants, of both conventional and non-conventional kinds. The need is accentuated increasingly by the rapid growth of human population particularly in the tropics (Raven, 1976).

The forests of the humid tropics are very fragile because of a combination of high rainfall, extremely leached and nutrient deficient soil and the long time span involved in the development of a dense virgin forest. Infact, the living biomass is the chief storage compartment for the mineral nutrients, rather than the soil. In contrast to this, in a more stable forest ecosystem type, the soil acts as an more important storage compartment for the mineral elements so that even if the forest is clear-cut over large areas, regeneration is quick with the elements stored in the living biomass, after clear-cutting the nutrient would soon be flushed out of the ecosystem due to high rainfall and rapid decomposition of the dead litter. Therefore, the relationship of man with the humid tropics environment could be fragile indeed, if the perturbations are of a larger magnitude and of frequent occurrence.

CONVERSION OF RAIN-FOREST

A detailed study concludes that the rate of conversion of rain-forest biome varies considerably depending upon the region (Myers, 1980). Many of the available reports on conversion of rain-forests suffer from lack of documentary evidence and for many countries not dependable statistics are available on the magnitude of the problem. This is true for Indian sub-continent too. Much of the low land forests of Australia, Philippines, Malayasia, Indonesia, Bangladesh, India, Sri Lanka, Thailand and West Africa would disappear by 1990. According to National Remote Sensing data (1983), the north-east region had 1, 04, 449 km^2 of closed forest in 1980-82 representing 40.94% of the total geographical area.

Timber extraction

Rain-forests are increasingly exploited for wood for timber and pulping. A little more than one-tenth of the world consumption of wood in these two forms comes from the rain-forest (Myers, 1980). The import of hardwood by developed countries during the last three decades has gone up from 4.2 to 53.3 million

m^3 and this is expected to almost double by the turn of the centry.

With rapid depletion of hardwood from the Western Ghats in India, a large proportion of the timber and plywood needs of the country is now being met from the rain-forests of the north-east. Indiscriminate clear-felling of forests of the mature phase has caused much damage in the past.

Fire wood extraction

For over a third of the world's population located in the developing countries, firewood which is a scarce commodity is a major problem of daily life. According to Eckholm (1975), no less than one and a half billion people in developing countries derive atleast 90 per cent of their energy needs from wood and charcoal; another 1 billion depend upon this for atleast 50% of their energy needs. In the rain-forest regions of the world, the rural population dependent upon fire wood as the energy source is estimated at about 1 billion. If the annual average individual consumption is 500 kg, the total consumption would be over 500 billion kg of firewood per year. This however, does not take into account the export to urban areas for charcoal production which is very common in many of the countries including India.

In north-east India, much of the fire wood consumed comes from secondary forests which are formed as a result of either large-scale timber extraction (Ramakrishnan, 1985a) or as a consequence of slash and burn agriculture. Only a small fraction comes from primary forests.

The rural tribal population of the north-east, as elsewhere, are chiefly dependent upon firewood for cooking (Mishra and Ramakrishnan, 1982a) through other items such as rice husk may also be used. In a Khasi village at Setthliew in north-east India, 20 members in the village annually import 3060 kg of firewood (52455 MJ of energy) from outside the village boundary. This accounts for about 58% of the total consumption. Thus with all round desertification in the vicinity of the village, more than 50% of this commodity comes from outside the village boundary often from a distance of more than 10-15 km.

Forest farming

One of the important economic activities of the tribal man, which has kept him so close to nature is the age old practice of slash and burn agriculture. This agriculture is one of the oldest of all agricultural systems and is still a source of sustenance for about 250 million people thinly scattered over 300 million ha of forested land of the tropics (Goodland, 1980). This land use is to be found in Latin America, the Carribean Islands, Africa and Asia. The total area under slash and burn agriculture and the rate at which conversion of rain-forests are occurring for this activity are difficult to evaluate on the basis of existing information. In the mid 1970s a total of atleast 140 million farmers occupied about 2 million km^2 of the rain-forest biome. They cleared atleast 1,00000 km^2 of forest each year (Myers, 1980). A major loss is from south-east Asia (Chandrasekharan, 1978; FAO, 1978) with not less than 85,000 km^2 each year. However, such reports do not explicitly classify the actual area under cropping in a given year and the different levels of degradation.

In India slash and burn agriculture (locally called as jhum) is practised chiefly by tribal communities located in the north-eastern region and in central India. Elsewhere in the country its extent is small, such as in isolated pockets in Orissa, Andhra Pradesh, Madhya Pradesh, Western-Ghat region, etc. The area affected by jhum has been estimated to be between 8 to 10 million hectares. The area under jhum in the north-east, based on 1974 census data is about 2.7×10^6 ha.

With about 140 million forest farmers in the humid tropics and with an average of seven members per family, there would be 20 million families. If each family cleared an additional hectare of land, the total area cleared would be 2,00000 km^2 each year (Myers, 1980). Half of the cleared area is assumed to be primary forest representing about 1% of the total. If this is projected to the north-eastern India, with 547×10^3 families involved at present and with an expected 766×10^3

families by the turn of the century (North-Eastern Council, 1982), the additional forests cleared would be about 5470 km^2, half of which could be primary forest. Encrochment by non-tribals into forest areas for purposes of slash and burn agriculture is a serious problem in some parts (Ramakrishnan, 1984).

SLASH AND BURN AGRICULTURAL SYSTEM

Africa is the largest among the three continental region of slash and burn agriculture in the tropics with greatest diversity in the practice and has received some attention (Nye and Greenland, 1960). This system of agriculture has been discussed against a wider back ground of conservation and development of natural resources of Africa by several workers (Harrory, 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 forest before plantation of a mixture of crops (Tothhill, 1948; Waidock et al., 1951; Tondeur, 1956). Among the study of slash and burn agriculture illustrating the varied responses of different tribes to different soil and vegetational differences in the African continent, the work of Schlippe (1956) on the Zande tribe in the border of the Sudan and Congo, 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 the northern Rhodesia are the most important. Allan (1965) has presented an excellent study of some African forms of slash and burn agriculture.

Cook (1921) is probably the first to describe ''Milpa'' system of agriculture in the humid forests of Latin America. Watters (1971) has written the best general account of slash and burn agriculture in Latin America with special reference to the cultivation practice in Venezuela, Mexico and Peru.

Pelzer (1948) has given an account of slash and burn agriculture in South-East Asia, and Gourou (1940) has described the practice in Indo-China. Freeman (1955) and Conklin (1957) have also considered this system in the Iban in Sarawak and Hanunoo in the Philippines respectively.

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 varied origin and culture that it shows great variation in crop combination, methods of cultivation and productivity. However, all these variant forms show a great similarity in their general characteristics and confirm 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 abondoning of the field for natural regeneration of vegetation.

The native subsistence agriculture practised by the Hanunoo in Philippines (Conklin, 1957) and the Garos at lower elevations of Meghalaya in the north-east India (Toky and Ramakrishnan, 1981a) are the best examples of slash and burn agriculture in humid tropical forests. In these areas, the entire vegetation, including large and small trees, are felled 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 winter months 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 shower in April-May, weeding is done followed by the sowing of a mixture of crops. While 8-13 crop species are grown together on a field by Garos, an extreme case of mixed cropping including 40-50 different crop species has been reported by Conklin (1957). In Arunachal Pradesh in north-east India a crop mixture of 15-33 species have been noted (Maikhuri, 1987). Crops are harvested successfully as the season progresses. After cropping for a year or two the land is left fallow.

The pattern of slash and burn agriculture at higher elevation of Meghalaya in north-east India is a modified version of its typical type in that 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 placed in parallel rows running along the slope covered by a thin layer of soil forming the elevated seed beds (ridges) alternate with narrow gaps (furrows) and are subjected to a slow burn. Planting of crops is confined only to the ridges (Mishra and Ramakrishnan, 1981).

Economic yield

The immediate cause of rotation of the fields under slash and burn agriculture is declining yields during successive years of cultivation. In the British Honduras, Charter (1941) found the yields of maize of peasant milpas was about 1000-800, 800-600, 600-400 kg ha^{-1} during successive years. Steggarda (1941) estimated that the yield in the second year, in the Yucatán Peninsula (Mexico) to be only about 80% as high as the first year. Tondeur (1956) reports that in Belgian Congo, the yields in the second year of cultivation was reduced sharply and this reduction was to the extent of 76 %, 86% and 33% for paddy, ground nuts 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). In the central Petén, Cowgill (1961) found second year Milpa yields to be only 71% as high as compared to the first year yield.

The Agro-Economic Research Centre, Jorhat conducted survey on jhum and concluded that the average rice yield was 800-900 kg ha^{-1} in the Garo hills, Mizoram and Arunachal Pradesh which compared favourably with the average rice yield of 1145 kg ha^{-1} for the country as a whole for the year 1971-72. On the other hand rice yield under jhum in Tripura was reported to be around 1200 kg ha^{-1} (Misra, 1976). At Burnihat in Meghalaya, the jhum rice yield was 853 kg ha^{-1} as compared to 3428 kg ha^{-1} under terracing. A more recent report of the Indian Council of Agricultural Research (Borthakur et al., 1978) suggested an amazingly low yield of 190 kg ha^{-1} of rice under jhum compared to 1860 kg ha^{-1} under terrace. None of these studies talk about the conversion factors used for the mixed cropping done under jhum, to express the yield in terms of rice. Our studies (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981) on comparative yield under jhum was significant. A 5-yr cycle (common at present) was compared with longer cycles of 10 and 30 years (more prevalent in the past) and showed that (i) a longer cycle gives better yield than short cycle (ii) 10-yr cycle is economically viable (iii) labour is the chief input into slash and burn agriculture.

Weed potential

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^{-1} when weeded four weeks after germination, but attained only 3217 kg ha^{-1} 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 yielded less than the first, probably because it was more weedy and therefore, the farmer likes to clear a fresh land than to continue cropping in the old plot. Toky and Ramakrishnan (1981a) and Mishra and Ramakrishnan (1981) reported that under shorter jhum cycles the weed problem get severe due to arrested succession by exotic weeds in north-east India.

Conklin (1957) estimated that a Hanunoo farmer in the Philippines spends about 300 man-hr per hectare in weeding on the first year land cleared from primary forest and about 600 man-hr on land cleared from secondary forest about 20 yrs old. Mishra and Ramakrishnan (1981) reported that weeding is one of the energy consuming tasks performed by women folk. They further indicated that the task is more energy consuming under shorter cycles under slash and burn agriculture in north-east India, an observation also confirmed by Toky and Ramakrishnan (1981a). Mishra and Ramakrishnan (1981) reported that the weed potential under terrace cultivation gets intensified when compared to a 10-yr jhum cycle in the same area, adversely affecting crop returns.

Non weed concept

Recently weeds have been viewed as an useful component in agro ecosystem and may play an important role in agricultural management of the future. Studies of Chacon and Gleissman (1982), Saxena and Ramakrishnan (1984a), Mishra and Ramakrishnan (1984) suggested that the non-weed concept, where weeds have a useful role to play, is an essential ingredient of traditional agro-ecosystems in different parts of the world and in the north-east India. Tripathi (1977) analysed the possible consequences of a complete eradication of the weed flora from agroecosystem. Altieri (1983) on the basis of a detailed review emphasised upon weed management as opposed to weed control.

Obviously, one of the important roles of the weeds in the crop lands is related to reduction in soil erosion, protection of the soil surface from solar radiation and improved soil micro-climate (Moody, 1975; Tripathi, 1977; Chacon and Gleissman, 1982). Ramakrishnan and his co-workers (Toky and Ramakrishaan, 1981a; Mishra and Ramakrishnan, 1983a) studied the reduction of soil erosion by weeds in jhum lands and observed considerable loss of nutrients before the plant cover (which includes weed population) is established.

Another important role of the weed lies in the recycling of nutrients through organic manure. Mishra and Ramakrishnan (1984) studied nitrogen budget of three jhum cycles under 15, 10 and 5-yrs at higher elevation of Meghalaya. Here, the nitrogen is recycled through weeds was estimated to range from 4.8 to 20.8 kg ha^{-1} of which about $^{1}/_{6}$th is ploughed back into the soil and the rest is eventually recycled via the manure pit of the village ecosystem (Mishra and Ramakrishnan, 1982).

Crop residues and weeded out biomass is used as a mulch by the farmers in Tanzania (Acland, 1971). Stigter argued that mulch used as shade by the traditional farmer of Tanzania is for the management of micro-climate in order to increase land productivity and yield capacity. De Schlippe (1956) indicated that weeds are useful elements in maintaining soil fertility in the agroecosystem.Swamy and Ramakrishnan (1986) from north-east India have reported that traditional weeding (involves retention of a certain proportion of the weed biomass *in situ*) has little effect on the economic yield potential of the mixture. On the other hand, it could contribute to conservation of soil resources upto about 20% as compared to a total weeding regime. Indeed, harvested weed biomass put back into the system is an efficient way of recycling of resources under stress.

Energetics

Energetics is an approach to examining the role of energy in a system. The application of this approach for an improved understanding of agricultural systems is a rather recent and well known perspective.

The usefulness of energetic analysis is questioned by many researchers. Some writers have characterized energetic analysis as inflexible in its view and not broad enough to be treated as a serious method of study. For instance, the policy recommendations of an energy analyst will often conflict with those of an economist. This has led to a long standing disagreement between the economist and the energy analyst as to the validity of each others approach (Georgescu-Roegen, 1979). Others, more favourably disposed consider the energetic view as compatible with a ''system'' approach and therefore a source of promise for a better understanding of rural development problems (Morse, 1982).

The increasing agricultural yields of the last few decades were possible through industrialization of agriculture involving large fossil energy subsidies, heavy fertilizer application to the soil and sophisticated chemical control measures to reduce pest and disease infestation and above all high yielding crop varieties. Such agricultural systems are efficient interms of human time and labour inputs but are highly inefficient from overall energy point of view as 5 to 50 units of fuel energy are required to produce 1 unit of food energy (Steinhart and Steinhart, 1974). Slash and burn agriculture has been held up as a model of productive efficiency where 5-50 units of food energy are harvested for each unit of energy input into the system (Rappaport, 1971; Steinhart and Steinhart, 1974; Mishra and Ramakrishnan, 1981; Toky and Ramakrishnan, 1982). Rappaport, (1971) provides relatively complete information in the energy expenditure of the Tsembaga people of New Guinea highlands. According to him, the farmers obtain an average of 16 food calories for each calorie human energy expenditure during farming which may go upto 20 under more favourable conditions. It has been suggested that it is possible to have increased crop production without departing too much from this traditional systems (Greenland, 1975; Revelle, 1976; Mutsaers et al., 1981; Ramakrishnan, 1985b) which has been considered as the most evolved system for the forested areas of the humid tropics (Conklin, 1957; Carneiro, 1960; Nye and Greenland, 1960; Watters, 1971; Ramakrishnan, 1984).

Soil fertility and nutrient budget

Ecosystem 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 (Liken et al., 1977) in which longer proportion of the nutrients is in the soil in exchangeable form would loose a relatively larger quantity of it than tropical rainforests as in these forests most of the nutrients are tied up in the biomass (Odum, 1971; Jordan et al., 1972) and mineral soils has very low nutrient content (Went and Stark, 1968). The long term success of slash and burn agriculture depends upon the recovery and maintenance of soil fertility. In hot, humid and high rainfall areas it is a serious problem and is more severe in situations where 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 and Greenland, 1960; Watters, 1971). A good deal of evidence suggests that a significant change in physio-chemical characteristics of the soil under slash and burn agriculture results in low yield per unit area which compel the farmers to abandon the land for fallow development (Popenoe, 1957; Nye and Greenland, 1960; Cowgill, 1961; Watters, 1971; Watters and Bascones, 1971).

When the forests are cleared and debris is burnt, all the cations are released on the surface of the soil as ash. Heavy losses of carbon, nitrogen and sulphur occur due to volatalization during burn (Nye and Greenland, 1960; De las Sales and Folster, 1976; Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983a; 1984). For phosphorus, though there are no obvious mechanism of volatalization, losses are reported through convection via particulates to the atmosphere

(Freedman, 1981). There are conflicting reports on addition ⌐ phosphorus through fire (Nye and Greenland, 1960; Stark, 1971; Stromgaard, 1984) and others suggesting some losses from the system (Harword and Jackson, 1975; Ashton, 1976; Mishra and Ramakrishnan, 1983a). Lloyd (1971) reported massive losses for phosphorus through fire.

After the burn and during cropping period loss of organic matter occur from the soil due to higher insulation and also due to rapid surface run-off. Joachim and Kandiah (1948), Nye and Greenland (1960), Zinke et al. (1978) and Jha et al. (1979) reported a net loss of carbon after a year of cropping. Juo and Lal (1977) estimated a requirement of 16 tonnes/ha/yr of dry plant materials to be added to the soil under slash and burn agriculture in order to maintain soil organic matter in surface soil at a level comparable to soil under secondary forest, as the rate of decomposition is faster under continuous cropping compared to that before burn. Nitrification after burn is shown to be accelerated due to high microbial activity. At the end of cropping period during slash and burn agriculture at higher elevation of Meghalaya, Mishra and Ramakrishnan (1984) estimated nitrogen losses from the agroecosystem to be about 640 kg ha^{-1}. Agroecosystems are open systems in which biogeochemical functions consists of inputs from various sources, outputs of various sinks and variable degree of internal cycling.

Hydrology

Toky and Ramakrishnan (1981b) reported that the shortening of the jhum cycle to 4-5 years in north-east India does not permit the recovery of soil fertility and has adversely affected the vegetation cover, biogeochemical and hydrological cycles. The loss of water through run-off and percolation and a consequent loss of sediment increases with the shortening of the jhum cycle. This may partly be due to poor physical characteristics of the soil and also particularly due to poor crop cover (Toky and Ramakrishnan, 1981b).

As a result of increased human population and reduced acrage, the jhum cycle (the fallow period between two successive croppings on the same site) has shortened drastically. Even a 5-yr jhum cycle is rare in the region. This has damaged the forests and the entire west Khasi hills district of Meghalaya is extremely desertified, of which Cherrapunji is an extreme case (Khiewtam, 1986; Ram, 1986). The only older forests left in this district are ''Sacred groves'' which are protected by the local tribes for their religious belief (Boojh and Ramakrishnan, 1983). Elsewhere, secondary succession is arrested at the level of weedy colonizers (Mishra and Ramakrishnan, 1983b; Toky and Ramakrishnan, 1983; Saxena and Ramakrishnan, 1984a; Swamy, 1986).

The fallow length is often reduced to 1 to 3 years, which permits only development of herbaceous vegetation. Sometimes the slash is brought from outside the field. Around city centres due to high population densities, cultivation is more intense and land is less amenable for fallowing. As a result of shortened fallow period there has been a drastic reduction in crop mixture too. The crop mixture varies from 2-6; where it used to be 20-30 sps; In extreme cases mono-cropping is practised with heavy subsidy of inorganic/organic fertilizers.

DEVELOPMENTAL STRATEGY

Terrace cultivation

With a view to arresting and reclaiming the degraded forest areas the Governmental agencies in north-east India have introduced and encouraged terrace cultivations from time to time.

Terraces are one of the oldest and most common type of soil conservation practices used for erosion control. The main purpose of the terrace is to shorten the slope length and to remove water velocity that cause erosion. There are several different kinds of terraces, and each designed to fit certain set of conditions.

To conserve and convey water for dry areas irrigation facilities are often provided. The gentle slopes of inland valleys are made into broad terraces and in places where the population reached a high density, such as parts of Ceylon, Java and Philippines terraced irrigable rice fields were labouriously constructed even on steep hill sides.

Although these systems are so far almost entirely confined to Asia, relatively large areas that are (or could be rendered) suitable for wet rice growing exist in other parts of the tropics, and in such places there are possibilities of replacing the predominant shifting cultivation with more permanent systems based on rice (Webster and Wilson, 1980).

Indigenous uplanders have employed terracing as an erosion control technique. The Bontocs of the northern Philippines have terraced their land for hundreds of years in order to use mountain slopes for paddy rice and vegetable production (Omengan and Sajise, 1981). The gen-gen of the Ikalahan is a variant of the bench terrace. Crop waste is piled on contour strips within cropping area and after several cropping, mounds of crop waste accumulate and serve to trap soil and water (Barker, 1984).

Adoption of terracing has been problematic. Land tenure uncertainity hindered the adoption of terracing as an agro-forestry project in Buhi, Camarines Sur, (UHP, 1979). Terracing was undertaken using funds provided by both the project and owners of titled upland areas. Tenant farmers on titled lands were hesitant to plant permanent crops on terraces because of the uncertainity of sharing the benefits. Land owners refused to grant permits for terracing, out of fear that the tenants would claim the land they terraced.

Bernales and de la Vega (1982) reported that the antique upland development project and the farmer occupancy programme in Do ña Remedios, Bulcan, encountered problems in convincing farmers to adopt bench terracing. Antique farmers considered the construction of bench terraces as a back-breaking activity, requiring collective effort of 5-10 farmers to terrace a hectare plot. The Bulcan farmers, on the other hand, content that they can not bench terrace because construction requires a carabao which most do not have. The objections in Buhi revolved around equity and distribution of benefits of soil conservation implements, while the Antique and Bulcan cases had more to do with labour requirements.

In order to discourage farmers from slash and burn agriculture, bench terrace was introduced into north-eastern region of India by Soil conservation department, giving subsidies. In the north-eastern region of India, replacement of slash and burn agriculture by intensive agricultural practice is probably not a realistic solution to the problem. As a solution to the problem, the Indian Council of Agricultural Research Station at Shillong has suggested partial terracing with horticultural and forestry development on upper two thirds of the slopes (Borthakur *et al.*, 1978). They claimed that run-off would be reduced from 144 mm to 8.1 mm and sediment loss reduced from 40.9 t ha^{-1} to 5.8 t ha^{-1} through terracing. Though run-off losses of soil nutrients are reduced by terracing, as the soil is loose and porous the leaching of nutrients through percolation is high (Mishra and Ramakrishnan, 1983c). Infact the reduced crop yield, physical chemical qualities of the soil gets so much adversely affected that the farmer very often has to leave the terrace plots after 6-8 years of continuous cropping, as land tends to become totally desertified (Ramakrishnan, 1984). In other words, this system demands heavy input of fertilizers for long term maintenance . Even the fertilizer put in is often un-utilized by the crops as it is lost through water (Ramakrishnan, 1984). Coincidental with this particular trend in scientific thinking, significant changes in agricultural policy in the humid tropics are now taking place on a local scale. Spurred by social pressure by endangered population increase on one hand, and by the adverse consequences of large scale deforestation on the other. Politicians and developmental agencies are becoming more concerned with the need for rational land utilization (Donaldson, 1978; Davison, 1982). The most encouraging aspect of this development is a growing appreciation of perennial tree crops as a major and profitable component in any cropping system, and of the need to involve local communities in development planning (Sanger, 1977; Adeyojur, 1980; Doyen, 1980; Wiersum, 1980).

Plantation

Plantation crops have been widely suggested as an alternative to slash and burn agriculture (Ruthenberg, 1971;, Andreae, 1980; Akachuku, 1985; Ramakrishnan, 1985a). Perennial crops are often profitable (Sanger, 1977; Adeyoju, 1980; Wiersum, 1980; Watson, 1983) only if based upon traditional systems (Schahezenski, 1984; Ramakrishnan, 1985a) and with involvement of the local communities.

Agro-forestry

If slash and burn agriculture is to be replaced by a life-style based on agroforestry, there are many traditional multicropping systems, involving tree crops, that can serve as models (Watson, 1983). They are typified by the kandy Gardens of Sri Lanka (Mc Connell and Dharmapala, 1978), the Indonesian homesteads (Harwood and Price, 1976), the Nigerian compound farms (Okigobo and Greenland, 1976) the South Indian home gardens (Sunderraj and Mitchell, 1987) and many others (Rea'tegui, 1979; Eden, 1980). Each of these systems is based on multistorey tree canopy that may produce timber, fruits and food crops.

VILLAGE ECOSYSTEM

Analysing the flow of energy through an ecosystem or society is useful in describing how the system functions (Loucks and D'Alessio, 1975). Ecosystem analysis uses measure for the efficiencies of energy exchange and the transformations of materials to describe the biological relations of a community of organism and the limits to productivity imposed by physiological constraints. Economic analysis uses measures of values to describe how individuals and communities are linked together. These two kinds of analysis can be independent. That is, a village ecosystem can be described without reference to its economy, and its economy can be defined without reference to the ecosystem. Ecosystem analysis and economics are complementary view points that can be used together in a way that will clarify the history of human communities and help to understand the goals of farmers in developing countries.

Agroecosystem

Agroecosystem occupy habitats created by humans who also determine which species will be allowed to survive in the area. With continuous habitat modification the cultivars and domesticated animals evolve genetic adaptations to the habitats created by humans and can not survive elsewhere. The result is an evolved symbiosis between human, and few species of plants and animals. The adaptations of cultivars include increase in harvestable food. Human populations of increasing density depend on the coevolved yields of cultivars and genetic changes in the behaviour of animals (Price, 1984).

Through trial and error, humans have become ecosystem engineers, allocating effort and crops so as to produce a reliable and sustainable supply of biomass for food, fuel, fibre and shelter. Until a few score years ago, the indigenous agricultural villages of Asia, Africa, and South America functioned as nearly independent agroecosystems. Sustainable self sufficiency was the first goal in the early evolution of agroecosystems and still has priority, even after complex economic relations develop. Villagers may cling to the tradition of meeting their demands from local biomass long after there are ways to meet these needs that economists see as more cost-effective alternatives.

Human energy is directed towards controlling plants in order to produce crops supplying food, fuel and fodder needed in a village. Villagers often come close to maintaining a self-sustained cycle of nutrients that is controlled by humans who use the solar energy stored in previous crops. Perhaps the interest in the management of village ecosystems developed in responses to two concerns. First, the rejection of the outside advice was perceived as a central problem in developing countries. Second, the operation of a solar-powered human ecosystem is intrinsically interesting. It is now believed that if outside advice is based on an understanding of how the village ecosystem works, it will usually be accepted, while suggestions that disrupt the pattern of labour demand, fuel supply or fodder will be rejected.

Acceptance and rejection now seem to be rational, intelligent decisions based on villagers insights or traditions and the decision generally embodies an intuitive understanding of how their ecosystem functions. Traditions are a guide for evaluating probabilities, such as the association of future weather with present conditions, which is often the basis for deciding upon a mix of crops that is most likely to meet the needs of food, fuel and fodder. Some combination of traditions and insights is also a guide, that villagers use in deciding how a new crop or process may affect the village ecosystem (Mitchell, 1983).

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) is worth mentioning here. In Lee's study, the input-output approach to subsistence has shown that Kung Bushmen of 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 105 k.cal to the energy requirement per person per day.

The energy input and yield of the Nunoa energy flow system, was analysed by Thomas (1970, 74). This system is based on productive unit, namely nuclear family which consists of an adult pair with four children. The vast majority of human energy expended in the productive process went into animal production, rather than agriculture. Agriculture inputs were, infact, only about $^{1}/_{7}$ as greater as those in herding. The energy input for agriculture was expended for various activities such as planting and harvesting. The activity yielded, at the end of the cycle, a total of 595,000 calories compared to an input of only 51,800 calories. The output/input ratio for this sub-system worked out to be 11.5.

Briscoe (1979) considered energetic analysis as a tool to view the social structure of a Bangladesh village. The system boundary is placed around the entire village and three (crop, domestic and fishing) sub-systems were analysed. Briscoe concluded that the issue of distribution is crucially related to control of available resources and the structure of social organization that governs the distribution of these resources from owners to users. Briscoe did not indicate specific energy ratios as he placed emphasis on who controls what share of the energy resources rather than on specific energetics of the sub-systems.

Village ecosystem study of Reddy (1981) in a south-Indian village at Ungra reported that this village is an open, dependent, land-humans-livestock ecosystem. He concluded that an understanding of the logic of village agricultural systems should be the basis for rural development.

From north-eastern India available studies on village ecosystem are of Mishra and Ramakrishnan (1982) for the Khasis at higher elevation of Meghalaya. A Khasi village ecosystem had an overall energy efficiency of 1.57. Animal husbandry formed an important link in the detritus food chain by utilizing vegetable waste of agricultural system. The forests, apart from providing the basis for agriculture, also met part of the fuelwood requirements of the village. The high efficiency of this village ecosystem was related to : (i) high labour input (ii) cultivating land under a sufficiently longer 10-yr jhum cycle, which permits sufficient recovery of nutrients (iii) rice cultivation on valley lands which gives sustained yield due to enrichment of nutrients from adjoining hill slopes, (iv) efficient recycling of food wastes and crop residues in manure pits and (v) swine husbandry, which is detritus based, where input is very minimal.

A detailed study on three villages in Kumaon hills of India was conducted by Pandey and Singh (1984) with a view to to investigate : (i) the energy efficiency of agriculture, (ii) the viability of these agroecosystems and (iii) the viability of forest ecosystems at the current level of agricultural activity. For each unit of energy employed in agronomic and animal husbandry production, 7 units of energy were expended from the forest ecosystem in the form of fodder and fuelwood. The ratio of energy expended as human labour for direct agro-activity, to that expended for fodder and fuel collection was 1:2.5.

In a study on village ecosystem at Panyakurichi, Sunderraj and Mitchell (1987) reported that if the external subsidy of fertilizer was removed, the village would lose its surplus in rice, but could meet all the other needs. If the water subsidy were lost, the villagers would have to return to dry-land farming and would be unlikely to meet their needs. Ths subsidies have allowed this village to function like the agroecosystem with a natural water supply, but they have not resulted in the villagers diverting all their efforts into specialized cash crops. The agroecosystem continues to be managed in a way that satisfies the needs for fuel and fodder from local biomass.

Animal husbandry system

In a world already suffering from wide spread malnutrition and indeed facing large scale starvation in the years to come, crucial decisions regarding the orientation of protein production must now be taken by developmental planners. Population growth rates indicate that by year 2000, 60% more food will be required to meet the requirement of the world population (FAO, 1977). Since food products of animal origin are richer in high quality proteins, animals have an important and well defined role to play in a rational and balanced food production system (Vandemaele, 1977). At present, animal production accounts for 25% of world protein needs (Pimentel et al., 1975).

In the traditional societies, with slash and burn agriculture as the major land use, animal husbandry particularly swine husbandry, is closely linked with the agricultural system all over the world (Rappaport, 1971; Mishra and Ramakrishnan, 1982; Ramakrishnan, 1984). The energy efficiency of cattle (for meat) was found to be very low (less than one) (Leach, 1976). This is because animals need more food energy input. Since ruminants are able to graze in remote areas unsuitable for crop production due to topography, climate etc., extensive ranching systems consume very little support energy and may therefore be considered energetically efficient (Wilson and Brig Stocke, 1980). Several scientists have adopted a positive approach to evaluating ruminants as producers of human food (Blaxter, 1975; Pimentel et al., 1975; Wedin et al., 1975). Rappaport (1971) has discussed the importance of Tsembaga swine husbandry as a practical way to store excess of food energy harvested during some of the productive years. With an energy expenditure of

18.8×10^2 MJ over a 10-yr period raising a single pig under Tsembaga system and with only 1.5% of return on food energy feed to pig meat energy, according to the calculations of Pimentel and Pimentel (1979), this system is not very efficient. Mc Arthur (1974), a leading Australian Nutritional Anthropologist, suggested that killing of swine in smaller numbers at more frequent intervals would be more efficient from nutritional and ecological points of view.

Swine husbandry is an integral part of shifting agriculture in north-eastern region of India (Mishra and Ramakrishnan, 1982). Pork is the chief source of animal protein for the Khasis of Meghalaya. Sizeable portion of the total protein consumed and much of the energy out of this is exported outside the village boundry . About $^1/_4$th of the total annual income generated within a tribal village comes from the animal husbandry unit. Tribal farmers of this region consume pigs not only as part of his normal diet but makes a feast of it during celebrations related to slash and burn agricultural procedures (Ramakrishnan, 1985).

In the world in which the total population is increasing and the area of land available for agriculture is finite, Payne (1985) has suggested integration of animal husbandry and crop production systems in the tropics to increase productivity per unit area of land.

The present study

Slash and burn agriculture, localley called as jhum is the predominant form of agriculture in north-east 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 on the same site is called as slash and burn agricultural cycle or jhum cycle.

Formerly the jhum cycle used to be 20-30 years, which ensured soil fertility and forest recovery so that the system was self-sustaining and in harmony with nature. However, under present day conditions of increased population pressure and reduced acrage, the jhum cycle has been reduced to 4-5 years. This, in turn, has adversely affected the quality of the environment both in terms of soil fertility and forest cover (Ramakrishnan, *et al.*, 1981; Ramakrishnan, 1985a). With a view to arresting and reclaiming the degraded forest areas the Governmental agencies have suggested various alternatives, such as terrace cultivation. But it has been generally seen that farmers in the north-eastern region often abandon the land after 6-8 years of continuous terrace cropping, as the land tends to become totally desertified (Ramakrishnan, 1984).

However, at Nayabunglow terrace cultivation is largely done by the immigrant Nepalis where as the tribal Khasi does slash and burn agriculture under a reduced cycle length of about 5 years. Some valley cultivation is also done. Continuous cropping on terraces upto about 12 to 15 years is frequently done by the Nepalis. The present study therefore, looks at the implications of terrace cultivation over such a long time period at Nayabunglow, 30 km north of Shillong in north-east India in terms of cropping pattern yield potential of the site making comparisons with jhum system and valley cultivation of rice wherever possible.

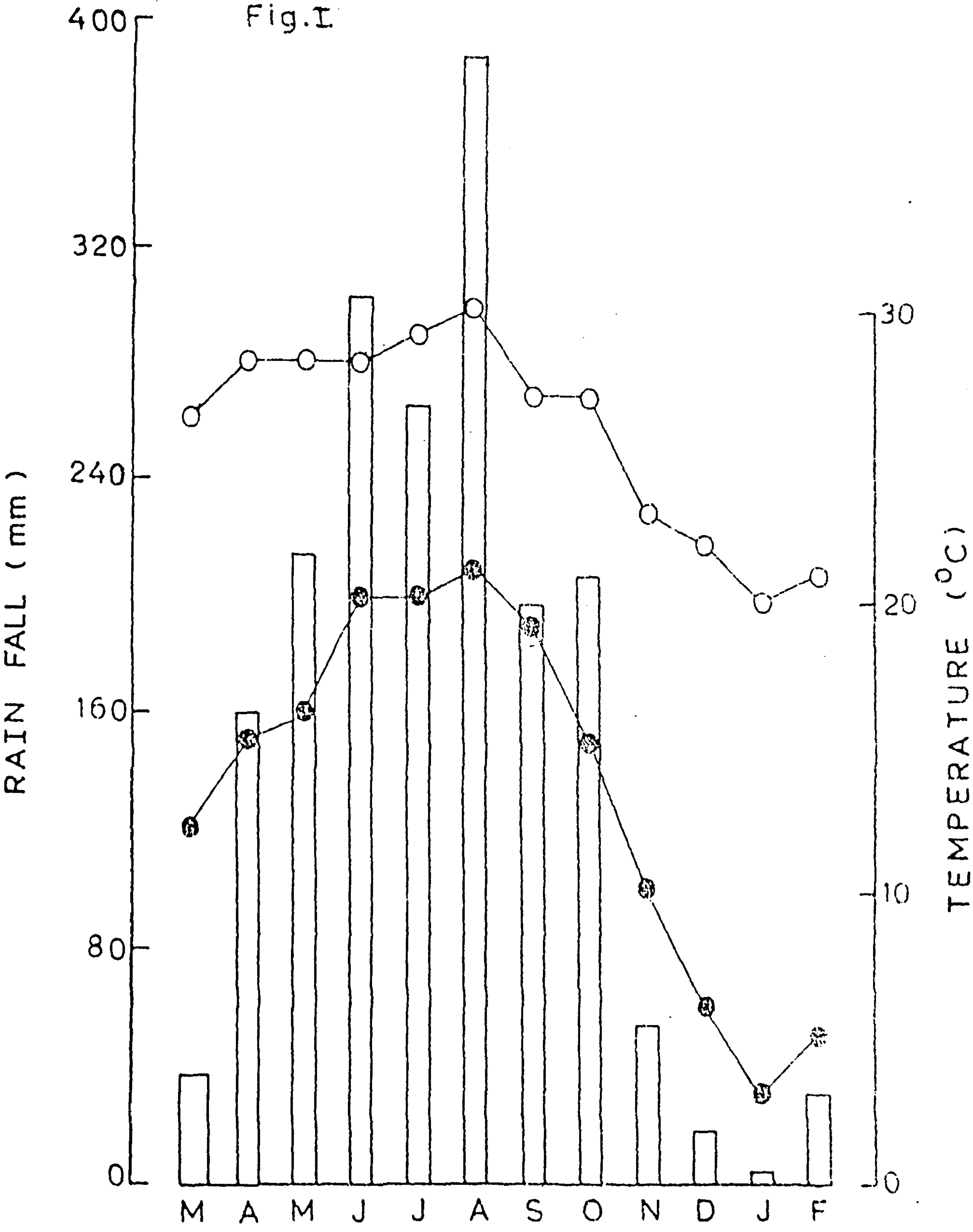
At Nayabunglow immigrant Nepalis co-exist with local Khasi tribe. A comparative study of the two communities were also undertaken with a view to evaluate the village ecosystem functions considering agriculture, animal husbandry and domestic as sub-system of the village. The inter linkages between the sub-systems have also been considered using money and energy as currencies for evaluation.

STUDY AREA AND CLIMATE

The present study area at Nayabunglow located about 30 km north of Shillong ($25^{o}45''$N $91^{o}54''$E) at an altitude of about 960 m in the Khasi hills of Meghalaya. The studies on land use systems (part I) was done on plots located around Nayabunglow. For the village ecosystem studies (part II), two of the villages in this area namely, Umtrou (Khasis) and Guntei (Nepalis) were selected.

Fig. I. Ombrothermic diagram for the study area ○ , mean maximum temperature; ◐ , mean minimum temperature; vertical bars, rainfall.

Fig.I



400
320
240
160
80
0
RAIN FALL (mm)
30
20
10
0
TEMPERATURE (^{o}C)
M
A
M
J
J
A
S
O
N
D
J
F

The climate of the area can be divided into four more or less marked seasons (i) the monsoon season of heavy rainfall during May-September (ii) a transitional period of low rainfall during October-November and (iii) a winter season during December-February and a windy dry summer during March-April. The average rainfall during the study period was 1800 mm. (Fig. I). The average maximum and minimum temperatures during the monsoon season were 28.6°C and 17.1°C, respectively, while during the winter periods these were 21.3°C and 3.95°C, respectively.

PART I

CHAPTER 1

ECONOMIC YIELD AND ENERGY EFFICIENCY OF SOME AGROECOSYSTEM TYPES OF MEGHALAYA IN NORTH-EAST INDIA

INTRODUCTION

Slash and burn agriculture (jhum) and valley land agriculture are two important traditional land uses of the tribals of north-east India (Ramakrishnan, 1984). During the last few decades the Governmental agencies have tried to replace jhum with terrace cultivation. Because of the cost involved in terracing and due to gradual degeneration of the soil properties on the terraces and take-over by weeds over a period of time, this land use system could be sustained as long as subsidies were given to the farmers (Ramakrishnan, 1984). However, in some locations, such as at Nayabunglow, terrace cultivation is being done by the immigrant Nepalis only, sometimes for a period ranging upto 30 years. It is not uncommon in the area to find abandoned terraces. The object of the present study is therefore, to look at the cropping and yield patterns on these terraces of different ages and compare it with traditional agroecosystems such as jhum and valley cultivation. Such a comparison is necessary to evaluate the ecological and economic reasons for terrace systems being an unpopular practice with the tribals in the area. In the larger context of maintaining soil fertility in agroecosystems of the humid tropics, the study aims at an evaluation of settled farming as a replacement to slash and burn agriculture.

DESCRIPTION OF AGRO ECOSYSTEM

Slash and burn agro ecosystem

The tribals of north-eastern hill region practice slash and burn agriculture locally called jhum. The practice consists of clear-cutting the forest at various stages of succession followed by drying the slash for a few months during December-April. They are kept in parallel rows running down the slopes and topped over with a thin soil cover so that these form ridges alternating with compacted furrows. Consequently, the burn of the slash is controlled. The slashing is total here, where as it is only partial involving only the lower branches of sparsely distributed pine trees along with ground vegetation at Shillong where a similar version is available (Mishra and Ramakrishnan, 1981). After burning and before the onset of monsoon in May, rhizomes of *Zingiber officinalis*, *Colocasia antiquorum*, *Curcuma domestica* and seeds of *Capsicum frutesence* and *Cucurbita maxima* are planted on the ridges. First harvest of ginger is done in August along with *Cucurbita maxima* and *Capsicum frutesence*. The harvest of ginger is only partial without disturbing the shoot and the attached rhizome. With the second harvest of ginger, Colocasia and turmeric are also taken out. Fertilizers are not used. The land is then abandoned for fallow regrowth through natural vegetational succession.

Terrace agro ecosystem

Terrace cultivation is closely similar to jhum in terms of crop mixture. The weed biomass of the intervening fallow period between two successive croppings is burnt before cropping. Organic manure is applied before the first crop mixture is sown in April. Zea mays, Phaseolus vulgaris, Vigna sinensis, Cucurbita maxima are raised together. Maize plant support the growth of the vine of Phaseolus vulgaris and Vigna sinensis. Second cropping (only on younger terraces) is done between August-December. Weeds pose a problem. Hand-hoeing is done to remove the weeds.

Valley agro ecosystem

Unlike valley cultivation involving only rice as done elsewhere (Toky and Ramakrishnan, 1981; Mishra and Ramakrishnan, 1981), valley cultivation at Nayabunglow involves mixed cropping of potato and Phaseolus vulgaris. Land is prepared into ridges and furrows during March. Bamboo sticks are used to support Phaselus vulgaris climbers. This is followed by second cropping involving wetrice cultivation. Organic manure (841 kg ha^{-1}) and inorganic fertilizer (26 kg ha^{-1}) are applied at the beginning of the first cropping followed by another inorganic fertilizer (183 kg ha^{-1}) before second cropping.

METHODS

For studies on the cropping and yield patterns, agro ecosystem types of different categories were selected at Nayabunglow about 30 km. from Shillong at an elevation of 960 metre.

The difference in crop mixture is due to differences in the mixture sown. Phytosociological analyses of crop and weeds were done at the peak growth period. Frequency, density and basal area measurements were based on 20 randomly placed 1 m^2 quadrats in each replicate plot. Importance value indices (IVI) were calculated following Kershaw (1973).

The biomass and economic yield measurements were based on the average of 15 individuals of each crop and weed species in each replicate. Economic yield per unit area was then computed using density values obtained for each crop species. Weed biomass recycled was computed on the basis of twenty 1 m^2 quadrats, in each plot.

Monetary and energy analysis

The monetary input/output analysis was done on the basis of the prevailing rates of wages for labour in the study area Rs. 17/= per day for male and Rs. 12/= per day for female. The total economic yield was converted into rupees on the basis of prevailing market prices. Economic efficiency was evaluated as output/input ratios.

Table 1.1. Energy values for different components considered in the agro-ecosystem (values expressed as dry wt. megajoule equivalent)

Category	Average energy value $MJ\ kg^{-1}$
Nutritive food value*	
Grains	16.29
Pulses	16.24
Leafy vegetables	13.75
Roots and tubers	13.76
Production costs**	
N	76.99
P_2O_5	13.95
K_2O	9.66

*Gopalan *et al*. (1978)

**Pimentel *et al*. (1973).

Labour input in man hours was recorded for each replicate plot under different agroecosystem type. Food energy consumed was apportioned to each activity (Leach, 1976) according to relative duration on the basis of grouping involving either sedentary, moderate or heavy work. Per hour energy expenditure of 0.418 MJ for sedentary work, 0.488 MJ for moderate work and 0.679 MJ for heavy work for an adult male and 0.331 MJ for sedentary, 0.383 MJ for moderate work and 0.523 MJ for heavy work for an adult female were used to calculate the labour energy input into the system (Gopalan *et al.*, 1978), One bullock hour was equated with 3.03 MJ (Mitchell, 1979). The input of energy through seeds was calculated on the basis of total energy expended to produce that fraction of crop yield. For calculating the output of energy under different agroecosystems, the total economic yield of various crops was converted into megajoules of energy by multiplying with standard values of various edible parts of crop as given in table 1.1. The energy efficiency was calculated as output/input ratios.

RESULTS

Mixed cropping on terraces had more emphasis on maize (Table 1.2), with a variety of legumes, vegetables, tuber and rhizome crops. However, this mixed cropping on a 4-yr old terrace was followed by a pure crop of *Eleusine coracana*. 12- and 15-yr old terraces alone had tuber and rhizome crops. 15-yr old terrace had fewer crop species.

Table 1.2. Importance value indices (IVI) of crop species on terraces of different ages in north-east India. Values in parantheses are density m^{-2}

Crop species	Terrace age (yr) 4	12	15
Grains and pulses			
Zea mays	229(5.3)	222(5)	186(6)
Vigna sinensis	31(0.2)	17(0.2)	33(1)
Phaseolus vulgaris	20(0.1)	-	12(0.4)
Leafy and fruit vegetables			
Momordica dioica	8(0.1)	7(0.02)	-
Cucurbita maxima	3(0.01)	5(0.01)	-
Hibiscus sabdariffa	5(0.01)	-	-
Tubers and rhizomes			
Ipomoea batatus	-	31(0.3)	41(1)
Colocasia antiquorum	-	18(0.1)	27(1)

Mono-cropping of *Eleusine coracana* (2nd crop) had IVI = 300, Density = 70.

Table 1.3. Importance value indices (IVI) of crop species under jhum agroecosystem in north-eastern India

	IVI
5-yr Jhum cycle	
Zimqiber officinalis	243
Colocasia antiquorum	57
7-yr Jhum cycle	
Zinqiber officinalis	137
Colocasia antiquorum	69
Curcuma domestica	19
Capsicum frutesence	67
Cucurbita maxima	8

Table 1.4. Total biomass (kg X 10^3 $ha^{-1}yr^{-1}$) of crop and weed under different agroecosystems in north-east India. Values in the parantheses are for biomass total for two croppings

	Terrace age (yr)			Jhum cycle (yr)		Valley
	4	12	15	5	7	
Crop biomass	6.3 ±0.5 (12.7 ±0.7)	6.0 ±0.8	5.4±0.3	5.2 ±0.1	10.7 ±0.6	6.2±0.3 (12.5±0.8)
Weed biomass	2.1 ±0.3 (3.09±0.5)	2.8 ±0.20	2.3±0.1	3.3 ±0.1	2.65±0.6	2.9±0.3 (7.1±0.1)
Weed recycled	0.6 ±0.1 (2.1 ±0.2)	1.01±0.05	1.1±0.02	1.01±0.02	0.87±0.1	1.2±0.1 (2.9±0.2)

Table 1.5. Mean economic yield (kg $ha^{-1}yr^{-1}$) of crop species on terraces in north-east India

Crop species	Terrace age (yr) 4	12	15
Grains and pulses			
Zea mays	2878 ±79.1	3108±59.5	2917 ±61
Vigna sinensis	2.4± 0.4	2± 0.3	15.1± 2.3
Phaseolus vulgaris	28 ± 2.9	-	53 ± 3.5
Leafy and fruit vegetables			
Momordica dioica	5 ± 1.2	2± 0.5	-
Cucurbita maxima	9.2± 1.7	10± 1.2	-
Hibiscus sabdariffa	1 ± 0.1	-	-
Tubers and rhizomes			
Ipomoea batatus	-	0	-
Colocasia antiquorum	-	0	154 ±10.4

Monocropping of *Elecusine coracana* (2nd crop) had mean economic yield of 3312±168.6 kg $ha^{-1}yr^{-1}$.

Table 1.6. Mean economic yield (kg $ha^{-1}yr^{-1}$) of crop species under jhum and valley cultivation in north-east India. Values in parantheses are yield for second crop

	kg/ha
5-yr Jhum cycle	
Zingiber officinalis	1371±30
	(943±58)
Colocasia antiquorum	104± 9
7-yr Jhum Cycle	
Zingiber officinalis	2138±41
	(1544±51)
Colocasia antiquorum	282±10
Curcuma domestica	44± 5
Capsicum frutesence	32± 8
Cucurbita maxima	58± 5
Valley (1st crop)	
Solanum tuberosum	1647±59
Phaseolus vulagaris	259± 8
Valley (2nd crop)	
Oryza sativa	3488±65

With more crop species under a 7-yr jhum cycle, the emphasis under both jhum cycles was on ginger (Table 1.3). Valley agroecosystem had more emphasis on potato and legumes. Valley cropping was a monoculture of rice.

Crop biomass even during the first cropping phase on the terraces was significantly higher ($P<0.05$) on a 4-yr old one compared to others; it was even more when two croppings on 4-yr old terrace is considered (Table 1.4). Crop biomass under 7-yr jhum cycle was significantly higher ($P<0.05$) compared to 5-yr jhum cycle. Valley system had comparable crop biomass as 4-yr old terrace. Weed biomass on the terraces varied with maximum on 12-yr old terrace. Weed potential was higher under 5-yr jhum cycle than under 7. Upto about 50% of the total weed biomass was recycled into the agro ecosystem.

The economic yield from maize was high on all terraces (Table 1.5). The yield from legumes was significantly higher ($P<0.05$) on 15-yr old terrace than on others. Tuber and rhizome crops were used only as cover species with no yield on 12-yr old terraces where as 15-yr old terrace yielded Colocasia antiquorum. 4-yr old terrace gave a high yield of Eleusine coracana.

Tubers and rhizomes accounted for a major proportion of the total yield under jhum (Table 1.6). 7-yr jhum cycle gave higher yield than 5-yr jhum cycle. The second harvest of ginger was consistently more than the first harvest.

Table 1.7. Monetary input-output (Rs. $ha^{-1}yr^{-1}$) in different agroecosystems in north-east India. Values in parantheses are for second crop

	Terrace age (yr)			Jhum cycle (yr)		Valley
	4	12	15	5	7	
Input total	3921±185 (2296±180)	3642± 87	4475±173	7156±379	10580±512	9447±249 (4925±130)
Labour	2023 (2116)	1869	2774	4857	6080	4747 (4000)
Manure	1726	1627	1500	-	-	578 (550)
Seed	172 (180)	146	201	2299	4500	4122 (375)
Output total	6823±185 (4968± 66)	5968±111	6761±138	7456±263	18836±423	29879±503 (7373±307)
Output/input ratio	1.7 (2.2)	1.6	1.5	1.04	1.8	3.2 (1.5)

Table 1.8. Energy input-output (MJ ha^{-1} yr^{-1}) in different agroecosystems. Values in parantheses for second crop

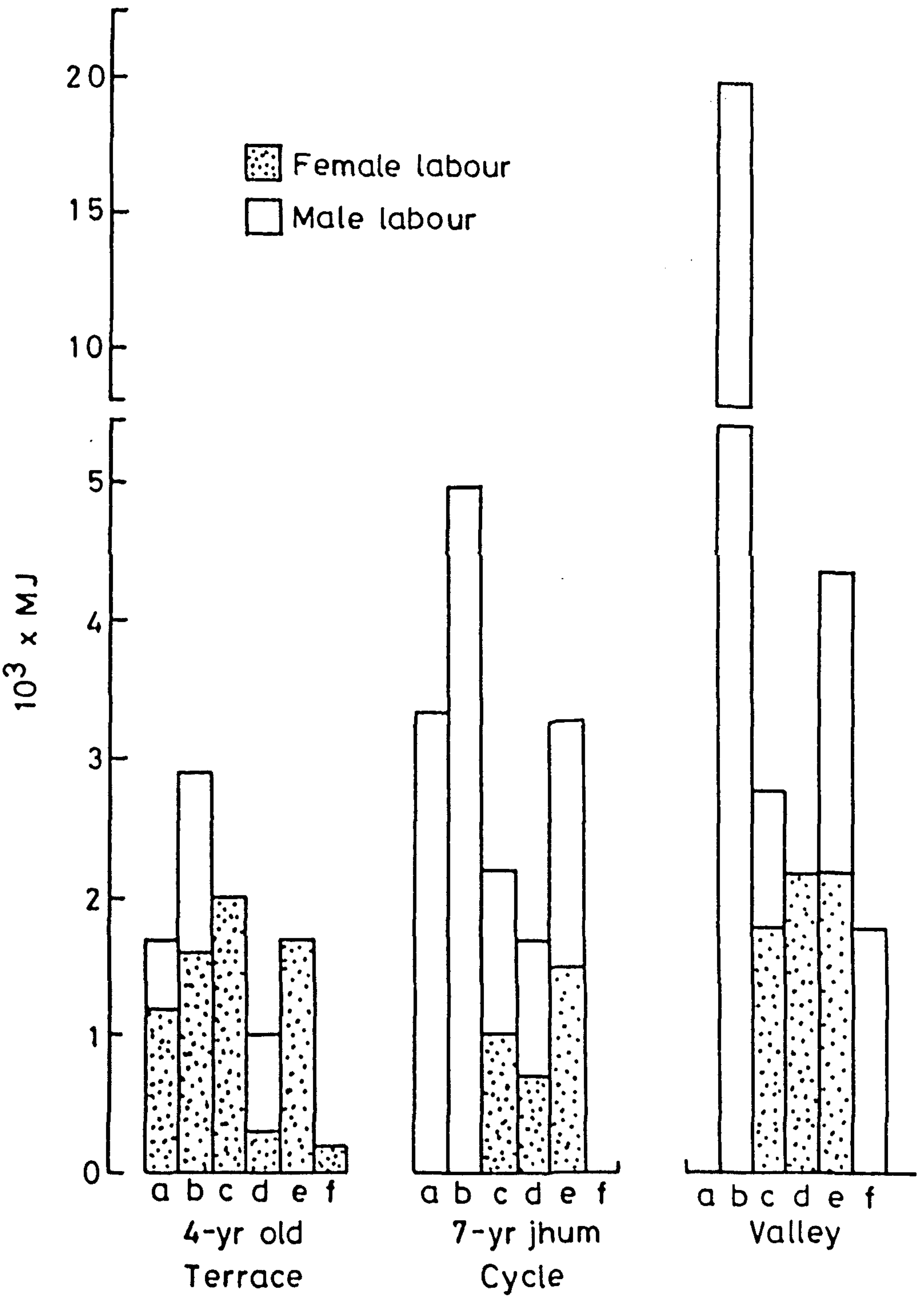
	Terrace age (yr) 4	12	15	Jhum cycle (yr) 5	7	Valley
Input total	4381± 68 (465± 44)	3820± 185	3790±312	1412± 49	1926± 58	3232± 83 (7987± 313)
Labour	502 (441)	534	720	1086	1442	1099 (1073)
Manure	3836	3254	3030	-	-	1572 (6481)
Seed	43 (24)	32	40	326	484	561 (433)
Output total	47573±1396 (53952± 23)	50815±1073	50734±565	20516±593	35143±279	26870± 134 (56820±1905)
Output/input	10.9 (116.03)	13.3	13.4	14.5	18.3	8.3 (7.1)

Labour was one of the major inputs into all agro ecosystems followed by organic manure (Table 1.7). Inorganic fertilizer was used only for valley cropping which was 9% of the total manure for the first crop and 100% for the second crop. The total monetary input into 4-yr old terrace was significantly higher ($P<0.05$) than for other terraces. Labour and seed inputs and the consequent total input into jhum was significantly higher ($P<0.05$) than under terraces. The total output was also higher under 7-yr jhum cycle than under terrace. The output from a 4-yr old terrace was two-fold than from 12- and 15-yr old terraces. The output from valley cropping was the highest compared to all other agro ecosystems. The monetary efficiency on terraces declined with age; it improved under a 7-yr jhum cycle than under 5-yr cycle. The efficiency of valley system was higher than all others.

In terms of energy, manure was more important of all the inputs (Table 1.8). The total input for valley cultivation was much higher than that for others; between terrace and jhum systems, the former had generally higher total input. The energy output pattern was similar to monetary output except that the energy output from valley cultivation was lesser than under 4-yr old terrace cultivation. The efficiency under jhum improved under longer cycles and was generally higher than on terraces. Valley cultivation had lowest energy efficien

Fig. 1.1 Allocation pattern of labour between male and female members of the family under different agroecosystems in north-east India

a) Slash and burn ; b) Land preparation; c) Sowing; d) Weeding; e) Harvesting and transplanting ; f) Drying, shelling threshing.



Female labour
Male labour
10^3 x MJ
20
15
10
5
4
3
2
1
0
a b c d e f
4-yr old Terrace
a b c d e f
7-yr jhum Cycle
a b c d e f
Valley

Table 1.9. Labour energy input (MJ $ha^{-1}yr^{-1}$) by the family and that obtained on co-operative and hired basis under different agroecosystem

	Labour		
	Family	Co-operative	Hired
4-yr Terrace	803	51	90
7-yr Jhum cycle	1224	361	—
Valley	464	-	1708

The labour allocation pattern for different operations between male and female was similar under a given type of agro-ecosystem and therefore 4-yr old terrace system alone is compared in Fig. 1.1 with 7-yr jhum cycle and valley cultivation. With all terrace operations done manually, the contribution by female was higher where as the jhum operations are largely done by males. Land preparation and processing of the yield under valley cultivation are done by males where as the other operations are done largely by the females.

Labour obtained on a co-operative basis or hired, besides that generated within the family varied depending upon the agroecosystem type (Table 1.9). The typical pattern presented shows that labour was hired for terrace and valley cultivation only. Terrace and jhum cultivation had labour contributed on a co-operative basis, the rest was obtained through family labour.

DISCUSSION

The traditional farmer in north-east India who practise slash and burn agriculture (jhum) follow similar cropping pattern for settled terrace farming too, wherever this land use has been introduced. The chief feature is the concept of mixed cropping, with diversity in economic yield (Ramakrishnan, 1985a). Even the valley cultivation in this study is a mixture of potato with legume for the first cropping season, unlike in other areas where it is often a wet cultivation of rice (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981).

As shown through earlier studies on jhum, the yield from This system was reasonable under a 7-yr cycle. The number of crop species also was more under longer cycle. This is to be expected because of longer time available for soil fertility recovery (Ramakrishnan and Toky, 1981) and possible reduction in weed potential of the site (Saxena and Ramakrishnan, 1984a). On a 4-yr old terrace the farmer does two croppings unlike one cropping on others. This may be due to decline in the physical properties of the soil on older terraces. Even the number of crop species were fewer on older terraces with greater emphasis on nitrogen fixing legumes and more nutrient use efficient tuber crops such as Colocasia antiquorum (Ramakrishnan, 1984).

Unlike the normal practice of wet rice cultivation in the valleys, the emphasis by the farmer here is on potato, which gave better monetary returns than rice. Being an area closer to the large township of Shillong, potato is a better commodity for export to the town fetching better returns than rice that could be only for local consumption. The chief advantage of valley cultivation is that it is self-sustainable due to nutrient wash-out from the hill slopes.

Inspite of the high input of organic manure for terrace cultivation, the economic returns from the terraces are often not comparable to the jhum system except perhaps for the return from a 4-yr old terrace that is comparable with a 5-yr jhum cycle. This suggests of the high cost in sustaining terrace agro ecosystem. Even the monetary output/input ratio declined with age of the terrace and was much lower than the efficiency of the jhum system under a 7-yr cycle. Valley cultivation of potato obviously is most efficient of all the systems and this is also evident from the higher efficiency of the second cropping of rice under valley which is only 1.49 compared to 3.16 for the first crop, largely of potato.

With labour as the chief energy input, all the agro ecosystems under consideration are energy efficient with a high efficiency for jhum. If two croppings on 4-yr old terrace were considered, this was more energy efficient than other terrace systems. The extremely high value for efficiency during second cropping on a 4-yr old terrace, particularly for energy because manure input given at the beginning of first cropping does not figure in the calculations of the second.

The energy efficiency of terrace and valley system compare favourably with traditional Indian agricultural systems which were shown to have an output/input ratio of about 9 (Mitchell, 1979). In any case these agro ecosystems are superior to the western agriculture where the yield is 1 or 2 units of food energy per unit energy input (Spedding, 1975; Leach, 1976; Pimentel and Pimentel, 1979).

In the calculations of energy and monetary efficiencies, labour has been considered to be one of the important inputs. However, labour is largely generated from within the family or within the village it self as a co-operative venture;

therefore in a sense it is free. If labour is excluded in the calculations, the efficiency would improve drastically. Valley cultivation with substantial hired male labour is different from others.

SUMMARY

Slash and burn agriculture (jhum) land valley cultivation are two important land use systems of tribals of north-east India. During the recent past terrace cultivation was introduced by the Governmental agencies to replace jhum. Mixed cropping is the common feature in all these systems. Yield under 7-yr jhum cycle was reasonable. The number of crop species, yield and energy efficiency were more under 4-yr old terrace than under older terraces. With high input of organic manure for terrace cultivation, the economic return from 4-yr old terrace was comparable with the 5-yr jhum cycle. This suggests the high cost in sustaining terraces. Monetary output/input declined with the age of the terrace. Valley cultivation of potato was more efficient than other land use systems. The energy efficiency of 4-yr old terrace was more than older terraces.

CHAPTER 2

SOIL NUTRIENT LOSSES AND FERTILITY CHANGES IN SOME AGROECOSYSTEM TYPES OF MEGHALAYA IN NORTH-EAST INDIA

INTRODUCTION

Slash and burn agriculture (locally called jhum) which is the traditional land use of tribals in north-east India was in harmony with the environment when it operated under a long jhum cycle (the length of the fallow period between two successive cropping on the same site) 10-20 years or more (Ramakrishnan, 1985b). With drastic reduction in the length of the cycle to about 4-5 years, the crop yield is low (Toky and Ramakrishnan, 1981) because of drastic decline in soil fertility (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983a) and increased weed potential (Saxena and Ramakrishnan, 1984a). In view of the distortions, Governmental agencies in the region have tried to introduce alternate land use systems on a experimental scale such as terracing, which the farmer adopted as long as the subsidies were given and discontinued as soon as subsidies were withdrawn. Infact, alternative land use strategies is an issue of critical importance in many other parts of the world, as in south east Asia, Africa and Latin America. In the north east region, where terracing is being practised over a period of time, it is done chiefly by the immigrant Nepalis and that too on well developed deep soils. The present study is aimed at an understanding of the soil fertility problems associated with terracing over an extended time period on the same site making comparisons with a jhum cropping system under a 5-yr cycle.

METHODS

The study was done at Nayabunglow about 30 km north of Shillong at an elevation of 960 m.

For studies pertaining to hydrology and soil fertility terraces of different ages (three replicates each) were selected. (i) 1-yr old terrace, which was a freshly prepared one, left fallow for a year with only weedy growth (ii) 4-yr old terrace, where mixed cropping was done and two crops are taken in a year between May-August and August-December, (iii) 12-yr old terrace, where mixed cropping was done. Initially taking two crops per year but only with one crop a year, for the past atleast 4-5 years. The data for the cropping system under a 5-yr jhum cycle and that under a 5-yr fallow are based on Ramakrishnan and Toky (1981).

Hydrology

For studies pertaining to run-off and sediment, the loss from a confined area of 1 X 10 m was collected in large collectors and removed periodically for analysis. Percolation studies were made with the help of zero-tension lysimeter of the Russian type (Buckmann and Brady, 1960). The soil was cut vertically to expose the profile. A tunnel was excavated at a depth of 40 cm (this is the depth to which most of the roots system penetrate) and a collector of 30X30X15 cm was placed in the tunnel. By pressing from below, the rim of the collector was firmly inserted into the undisturbed soil above. The water percolating through the soil was tapped from the collector into receptacles from time to time, for analyses. Formaldehyde (40%) was used to stop the biological activity immediately after collection. The analyses of water samples were done following the methods given by Allen et al., (1974). Nitrate-nitrogen was estimated by phenol-disulphonic acid method and phosphate-phosphorus by molybdenum blue method. Potassium was estimated by flame-emission method, while calcium and magnesium were analysed by EDTA titration method.

Soil fertility

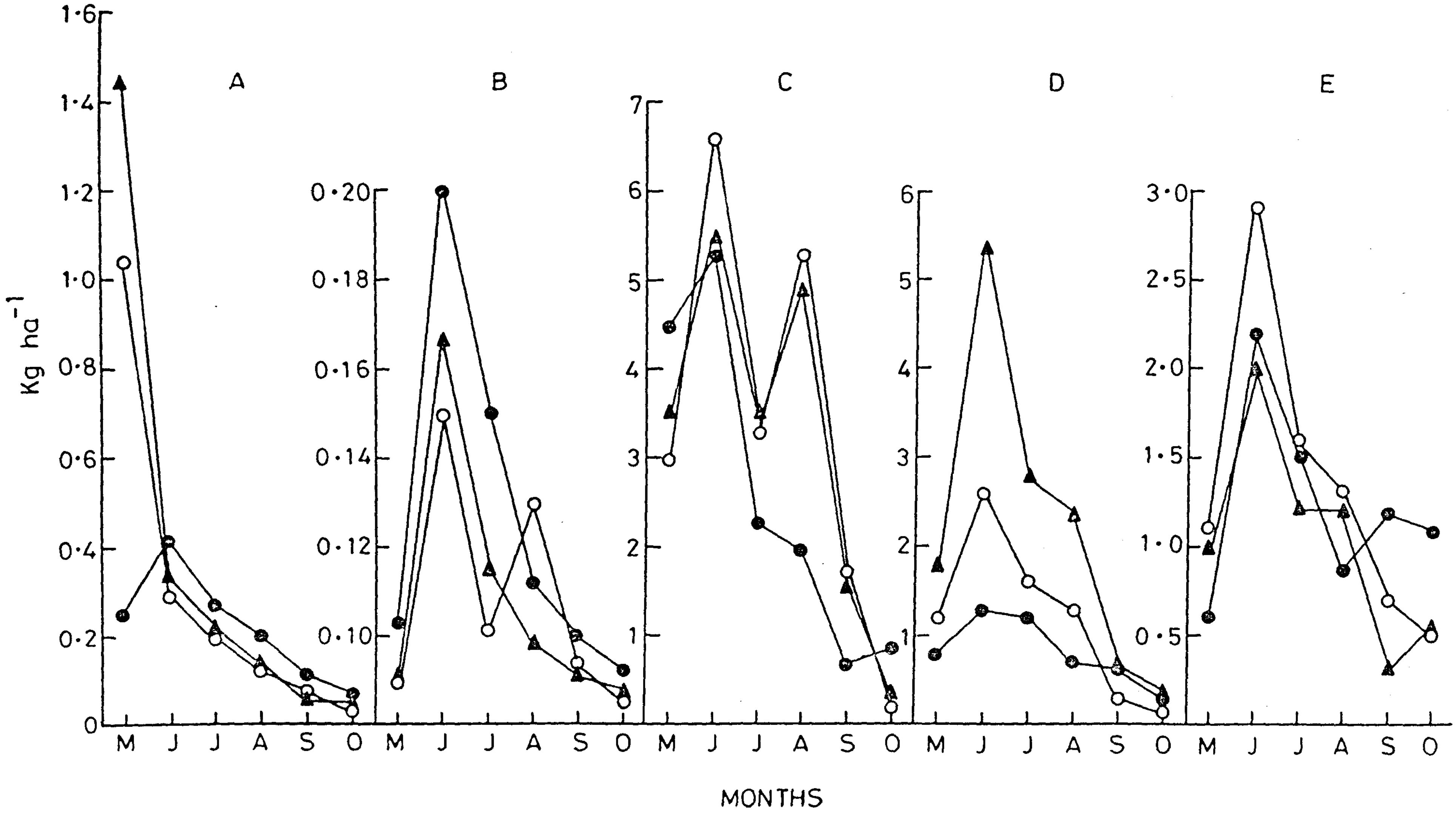
Soil fertility studies were done at all the sites . Soil s ampling was done at two times: (i) before the cropping, (ii) after the cropping. Sampling at each site was based on ten collections upto a depth of 40 cm at regular intervals of 0-7, 7-14, 14-28, 28-40 cm. A composite sample for each depth was prepared by thoroughly mixing the ten samples of a given replicate plot.

Soil samples were air dried, ground, passed through a 0.2 mm sieve and stored in glass jars. Total nitrogen, organic carbon, nitrate-nitrogen, phosphate-phosphorus and cations were analysed following standard methods (Allen et al., 1974). Thus, soil organic carbon was determined by the Walkely-Black method and total nitrogen by Kjeldahl method. Calcium and magnesium were estimated by EDTA titration method. While potassium was determined by flame emission method after

Table 2.1. Total loss of sediment (t $ha^{-1} yr^{-1}$) and water (cm) under terrace, jhum agro-ecosystem and forested fallow in north-east India.

Category of loss	Terrace age (yr)			Jhum cycle age (yr)	Jhum fallow age (yr)
	1	4	12	5	5
Sediment	2.2±0.1	2.7±0.2	3.3±0.3	30.05±1.2	1.13±0.04
Run-off water	45.4±4.01	32.7±0.5	34.9±2.1	36.64±1.8	26.90±1.8
Percolatation water	18.0±1.7	15.6±0.7	12.6±1.2	22.92±1.8	21.30±2.02

Fig. 2.1 Monthly loss of NO_3-N (A), PO_4-P (B), Potassium (C), Calcium (D) and Magnesium (E) in run-off water during cropping under terrace system. ●, 1-yr old terrace; O, 4-yr old terrace; , 12-yr old terrace.



A
B
C
D
E
Kg ha^{-1}
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
0·10
0·12
0·14
0·16
0·18
0·20
1
2
3
4
5
6
7
0·5
1·0
1·5
2·0
2·5
3·0
M J J A S O
MONTHS

extracting the soil with 1M ammonium acetate at pH 7. Nitrate-nitrogen was analysed by phenol-disulphonic acid method and phosphate-phosphorus colorimetrically by molybdenum blue method after extraction with Bray and Kurtz's (1945) solution. Soil bulk density was used for subsequent conversion of analytical data to field weight per unit area.

RESULTS

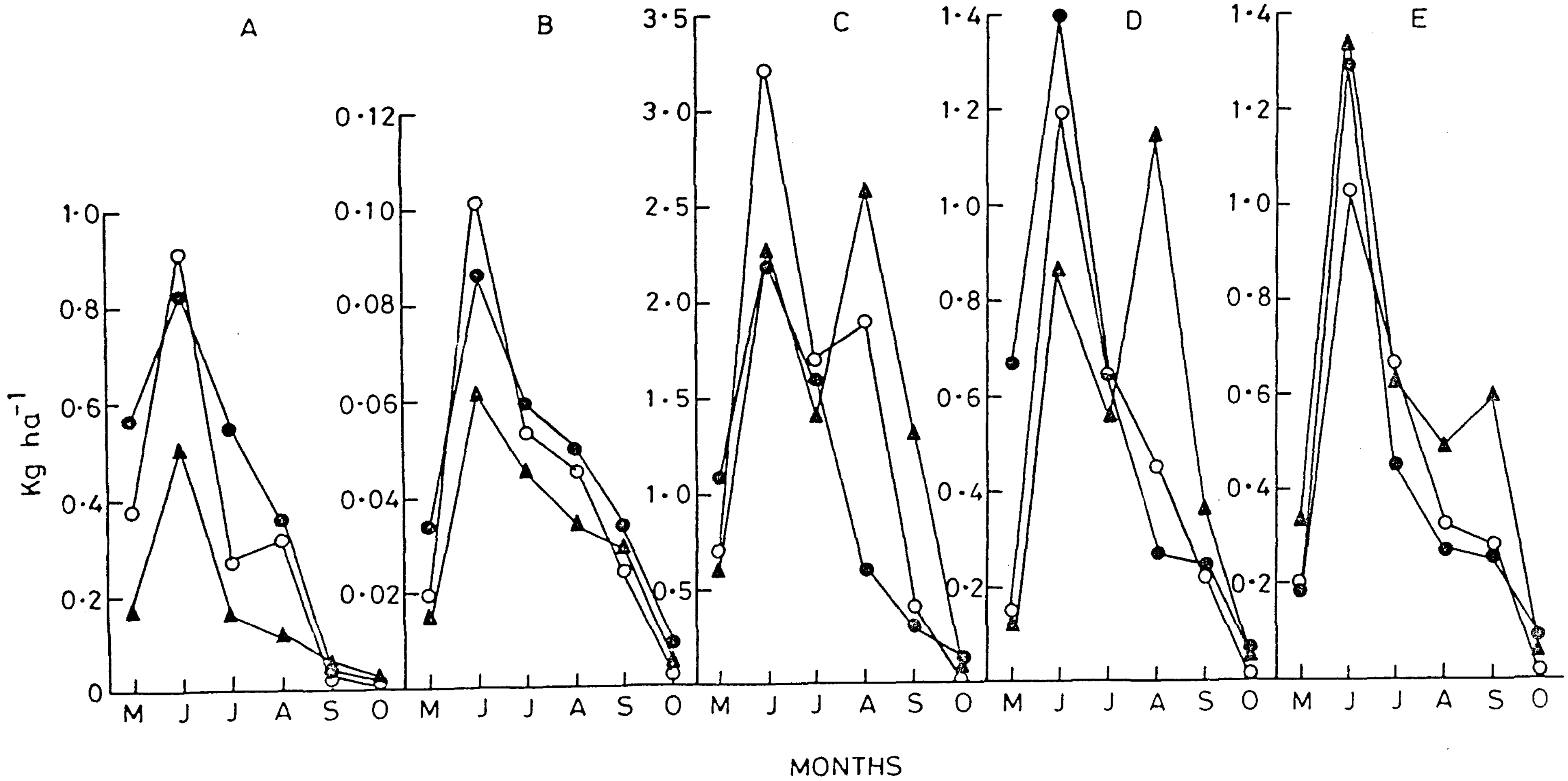
The sediment loss through run-off water was drastically reduced under terraces compared to the jhum plots during cropping (Table 2.1). However, the loss of sediment was more ($P<0.05$) on terraces compared to 5-yr old jhum fallow. Water losses through run-off was significantly higher ($P<0.05$) in the jhum plot under cropping and on terraces only when compared with the jhum fallows plot. The percolated water under jhum system was significantly higher ($P<0.05$) only when compared to the 12-yr old terrace. Sediment loss increased but the run-off and percolated water loss declined ($P<0.05$) in older terraces.

The loss pattern of nutrients from the terraces presented in Fig. 2.1 showed that the losses reached its maximum during the early part of the monsoon with a sharp decline subsequently.

Table 2.2. Total loss of nutrients (kg $ha^{-1} yr^{-1}$) in run-off water under different agroecosystems and jhum fallow in north-east India.

Nutrients	Terrace age (yr)			Jhum cycle age (yr)	Jhum fallow age (yr)
	1	4	12	5	5
NO_3-N	1.3±0.12	1.8±0.2	2.2±0.2	5.3±0.5	0.8±0.06
PO_4-P	0.7±0.06	0.5±0.03	0.5±0.05	0.9±0.1	0.1±0.008
K^+	15.6±1.4	20.0±1.7	19.3±1.9	51.0±3.5	0.9±0.9
Ca^{++}	5.0±0.4	7.1±0.5	13.3±1.1	13.8±1.3	2.0±0.5
Mg^{++}	7.5±0.5	8.1±0.6	6.1±0.6	9.5±0.9	1.3±0.1

Fig. 2.2 Monthly loss of NO_3-N (A), PO_4-P (B), Potassium (C), Calcium (D) and Magnesium (E) in percolated water during cropping under terrace system. ●, 1-yr old terrace; O, 4-yr old terrace; , 12-yr old terrace.



A
B
C
D
E
Kg ha^-1
1·0
0·8
0·6
0·4
0·2
0
0·12
0·10
0·08
0·06
0·04
0·02
3·5
3·0
2·5
2·0
1·5
1·0
0·5
1·4
1·2
1·0
0·8
0·6
0·4
0·2
M J J A S O
MONTHS

Table 2.3. Total loss of nutrients (kg $ha^{-1} yr^{-1}$) in percolated water under different agroecosystems and jhum fallow in north-east India

Nutrients	Terrace age (yr)			Jhum cycle age (yr)	Jhum fallow age (yr)
	1	4	12	5	5
NO_3-N	2.4±0.2	2.1±0.2	0.99±0.08	9.2 ±0.64	1.1 ±0.09
PO_4-P	0.3±0.02	0.3±0.01	0.2 ±0.2	0.07±0.01	0.02±0.001
K^+	5.9±0.5	7.9±0.4	8.3 ±0.5	13.7 ±0.6	0.5 ±0.02
Ca^{++}	3.3±0.3	2.7±0.2	3.1 ±0.2	4.6 ±0.4	2.7 ±0.2
Mg^{++}	2.5±0.2	2.5±0.1	3.4 ±0.3	2.3 ±0.1	0.9 ±0.1

Table 2.4. Concentration of nutrients in the upper layer of soil (0-7 cm) under 4 year terrace before and after cropping. (Values in the parantheses are nutrient concentration for 12-yr old terrace)

	%		mg $100gm^{-1}$		meq $100gm^{-1}$		
Sampling period	C	N	NO_3-N	PO_4-P	K	Ca	Mg
March	1.64±0.3	0.18±0.1	0.39±0.1	0.59±0.03	0.34±0.09	2.98±0.3	2.78±1.5
	(2.26±0.2)	(0.19±0.01)	(0.65±0.1)	(0.59±0.05)	(0.70±0.1)	(2.20±0.1)	(4.11±0.2)
December	1.61±0.02	0.14±0.01	0.34±0.04	0.53±0.02	0.32±0.1	1.13±0.3	2.67±0.01
	(2.17±0.05)	(0.17±0.01)	(0.36±0.02)	(0.51±0.04)	(0.40±0.6)	(1.90±0.04)	(3.43±0.03)

In general, maximum losses of nutrients from all the systems occurred with respect to potassium (Table 2.2). Nutrient losses with respect to calcium alone was significantly higher ($P<0.05$) in older terraces. Compared to the terrace system the losses during the cropping phase under jhum was higher ($P<0.05$). However, the losses from the 5-yr old jhum fallow was significantly lower ($P<0.01$) compared to the terrace system.

The pattern of losses of nutrients during the monsoon period through percolated water was similar to that through run-off water (Fig. 2.2).

Percolation loss of potassium was higher than that of other nutrients (Table 2.3). While the loss of phosphorus and calcium remained more or less the same in older terraces compared to a 1-yr old terrace. Potassium and magnesium losses significantly increased ($P<0.05$); nitrate-nitrogen losses sharply declined in older terraces. Compared to the cropping phase of the jhum system the losses of nitrate-nitrogen, potassium and calcium were significantly lower ($P<0.01$) on terraces, where as phosphate-phosphorus loss was higher. The loss of all nutrients were significantly higher ($P<0.01$) on the terraces compared to the jhum fallow.

The concentration of nutrients in the surface soil (0-7 cm) alone is presented in Table 2.4. In 12-yr old terrace, nutrient concentration before cropping was higher than in a

Fig. 2.3 Changes in quantity of carbon, total nitrogen, nitrate-nitrogen and available phosphorus in a soil column upto 40 cm depth under
A, 1-yr old terrace; B, 4-yr old terrace;
C, 12-yr old terrace; D, 5-yr jhum cycle;
E, 5-yr jhum fallow

1, before cropping; 365, after cropping

■ , 0-7 cm; ▨ , 7-14 cm; ⊡ , 14-28 cm;
□ , 28-40 cm.

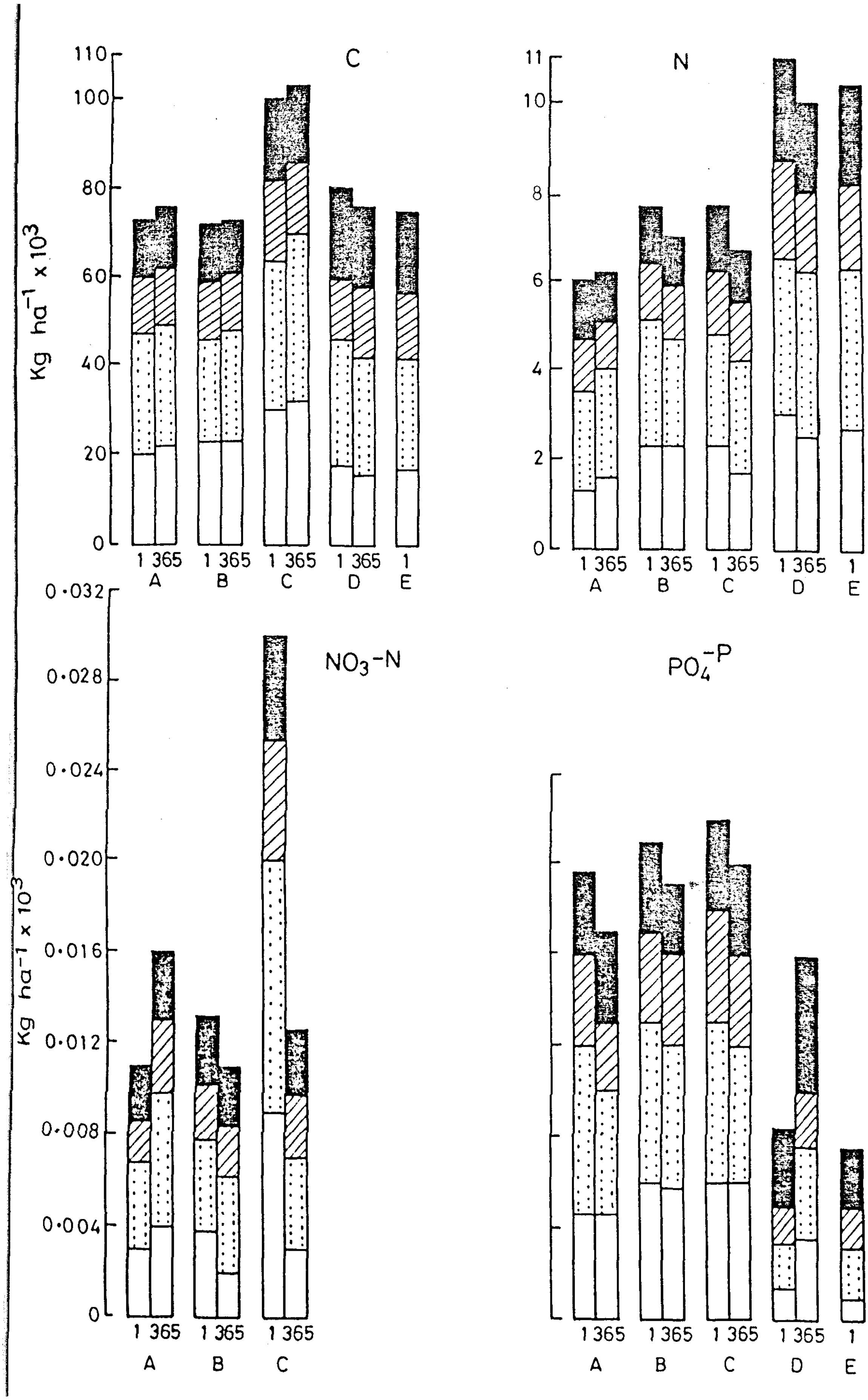
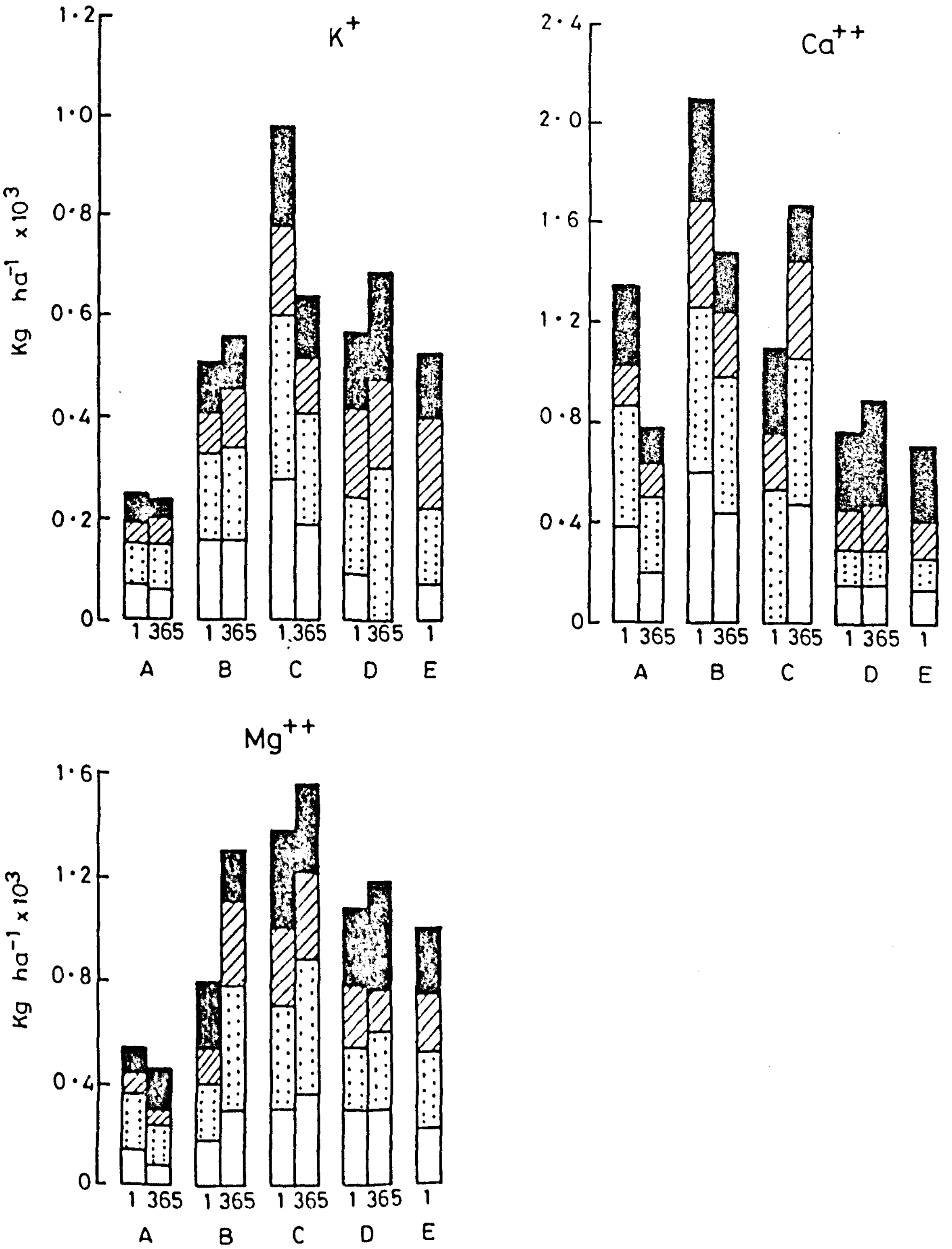

C
N
NO_3-N
PO_4^-P
Kg ha⁻¹ x 10³
Kg ha⁻¹ x 10³
110
100
80
60
40
20
0
11
10
8
6
4
2
0
0·032
0·028
0·024
0·020
0·016
0·012
0·008
0·004
0
1 365 1 365 1 365 1 365 1
A B C D E
1 365 1 365 1 365
A B C

Fig. 2.4 Changes in quantity of potassium, calcium and magnesium in a soil column upto 40 cm depth under A, 1-yr old terrace; B, 4-yr old terrace; C, 12-yr old terrace:, D, 5-yr jhum cycle; E, 5-yr jhum fallow

1, before cropping; 365, after cropping ■, 0-7 cm; ▨, 7-14 cm; ⊞, 14-28 cm; □, 28-40 cm.



K+
Ca++
Mg++
Kg ha-1 x10³
1·2
1·0
0·8
0·6
0·4
0·2
0
2·4
2·0
1·6
1·2
0·8
0·4
0
1·6
1·2
0·8
0·4
0
1 365
1
A
B
C
D
E

4-yr old terrace. However, after cropping either there was little significant difference between the two terraces or the level was somewhat lower as for phosphate-phosphorus. Though the data for different depths are not shown here, there was a significant decline in concentration with depth.

Starting with a lower quantity of nutrients in a 1-yr old terrace, it reached its maximum in a 12-yr old one (Fig. 2.3, 2.4). Fluctuation in the nutrient quantity was more prounounced in the surface soil layers. Nutrient quantities at the end of cropping either increased or declined or was not significantly altered for a year. Except for total nitrogen, the quantity of others generally was lower in the jhum system both during cropping and fallow phases.

DISCUSSION

Our earlier studies (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983c) suggested that losses during the cropping season under jhum could be extremely high with sediment losses upto about 30 ton $ha^{-1}yr^{-1}$. A consequence of terracing is the drastic reduction in this loss, though the losses could be higher than in a 5-yr old jhum fallow plot; these losses increased with terrace age. This increase in sediment loss in older terraces may be related to a decline in soil physical properties under continuous cropping.

A freshly prepared terrace is left fallow for a year with only weedy growth on it and this may explain higher run-off and percolation water here compared to older terraces. In general the losses from the terrace system were much lower than under the jhum cropping phase, though it was higher than that under the fallow phase. Though the loss pattern on terraces of different ages did not differ much, it was interesting to note that the loss of a highly labile element (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983c) such as potassium increased with increase in terrace age. Even nitrate-nitrogen loss through run-off increased significantly in older terraces.

The loss pattern of nutrients through run-off and infiltration was similar to that reported for the jhum system (Toky and Ramakrishnan, 1981b). Where it was shown that maximum losses occurred during the early cropping phase before crop cover is established.

The ultimate soil fertility status of terrace systems under continuous cropping would be a consequence of not only the depletion processes that operate in the soil ecosystem, over a time period under successive croppings, but would also depend upon the agricultural practices. A comparison of the soil fertility status under 4-yr and 12-yr old terraces suggests that either there are little difference in a given nutrient level between the two or, that even there may be an actual increase in the level of soil fertility in the latter. Under a 12-yr old terrace, for example, only one mixed crop of maize and legume Vigna sinensis are taken and the biomass other than the economic yield is ploughed back into the plot. This is apart from 2761 kg $ha^{-1}yr^{-1}$ and 2342 kg $ha^{-1}yr^{-1}$ of cow dung put into the system under 4- and 12-yr old terraces, respectively. Besides due to higher yield capability of the soil under 4-yr old terrace, two crops are taken in a year (a mixed maize and legume between May-August and another Eleusine coracana between August-December). Unlike in the 12-yr old terrace where crop biomass is recycled yielding 42 kg, 0.5 kg, 55 kg of NPK respectively through it, only Eleusine coracana raised as a second crop is recycled under a 4-yr old terrace yielding 17 kg, 0.5 kg, 49 kg of NPK respectively. In other words, more biomass is recycled through old terraces. A 12-yr old terrace is often fallowed out from time to time to recover soil fertility. Inspite of this, the nutrient concentration in a 12-yr old terrace was more drastically reduced at the end of cropping compared to the level before cropping, contrasting with a 4-yr old terrace.

One of the reasons why terrace cultivation is done only by the Nepalis is because they being immigrants in the area and can not own land in the tribal areas and therefore are dependent upon leased land. The city folk owning the land prefer the farmer to do sedentary agriculture such as terracing rather than slash and burn agriculture. More importantly, the need to fertilize terraced land is acute. Since the Nepalis alone own cattle for milking, they alone are able to obtain organic manure such as cow dung to sustain the terraces by maintaining a reasonable soil fertility level.

One of the consequence of terracing is the gradual decline in the ability of the system to recover lost soil fertility except through higher input of fertilizers. Intensified weed of the potential of the site over a time period of (Chapter 1) also contribute to a decline in the ecological and economic efficiencies of the system (Chapter 1). Besides, maintenance cost of the terraces themselves increases, as there is continuous damage along the periphery due to heavy wash-out under high rainfall. It is for the reason that terrace has not been able to replace slash and burn agriculture as an alternative land use system, inspite of Governmental subsidies. The slash and burn agriculture farmer, therefore, has rejected it from time to time.

SUMMARY

The pattern of sediment and nutrient losses through water at the time of cropping and the soil fertility status before and after cropping under 1-, 4- and 12-year old terraces maintained for cultivation were compared with an agro ecosystem under 5-yr jhum cycle and land under 5-yr old fallow. Though there was a sharp reduction in the losses of sediment and nutrients in terraces compared to the agro ecosystem under jhum, the losses were higher than that under a 5-yr old fallow. Losses through hydrology increased in older terraces and this was more pronounced for nitrate-nitrogen and potassium. Older terraces were less fertile than the younger ones. The implications of these observations are discussed.

CHAPTER 3

NUTRIENT BUDGET UNDER TERRACE AGROECOSYSTEM OF MEGHALAYA IN NORTH-EAST INDIA. I. NITROGEN AND PHOSPHORUS

INTRODUCTION

Slash and burn agriculture is the chief land use of the tribals of the north-east India (Ramakrishnan, 1985a). However, this land use practice is becoming more and more untenable in north-east India because of shortening of the agricultural cycle and the consequent inability of the system to recover the nutrients (Toky and Ramakrishnan, 1981) during the short fallow period between two successive cropping on the same site, as also shown by studies from elsewhere (Nye and Greenland, 1960; FAO, 1978; Kartawinata *et al.*, 1981).

Nitrogen and phosphorus are two critical elements in the soil in the humid tropics as they are extremely labile and often in short supply (Brady, 1982; Gliessman, 1980; Sanchez *et al.*, 1982; Odum, 1973). Our earlier studies on slash and burn agriculture shows that nitrogen and phosphorus budgets under this system are adversely affected under shorter cycles (Mishra and Ramakrishnan, 1984; Swamy and Ramakrishnan, 1988). Though terrace cultivation has been encouraged by Governmental agencies, very often it has not been favoured by the tribals themselves. However, in areas such as Nayabunglow, in Meghalaya, in north-east India, the immigrant Nepalis have been involved in this land use system for many years. Therefore, a comparative analysis of 4- and 12-yr old terrace agroecosystems were analysed from the point of view of nitrogen and phosphorus budgets, in order to understand the strengths/ weaknesses in this land use that largely is rejected by the local people.

METHODS

4- and 12-yr old terrace plots (each with three replicates were identified at an elevation of 960 m in Meghalaya in north-east India. While selecting the plots similar aspects and topographic conditions were ensured.

Direct fall through precipitation was collected from 10 random points in each plot. Soil sampling upto a depth of 40 cm was done by using a core sampler at 15 random points on each plot at three times during the year: (i) day before burning the slash prior to cropping, (ii) a day after the burn and (iii) at the end of cropping.

The amount of slash burnt and the organic manure input into the agroecosystem were quantified on the basis of 10 observations made in each plot. The nutrient input into the agroecosystem was then quantified. Nutrients removed through agroecosystem through crop thinning, crop uptake, weed uptake and recycling through weeds ploughed back into the system were all based on 10 random observations in each plot using 1 m^2 quadrats.

For studies pertaining to nitrogen and phosphorus losses through sediment and run-off water, loss from a confined area of 1 X 10 m was collected in large collectors and sampled periodically for chemical analysis. For the study of percolation loss of nitrogen and phosphorus, zero tension lysmeters were used. Soil was cut vertically at 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 30X30X15 cm 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 five replicates in each plot. A few drops of 40% formal dehyde was added to the samples to stop biological activity immediately after collection. After analysing the fresh soil/water samples for nitrate-nitrogen and phosphate-phosphorus they were stored in polythene jars, for subsequent analysis.

The amount of nutrient present in the soil pool (kg ha^{-1}) was calculated to a depth of 40 cm using soil bulk density estimates calculated for each site, at depths of 0-7, 7-14, 14-28 and 28-40 cm, considered separately. Bulk density or volume weight (the quotient of the air dry mass weight of the soil to the total volume it occupies in each field) was determined from the air dry mass of a known field volume of soil.

The soil was air dried and plant samples were oven dried at 60°C for 48 hours and passed through 0.2 mm sieve and stored in glass jars for subsequent analysis. The samples were analysed by procedures given by Allen et al. (1974). In the soil and water samples nitrate-nitrogen were estimated colorimetrically by phenol disulphonic acid method. Total nitrogen in soil and in plant samples were estimated by micro-Kjeldahl method. Soil phosphorus was extracted by Bray and Kurtz's (1945) method and was measured by molybdenum-blue method. Phosphorus in plant samples were estimated by molybdenum-blue method, after wet digestion with triple acid (perchloric acid, nitric acid and sulphuric acid).

Calculation of the amount of nutrient loss through fire was based on the difference between the pre-burn (a day before the burn) and post-burn (a day after the burn) stages upto a depth of 40 cm : (nutrients in the pre-burn soil pool + addition through slash) - (nutrients in the post-burn soil pool) = loss of nutrients due to fire.

Input and output of total nitrogen and phosphorus for each plot were calculated on the basis of the amount of that particular input/output and the concentration of the element in it.

Table 3.1. Loss of total nitrogen and available phosphorus (kg $ha^{-1}yr^{-1}$) under terrace agroecosystem in north-east India. Values in parantheses are for phosphorus

		Terrace age (yr) 4	12
(a)	Pre-burn soil pool	7715 (21.3)	7674 (22.19)
(b)	Addition through		
	Weed residue	13.2 (0.15)	25.19(0.35)
	Crop residue	18.25(0.42)	40.26(0.56)
(a+b)	Total soil pool before burning	7746.45(21.87)	7739.45(23)
(c)	Post-burn soil pool	7620.33(21.38)	7500 (22.06)
a+b-c	Loss	126.12(0.49)	239.45(0.94)

RESULTS

Nitrogen in the pre-burn soil pool was more in 4-yr old terrace than in 12-yr old one where as the reverse was true for phosphorus (Table 3.1). The addition of nitrogen and phosphorus through weed and crop residues was more in 12-yr old terrace than in 4-yr old one. The decline in the level of soil nitrogen after the burn was more than that of phosphorus. This loss through fire was more pronounced in the 12-yr old terrace compared to 4-yr old one.

Importance value indices (IVI) of dicot weeds especially of compositae family were more on the terraces during the cropping of maize (Table 3.2). But, graminaceous species dominated during the second cropping of Eleusine coracana in 4-yr old terrace.

Weed biomass under 12-yr old terrace during the first cropping was significantly higher ($P<0.01$) than under 4-yr old one (Table 3.3). However, 4-yr old terrace had more weed biomass generated because of two crops raised. During the first cropping nitrogen and phosphorus removal by the weed under 12-yr old terrace was almost double of that under 4-yr old terrace. The differentail in nutrient removal by weeds under 4- and 12-yr old terraces that was observed was still maintained inspite of considering the second crop raised under 4-yr old terrace.

Table 3.2. Importance value indices (IVI) and density m^{-2} of weed species under terrace agroecosystem in north-east India. Values in parantheses are for second cropping

Name of the species	Terrace age (yr) 4		12	
	Density/m^2	IVI	Density/m^2	IVI
Ageratum conyzoides L.	320(42)	71(25)	1162	141
Bidens biternata Merr and Sherff.	0(0)	0(0)	2	2
Brachiaria villosa A. Camus.	2(22)	5(9)	13	5
Borreria hispida K. Schumm.	152(208)	50(67)	212	34
Commelina benghalensis Linn.	0(0)	0(0)	8	2
Crotolaria striata D.C.	0(0)	0(0)	2	8
Cynodon dactylon Pers.	1(0)	3(0)	3	2
Cyperus quadrangularis	2(3)	10(3)	29	14
Digitaria adscenens H.B.K.	6(70)	14(33)	22	7
Emilia sanchifolia (Linn.) D.C.	0((0)	10(8)	8	6
Gallinsloga parviflora Cav.	0(0)	0(0)	8	6
Imperata cylindrica Beaw.	14(38)	17(31)	0	0
Oxalis latifolia H.B.K.	0(0)	0(0)	21	6
Mimosa sp.	3(0)	4(0)	3	3
Panicum khasianum Munro	0(24)	0(8)	2	2
Pennisetum polystachyon Schult.	19(83)	21(69)	5	3
Spillanthes acmella non mull.	408(83)	94(47)	517	59

Table 3.3. Biomass and nutrient (kg ha^{-1}) contribution through weed in terrace agroecosystem during cropping in north-east India. Values in parantheses are for grasses.

	Terrace age (yr)					
	4			12		
	Biomass	Nitrogen	Phosphorus	Biomass	Nitrogen	Phosphorus
1st cropping						
Total weed biomass	2050.2 (741.1)	22.6 (6.31)	0.2 (0.07)	2759.1 (254.5)	43.8 (2.5)	0.4 (0.03)
Weed put back	547.5 (167.4)	7.8 (2.4)	0.05 (0.02)	1009.3 (142.5)	8.5 (0.9)	0.13 (0.01)
2nd cropping						
Weed slash ploughed in prior to 2nd cropping	1502.7 (573.7)	14.9 (3.9)	0.2 (0.06)	-	-	-
Weed biomass	1038 (628.3)	12.5 (5.8)	0.1 (0.05)	-	-	-

Table 3.4. Nitrogen and phosphorus output (kg ha^{-1}) through edible and non-edible crop biomass under terrace ecosystem in north-east India. Values in parantheses are for phosphorus

Crop species	Terrace age (yr) 4 Edible	4 Non-edible	12 Edible	12 Non-edible
Grains				
Zea mays	33.82 (9.07)	60.66 (0.79)	27.2 (9.70)	39.95 (0.51)
Eleusine coracana	12.42 (0.27)	17.20 (0.45)	--	--
Vigna sinensis	0.03 (0.0002)	1.0 (0.008)	0.024(0.0002)	1.24 (0.013)
Phaseolus vulgaris	0.33 (0.003)	0.69 (0.005)	--	--
Total	46.6 ±4.9	79.55 ±3.4	27.22 ±2.4	41.19 ±4.2
	(9.34 ±0.8)	(1.25 ±0.2)	(9.70 ±0.8)	(0.52 ±0.1)
Leafy and fruit vegetables				
Momordica dioica	0.02 (0.004)	0.2 (0.003)	0.008(0.001)	0.37 (0.012)
Cucurbita maxima	0.29 (0.023)	0.002(0.002)	0.38 (0.02)	0.001 (0.001)
Hibiscus sabdariffa	0.003(0.0001)	0.022(0.00045)	--	--
Total	0.313±0.06	0.22 ±0.04	0.39 ±0.04	0.37 ±0.04
	(0.027±0.005)	(0.005±0.002)	(0.02 ±0.007)	(0.013 ±0.003)
Tubers and rhizomes				
Ipomoea batatus	--	--	--	0.45 (0.006)
Colocasia antiquorum	--	--	--	0.009 (0.0006)
Total	--	--	--	0.46 ±0.05
				(0.0006±0.002)
Grand total	46.91 ±4.7	79.77 ±3.0	27.61 ±3.3	42.02 ±3.5
	(9.37 ±0.9)	(1.26 ±0.1)	(9.72 ±1.1)	(0.54 ±0.1)

Dash represents absence of the species.

Table 3.5. Input/output patterns for nitrogen and phosphorus (kg $ha^{-1}yr^{-1}$) under terrace agroecosystems in north-east India. Value in the parantheses are for phosphorus

		Terrace age (yr) 4	12
Inputs			
Precipitation		4.28(1.09)	4.28(1.09)
Addition through plant biomass before fire		31.45(0.57)	65.45(0.81)
Thinned crop biomass		8.46(0.07)	3.93(0.03)
Weeds ploughed back during	1st crop	7.75(0.05)	8.46(0.13)
	2nd crop	14.88(0.13)	
Organic manure		13.8 (8.3)	11.7 (7.0)
Total		80.62(10.21)	93.82(9.06)
Outputs			
Fire		126.12(0.48)	239.45(0.94)
Sediment		4.07(0.01)	5.24(0.02)
Run-off		1.8 (0.5)	2.2 (0.5)
Percolation		2.1 (0.3)	0.99(0.2)
Weed removal during	1st crop	22.63(0.2)	43.75(0.41)
	2nd crop	12.52(0.09)	
Crop removal	1st crop	105.52(9.98)	73.93(10.28)
	2nd crop	29.62(0.71)	
Total		304.38(12.27)	365.56(12.35)
Net difference		223.76(2.06)	271.74(3.29)

Table 3.6. Net change in nitrogen and available phosphorus (kg $ha^{-1}yr^{-1}$) under terrace agroecosystems in north-east India. Values in the parantheses are for phosphorus

	Terrace age (yr)	
	4	12
Soil pool before burning	7715(21.30)	7674(22.19)
Soil pool at the end of cropping	6977(19.78)	6754(20.28)
Net difference	738(1.52)	920(1.91)

The amount of nitrogen removed through non-edible biomass was significantly higher ($P<0.01$) compared to that removed by edible biomass where as reverse was true for phosphorus (Table 3.4). Nitrogen and phosphorus removal through edible and non-edible components were higher under 4-yr old terrace than under 12-yr old one. During the second cropping of *Eleusine coracana*, nitrogen and phosphorus removal was higher through non-edible components than through edible parts.

Amongst the inputs into the agroecosystems the nutrients through weed slash was more under 12-yr old terrace whereas that through thinned crop biomass was more under 4-yr old one (Table 3.5). Nutrient input through weed biomass was higher under 4-yr old terrace because of the second cropping. More nutrients were removed through weeds under 12-yr old terrace where as crop removal was more under 4-yr old one. The net loss from the system was significantly higher ($P<0.05$) under 12-yr old terrace than under 4-yr old one.

At the end of cropping, the system had more nitrogen and phosphorus in the soil under 4-yr old terrace compared to 12-yr old one (Table 3.6). Consequently the net loss from the system after a year of cropping was more under 12-yr old terrace.

DISCUSSION

Though terrace cultivation has been introduced as an alternative to slash and burn agriculture (jhum) by Governmental agencies in Nayabunglow where this study was done, this landuse has been accepted only by the immigrant Nepalis who have been living in this area for many years; they have based it to some extent on jhum procedures. Thus, apart from slash and burn operations, they also do mixed cropping as under jhum. The slash available is limited to the biomass of weeds produced during the intervening fallow phase between December of the previous year and May of the following year, apart from the crop residue of the earlier cropping phase. Therefore, the terrace plot is subjected to a cool burn, so that the loss through volatalization is much less than under jhum (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983a). However, the loss of nitrogen from 12-yr old terrace plot is almost double that under 4-yr old plot because of increased weed potential in older sites (Saxena and Ramakrishnan, 1984a) that contributes to more slash load.

Unlike nitrogen volatalization(Allen, 1964; Knight, 1965; Debel and Ralston, 1970) there are no obvious mechanisms for volatalization of phosphorus, though heavy losses of this element has been reported earlier by some workers (Rajson, 1980; Ashton, 1976; Mishra and Ramakrishnan, 1983a). The slight loss of phosphorus reported here under a cool burn may be due to convective losses of particulates (Freedman, 1981).

Weed potential on a site in the humid tropics is a function of the frequency in perturbation. Thus, with shortening in the jhum cycle to 4-5 years the weed potential of the site would get exaggerated (Saxena and Ramakrishnan, 1984a) resulting in an arrested succession at the weed stage because during the short fallow period secondary succession is not allowed to go beyond this stage (Toky and Ramakrishnan, 1983). With continuous cropping on a terrace over a longer time it is reasonable to expect an increase in weed potential of the site as seen from the present study. More interestingly, whereas during the first cropping on a 4-yr old terrace the weeds are largely dicots of the family Compositae, during the second cropping on the same site they are largely graminaceous. With a drastic decline in the nutrient status of the soil after the first crop removal the C_4 grasses have an advantage over C_3 dicots because of their higher nitrogen use efficiencies (Saxena and Ramakrishnan, 1984b). This is reflected in the proportion contributed by dicot versus graminaceous weeds in terms of biomass and in terms of nitrogen. For a given quantity of weed biomass, graminaceous species consume much less nitrogen compared to dicot weeds. Thus, the weed species growing in less fertile soils have generally lower nutrient concentrations unlike some others that may have luxury consumption but with reduced growth rate (Epstein, 1972; Chapin, 1980; Auclair, 1977).

The total amount of nitrogen and phosphorus recycled through crop residue was 1 $\frac{1}{2}$ times more than that was removed through the edible component; this was more obvious for grains and pulses. With a large biomass for the non-edible component as compared to the edible component in traditional crop cultivars (Sanchez, 1976; Ramakrishnan, 1984), lesser nutrient removal through economic yield is expected.

A comparison of nitrogen/phosphorus budgets under 4- and 12-yr old terrace suggest that only about $^1/_3$ of the weed biomass is recycled into the crop system where as $^2/_3$ is retained _in situ_. This is because of the farmers involvement in other extra activities such as jhum, valley cultivation and animal husbandry. In any case, this weed biomass retained is a drain on the resources with possible reduction in yield of the crops. While nutrients removal through weeds was higher under 12-yr old terrace inspite of one cropping only, poorer soil physical properties under longer cropping period would also exaggerate nutrient loss through sediment and run-off water. The crop removal here is very low indeed. All these result in a greater net loss from older terraces.

Over a period of time, the terrace becomes less productive and eventually contributes to desertification of the site. The farmer is then forced to leave the plot permanently. While under jhum, labile element such as nitrogen and phosphorus is recovered during the fallow phase of secondary succession, such a recovery does not happen under terrace cultivation because of continuous cropping. Therefore under of terraces, nitrogen and phosphorus are critical elements and these can be maintained effectively in the system only through tighter recycling of organic resources or through input of inorganic fertilizers.

SUMMARY

Nitrogen and phosphorus budgets under 4- and 12-yr old terrace agroecosystems were analysed at Nayabunglow at an elevation of 960 m in Meghalaya in north-east India. Nitrogen and phosphorus losses due to fire under 12-yr old terraces were more than under 4-yr old one due to greater slash load. On 4-yr old terrace, where a second cropping was done, a shift from dicot to monocot weeds occurred during the second cropping and thus was related to reduced nutrient availability at this time. The net loss of nitrogen and phosphorus from the system was more from the older terrace.

CHAPTER 4

NUTRIENT BUDGET UNDER TERRACE AGROECOSYSTEM OF MEGHALAYA IN NORTH-EAST INDIA. II. CALCIUM MAGNESIUM AND POTASSIUM

INTRODUCTION

In an earlier chapter (Chapter 3) nitrogen and phosphorus budgets under terrace cultivation in north-east India was considered and shown that large quantities of nitrogen and some of phosphorus is lost during the burn. Volatalization of nitrogen (Allen, 1964; Knight, 1965; Debel and Ralston, 1970; Mishra and Ramakrishnan, 1984) and loss through particulates for phosphorus (Freedman, 1981) were implicated. Terrace cultivation introduced as an alternative to slash and burn agriculture (jhum) in north-east India has had only limited acceptance by the local communities and where practiced it is largely by the immigrant Nepalis, but incorporating some of the features of slash and burn agriculture such as slash and burn of the weeds and crop residues followed by mixed cropping. One of the important factors affecting long term sustainability of terrace cultivation is related to soil fertility maintenance. The present paper considers the budgeting of cations under terraces maintained for different time durations at Nayabunglow 30 km north of Shillong in Meghalaya (960 m) in north-east India.

METHODS

4- and 12-yr old terrace plots (each with three replicates) were identified at Nayabunglow 30 km north of Shillong at an elevation of 960 m, in Meghalaya in north-east India. While selecting the plots similar aspect and topographic conditions were ensured.

Direct fall through precipitation was collected from 10 random points in each plot. Soil sampling upto a depth of 40 cm was done by using a core sampler at 15 random points on each plot at three times during the year : (i) a day before burning the slash prior to cropping, (ii) a day after the burn and (iii) at the end of cropping.

The amount of slash burnt and the organic manure input into the agroecosystem were quantified on the basis of 10 observations made in each plot. The nutrient input into the agroecosystem was then quantified. Nutrients removed through crop thinning, crop uptake, weed uptake and recycling through weeds ploughed back into the system were all based on 10 random observations in each plot, using 1 m^2 quadrats.

For studies pertaining to cation losses through sediment and run-off water, loss from a confined area of 1 X 10 m was collected in large collectors and sampled periodically for chemical analysis. For the study of percolation loss of cations, zero tension lysimeters were used. Soil was cut vertically at 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 30X30X15 cm 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 were based on five replicates in each plot. A few drops of 40% formal-dehyde was added to the samples to stop biological activity immediately after collection.

The amount of nutrients present in the soil pool (kg ha^{-1}) was calculated to a depth of 40 cm using soil bulk density estimates calculated for each site, at depths of 0-7, 7-14, 14-28 and 28-40 cm, considered separately. Bulk density or volume weight (the quotient of the air dry mass weight of the soil to the total volume it occupies in each field) was determined from the air dry mass of a known field volume of soil.

The soil was air dried and plant samples were oven dried at 60°C for 48 hours, powdered and passed through 0.2 mm sieve and stored in glass jars for subsequent analysis by procedures given by Allen _et al_., (1974). Plant samples were wet digested with triple acids (perchloric acid, nitric acid and sulphuric acid) and soils were extracted with 1 M ammonium acetate solution at pH 7. Thus calcium and magnesium were estimated by EDTA titration and potassium by flame emission method.

Table 4.1. Gain of cations through fire (kg ha^{-1}) under terrace agroecosystem in north-east India

	Terrace age (yr)					
	4			12		
	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Pre-burn soil pool	510	2122	792	982	1385	1086
Addition through						
Weed residue	23	10	13	38	26	27
Crop residue	57	39	32	53	36	32
Post-burn soil pool	797	2272	1043	1155	1581	1308
Net gain	207	101	205	82	134	165

Table 4.2. Contribution through weed (kg ha^{-1}) during cropping under terrace agroecosystem in north-east India. Values within parantheses are for grasses

	Terrace age (yr)							
	4				12			
	Biomass	Potassium	Calcium	Magnesium	Biomass	Potassium	Calcium	Magnesium
1st cropping								
Weed biomass	2050(741)	32(10)	20(6.2)	23(8)	2759(255)	44(5)	37(2)	43(3)
Weed recycled during cropping	548(167)	8(3)	6(2)	7(2)	1009(143)	15(2)	12(1)	13(1.2)
2nd cropping								
Weed slash ploughed in prior to second cropping	1503(574)	23(7.4)	14(5)	16(6)	--	--	--	--
Weed biomass	1038(628)	17(7.1)	11(5.2)	12(5.4)	--	--	--	--

-- Indicates absence of cropping.

Calculations of the amount of nutrients (potassium, calcium and magnesium) gained due to slash burning are based on the differences of that element present in the soil up to a depth of 40 cm between pre-burn (a day before burn) and that present in the soil a day after burn. Input and output of elements for each plot were calculated on the basis of the amount of that particular input/output and the concentration of the element in it.

RESULTS

Potassium and magnesium in the soil pool at different stages were markedly higher under 12-yr old terrace than under 4-yr old terrace (Table 4.1). Addition through weed and crop residue was more under 12-yr old terrace than under 4-yr old one. The net gain of potassium and magnesium in the post-burn soil pool was more under 4-yr old terrace than under 12-yr old one and the reverse was true for calcium.

During the first cropping, more cation was immobilized by the weeds and more addition occurred through them under 12-yr old terrace than under 4-yr old one (Table 4.2). However, the proportional contribution through grasses was more under 4-yr old terrace than under 12-yr. During the second cropping on 4-yr old terrace, the cations recycled through weeds originated from the previous cropping season. Further the

Table 4.3. Cation removal (kg ha^{-1}) through edible and non-edible crop biomass under terrace agroecosystems in north-east India. Values within parantheses are for non-edible component

	Terrace age (yr) 4			12		
	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Grains and pulses						
Zea mays	7.8 (42.4)	11.5 (34.6)	17.8 (37.1)	11.8 (49.3)	12.43 (27)	15.5 (23.8
Eleusine coracana[1]	18.9 (49.1)	33.1 (37.1)	16.6 (36.1)	--	--	--
Vigna sinensis	0.02 (0.9)	0.02 (0.34)	0.02(0.6)	0.02 (2.02)	0.012(0.5)	0.02(0.8
Phaseolus vulgaris	0.18 (0.7)	0.2 (0.26)	0.28(0.5)	--	--	--
Total	26.9 (93.1)	44.82 (72.3)	34.7 (74.3)	11.8 (51.3)	12.44 (27.5)	15.6 (24.5
Leafy and fruit vegetables						
Momordica dioica	0.03 (0.4)	0.02 (0.2)	0.03(0.02)	0.013(1.3)	0.01 (0.45)	0.02(0.4
Cucurbita maxima	1.38 (0.2)	0.03 (1)	0.05(0.01)	2.5 (0.2)	0.04 (0.04)	0.05(0.06
Hibiscus sabdariffa	0.009(0.03)	0.005(0.004)	0.01(0.02)	--	--	--
Total	1.4 (0.6)	0.06 (0.3)	0.09(0.06)	2.5 (1.4)	0.05 (0.5)	0.1 (0.5
Tuber and rhizomes						
Ipomoea batatus	--	--	--	- (1.6)	- (0.3)	- ((0.4
Colocasia antiquorum	--	--	--	- (0.2)	- (0.003)	- (0.1
Total	--	--	--	- (1.8)	- (0.3)	- (0.5
Grand total	28.3 (93.7)	44.9 (72.6)	34.8 (74.4)	14.3 (54.5)	12.5 (28.3)	15.6 (25.5

[1]Grown as a 2nd crop of the mono cropping system.

Table 4.4. Input/output patterns for cations (kg ha^{-1}) under terrace agroecosystems in north-east India

	Terrace age (yr)					
	4			12		
	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
Inputs						
Precipitation	4.1	7.4	7	4.1	7.4	7
Addition through fire	207	101	205	82	134	165
Thinned crop biomass	6.8	4.1	3.8	5.01	2.0	1.8
Weeds ploughed back during						
1st crop	23.4	14.4	15.9	14.6	12.2	13
2nd crop	8.3	5.9	7.1	-	-	-
Organic manure	16.6	10.2	9.1	14.1	8.7	7.7
Total (a)	266	143	248	120	164	195
Outputs						
Sediment	2.1	3.6	4.1	5.1	4.6	5.1
Run-off	20	7.1	8.1	19.3	13.3	6.1
Percolation	7.9	2.7	2.5	6.1	3.1	3.4
Weed removal during						
1st crop	31.7	20.3	23.0	44.3	36.8	43
2nd crop	16.8	10.8	11.9	-	-	-
Crop removal during						
1st crop	60.8	51.3	60.3	73.8	42.8	43
2nd crop	68.0	70.2	53	-	-	-
Total (b)	207	166	163	149	101	101
Net differences (a-b)	+ 59	- 23	+ 85	- 29	+ 63	+ 94

Table 4.5. Net change in nutrients (kg $ha^{-1}yr^{-1}$) under terrace agroecosystem in north-east India

	Terrace age (yr)					
	4			12		
	Potassium	Calcium	Magnesium	Potassium	Calcium	Magnesium
(a) Soil pool before burning	510	2122	792	982	1085	1379
(b) Soil pool at the end of the cropping	552	1473	1307	643	1670	1547
(a-b) Net difference	42	649	574	339	584	168

proportional contribution by grass species was more than through dicots.

Total nutrient removal by edible and non-edible components of crop species was higher under 4-yr old terrace than under 12-yr old one (Table 4.3). If the second cropping done under 4-yr old terrace is excluded the reverse was found to be the case. *Eleusine coracana* under 4-yr old terrace removed a larger proportion of potassium during the second cropping season than other species of the first cropping phase. Removal of nutrients through non-edible component for a given species was significantly higher ($P<0.01$) than through edible parts.

The input/output pattern for cations is given in Table 4.4. While there was a net gain of potassium under 4-yr old terrace, there was loss under 12-yr old one; the reverse was true for calcium. Magnesium gain was more or less similar under 4- and 12-yr old terraces. In general, the input and output totals were more under 4-yr old terrace than under 12-yr.

Nutrient status both before burn and after cropping was higher under 12-yr old terrace than under 4-yr old one, the exception being calcium (Table 4.5). A net loss in calcium under 4-yr old terrace and a similar loss for potassium under 12-yr old terrace were noted, while others showed a net gain at the end of cropping.

DISCUSSION

Terrace cultivation introduced as an alternative land use to replace jhum is largely practised by non-tribal immigrant Nepalis in this region. Apart from the input of organic fertilizers such as cow dung, for terrace cultivation slash and burn operation associated with shifting agriculture (Nye and Greenland, 1960; Spencer, 1966; Ruthenburg, 1976; Ramakrishnan, 1984) is also done. However, the slash is largely the crop and weed residues from the previous cropping season. While massive losses of nitrogen and some loss of phosphorus are associated with the cool burn (Chapter 3), a substantial increase in exchangeable cations occurred after the burn. All the increase that occurred in the soil pool could not be accounted by the input through ash. Obviously, mobilization of cations into the exchange pool after the burn may be an important factor and may be related to increased cation exchange capacity of the soil and the consequent interchange between non-exchangeable to exchangeable forms due to burning (Stromgaard, 1984).

With a higher weed potential on older terraces, the biomass recycled through this component of the agroecosystem is two times more under a 12-yr old terrace than under 4-yr old one, during the first cropping. During the second cropping under 4-yr old terrace, the weed slash from the previous cropping phase is just ploughed in and not subjected to burn. If this is considered together with the weed biomass put back during the first cropping phase, the weed recycled becomes more under 4-yr old terrace than under 12-yr old one. Because of higher weed potential of the site under 12-yr old terrace, the nutrient removal by the weed population was more here compared to 4-yr old one, inspite of two croppings under the latter situation. In contrast to this, crop removal of cations was markedly higher under 4-yr old terrace than in the older one.

The above discussed differences between the two terrace systems when considered along with nutrient losses related to hydrology (where losses were more under older terraces because of poor physical quality of the soil) the input was higher than the output for a labile element such as potassium under a 4-yr old terrace. This may be related to drastic decline in the nutrient status of the soil under continuous cropping (Asamoa, 1980; Cowgill, 1961; Bray, 1975; Sanchez, 1976) which results in decline in crop production. The negative value for calcium under 4-yr old terrace may be related to high uptake by Eleusine coracana during second cropping.

The results presented here and that for nitrogen and phosphorus presented earlier (Chapter 3) thus suggests that continuous cropping on terraces apart from adversely affecting soil fertility also results in increased weed potential of the site, both of which contribute to reduced crop yield.

SUMMARY

Cation budgeting was done under 4- and 12-yr old terraces at higher elevation of Meghalaya (960 m) in north-east India. Cation addition occurred after burning the biomass prior to cropping, both through crop and weed residue and also through fire effects related to conversion from non-exchangeable to exchangeable form. While nutrient removal through weeds was more under 12-yr old terrace than under 4-yr old one, the reverse was true for that removed by crop. Nutrient deficit, particularly potassium, was obvious under 12-yr old terrace. Decline in soil fertility and increase in weed potential are implicated in reduced crop yield.

PART II

CHAPTER 5

COMPARATIVE STUDY OF ENERGY FLOW THROUGH VILLAGE ECOSYSTEMS OF TWO CO EXISTING COMMUNITIES (THE KHASIS AND THE NEPALIS) OF MEGHALAYA IN NORTH EAST INDIA

INTRODUCTION

Analysing the flow of energy through an ecosystem or a society is useful in describing how the system functions (Loucks and D' Alessio, 1975). Such an approach presupposes the ordering of the great number of phenomena which can be observed in a given rural area into entities or systems, ie., sets of related elements. A village is both an ecosystem and an independent unit of economic activity. A village ecosystem could, therefore, be considered as a number of sub-systems with agriculture, animal husbandry and domestic as sub-systems and as independent units of economic activity (Walter, 1973; Sunderraj and Mitchell, 1987; Reddy, 1981). Studies on village ecosystem function in traditional societies are limited except for a few studies from north-east India (Mishra and Ramakrishnan, 1982). The studies on coexistence of two distinct communities in a given area with a common resource base is also limited (Maikhuri, 1987). As the closeness of the village ecosystem to city centres has also had its impact, the present study is aimed at looking at the ecosystem function of two villages located close to Shillong, a large city in the region. The study also aims at a comparative analysis of two communities, one the local Khasi community and the other the Nepalis and to evaluate the differences using money and energy as currencies for economic and ecologic efficiencies.

DESCRIPTION OF AGROECOSYSTEM

Slash and burn agriculture

The tribals of north-east India practise slash and burn agriculture locally called jhum. The practice consists of clear-cutting the forest at various stages of succession followed by drying the slash for a few months during December-April. The dried slash is kept in parallel rows running down the slope and topped over by a thin layer of soil so that these form ridges alternating with compacted furrows. Thus the slash is burnt in a controlled manner. After burning and before the onset of the monsoon in May, rhizomes of *Zingiber officinalis*, *Colocasia antiquorum* and seeds of various vegetables are planted on the ridges. First harvest of ginger is done in August along with vegetable crops. The harvest of ginger is partial without disturbing the shoot. The second harvest of ginger and tuber crops is done during December. Fertilizers are not used in this system. The land is abandoned for fallow regrowth through natural vegetational succession.

Valley cultivation

Wet rice cultivation is done in valley lands. A crop of rice is taken annually both by the Khasis and the Nepalis. Some inorganic fertilizer at the rate of 102 kg ha^{-1} is added in the soil by both the communities. Ploughing and land preparation is done during the month of May-June using bullocks. Khasis hire bullocks for the land preparation. Other operations such as transplanting, weeding, harvesting, threshing etc. are done manually by both male and female members of the family. Both Khasis and Nepalis give land revenue as rent to the Khasi owner of the land in the city.

Pine apple plantation

Pine apples (Ananas comosus) are cultivated on slopes by only 7 out of 42 families of the Khasis. Two harvests are taken from the same plot, once in July-August (monsoon variety) and another in December-January (winter variety). Weeding is done twice in June and December.

Kitchen garden

A mixture of crops are grown together in the kitchen garden. After the initial application of organic manure in the plot in March, the field is prepared by using bullocks by male members of the family. A mixture of crops are dibbled in May after the onset of monsoon. Other preparation such as weeding, harvesting are done manually by both male and female members of the family. Second crop of Eleusine coracana is done between August-December in the same plot.

Table 5.1. Ecosystem structure of typical Khasi and Nepali villages in Meghalaya in north-east India

	Khasis/ Umtrou	Nepalis/ Guntei
Number of household	40	42
Total human population	198	172
Adult male	64	59
Adult female	58	41
Children 5-7 yrs old	39	44
Children 7-9 yrs old	18	6
Children 9-12 yrs old	19	22
Total area under cultivation (ha)	14.3	27
Area under jhum	3	-
Area under valley	9	11.9
Area under pine-apple plantation	2.3	-
Area under kitchen garden	-	13
Area under fodder grass cultivation	-	2
Total animal population	86	251
Pig	24	-
Milking cow	-	96
Bullock	-	55
Goat	-	53
Chicken	62	47

Fodder grass cultivation

Fodder grass Pennisetum purpurea is done by the Nepalis for their cattle, by broadcasting seeds in May after the first few showers and after preparing the land as for the kitchen garden.

METHODS

For studies of village ecosystem of the Khasis and the Nepalis (Table 5.1) nine house holds of each category were selected. All the activities in the village were closely monitored and quantified over a one year period. The observations on agriculture were based on three replicate plots. While selecting the plots care was taken to ensure similar topographic conditions.

Phytosociology of crop species and economic yield was calculated on the basis of yield from the entire plot. Economic yield per plant of each species was determined by taking the average of 10 plants from each replicate plot. Total economic yield was converted into rupees on the basis of prevailing market prices.

The energy values for economic yield of crops were based on standard values given in Table 5.2. Energy input through seed was calculated on the basis of total energy expended to produce that fraction of the crop yield.

Table 5.2. Caloric values for different crops (dry wt. megajoule equivalent)

Category	Average energy value ($MJ\ kg^{-1}$)
Nutritive food value*	
Grains	16.29
Pulses	16.24
Leafy vegetables	13.75
Roots and tubers	13.76
Pine apple	15.78
Fodder grass**	15.77
Production costs***	
N	76.99
P_2O_5	13.95
K_2O	9.66

*Gopalan *et al*. (1978)

**Mitchell (1979)

***Pimental *et al*. (1973)

Labour hour expended for each category of work was recorded. Total food energy consumed was apportioned to each activity (Leach, 1976) according to relative duration on the basis of groupings, involving either sedentary, moderate or heavy work. Per hour energy expenditure of 0.418 MJ for sedentary work, 0.488 MJ for moderate work and 0.679 MJ for heavy work for an adult male and 0.331 MJ for sedentary work, 0.383 MJ for moderate work and 0.523 MJ for heavy work for an adult female, were used to calaulate labour energy input into the sub-systems (Gopalan et al., 1978). Per hour energy expenditure by a pair of bullock was calculated to be 3.03 MJ per hour (Mitchell, 1979).

Input of fertilizer was converted into energy by multiplying quantities by the standard values given in Table 5.2.

The weight gained by each category of animal at the time of slaughter was used for calculating annual meat production. The values thus obtained were corrected using a dressing percentage of 75, 56 and 70 for pig, lamb and fowl respectively (Ranjhan, 1977). Using the energy values 4.937, 4.56 for goat meat and chicken, respectively (Gopalan et al., 1978) and 17.121 MJ kg^{-1} for pork (Ranjhan, 1977) the energy equivalent of secondary production through animal was calculated. Similarly the energy values for the cows' milk and egg was 2.8 and 7.238, respectively (Gopalan et al., 1978).

Table5.3. Energy values (MJ kg^{-1}) for different components considered in the different husbandry system

Category	Energy value
Feed/Fodder[1]	
Grains	16.29
Tuber	13.76
Straw	8.899
Rice hull	8.46
Oil cake	3.65
Green fodder[2]	15.77
Fire wood	19.69
Manure	Replacement cost
Swine dung[3]	1.32
Goat dung	2.00
Cattle dung	2.98
Poultry dung	2.98

[1]Ranjhan (1979)

[2]Mitchell (1979)

[3]Percentage of N, P_2O_5, and K_2O in various items were 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 cattle dung 1.61, 0.85 and 1.2; in poultry dung 5.14, 4.19 and 2.5.

Energy output through animal power (1 pair of bullock hour = 3.03 MJ) was based on Mitchell (1979). The total dung production per animal of each category was expressed on a dry weight basis. This was then converted into energy by multiplying their quantities with standard values given in Table 5.3.

Cost-benefit analysis of agriculture and animal husbandry sub-systems was calculated on the basis of prevailing market rates. Thus labour wages for agriculture were calculated at the rate of Rs. 17 and Rs. 12 for male and female labour, respectively. Economic efficiency was calculated as output/input ratio.

Estimation of actual amount of food/fuelwood consumed was based on regular measurement made in the village and the energy equivalent of the food items (Gopalan _et al_., 1978) and 19.7 MJ Kg^{-1} for fuelwood (Mitchell, 1979). The protein equivalents of all food produced and that part of it consumed was determined by multiplying the quantity of food and their respective protein contents (Gopalan _et al_., 1978).

For calculating the output of energy the total economic yield of various crops was converted into megajoules of energy by multiplying with standard values of various edible parts of crops as given in Table 5.2.

The estimation of feed and fodder consumed by livestock was based on daily ration consumed by the animals and converted

Table 5.4. Daily food energy requirement of different categories of animals (Ranjhan, 1977)

Category	Body wt/age	Daily energy requirement (MJ)
Cattle	600 kg	79
	300 kg	
Goat adult	20-25 kg	69.7
Juvenile	15-20 kg	10.5
	5-15 kg	5.9
Pig	40-50 kg	13.8
	30-40 kg	13.9
	20-30 kg	13.8
	10-20 kg	14.7
Poultry	0- 8 weeks	11.1
	8-20 weeks	10.6
	20 weeks or more	11.5

ıto energy equivalent by multiplying the quantities consumed ith standard values Table 5.3. The difference between the tandard food energy requirement under Indian conditions (Table 5.4) or each category of animal (Ranjhan, 1977) was substracted from ıe stall feeding values to obtain the food energy consumed ırough grazing/browsing/scavenging.

For calculating the theoretical food energy/protein requirement of the humans, the total consumption unit (adult man value) for the family was calculated from the energy consumption scale suggested by Gopalan _et al_. (1978):, one adult male, 1 unit; one adult female 0.9 unit, children aged 5-7 years, 7-9 years and 9-12 years, 0.6, 0.7 and 0.8 units respectively. The total number of units were then multiplied by the food energy equivalent of an adult (1 unit) of 10.042 MJ day^{-1} and protein equivalent of an adult (1 unit) of 55 g day^{-1} (Gopalan et al., 1978) to calculate daily food energy/protein requirement. 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).

The monetary values of each commodity was calculated on the basis of prevailing market price.

Table 5.5. Mean economic yield (kg $ha^{-1}yr^{-1}$ and Rs. $ha^{-1}yr^{-1}$) of crop species under different agroecosystem and horticultural plantation of the Khasi tribe in Nayabunglow in north-east India

	kg $ha^{-1}yr^{-1}$	Rs. $ha^{-1}yr^{-1}$
5-yr jhum cycle		
Zingiber officinalis[1]	1248(745)	6117(3727)
Colocasia antiquorum	105	563
Ipomoea batatus	213	840
7-yr jhum cycle		
Zingiber officinalis[1]	1911(1266)	11663(8440)
Colocasia antiquorum	187	737
Cucurbita maxima	38	690
Capsicum frutesence	36	1104
10-yr jhum cycle		
Zingiber officinalis[1]	2301(1622)	14208(10813)
Colocasia antiquorum	235	926
Ipomoea batatus	270	1065
Cucurbita maxima	33	1183
Capsicum frutesence	32	988
Valley		
Oryza sativa	2934	5501
Horticultural plantation		
Ananas comosus[1]	2933(803)	77000(24500)

[1]Yield from second cropping done during September to December is given in parantheses.

Table 5.6. Energy (MJ $ha^{-1}yr^{-1}$) and monetary (Rs. $ha^{-1}yr^{-1}$) efficiency in different agroecosystem of the Khasis in Nayabunglow in north-east India

	Jhum cycle (yr) 5		7		10		Valley		Pineapple	
	Energy	Economy	Energy	Economy	Energy	Economy	Energy	Economy	Energy	Economy
Input total	1718	7431	2032	9693	2046	10548	4903	4257	820	3461
Human labour	1253	4800	1533	6154	1584	6902	678	3150	820	3461
Bullock power	--	--	--	--	--	--	491	533	--	--
Seed	465	2631	499	3539	462	3646	193	300	--	--
Inorganic fertilizer	--	--	--	--	--	--	3541	274	--	--
Output total	21561	7520	29886	14194	39505	18370	47795	6334[1]	46270	77000
Output/input ratio	12.55	1.01	14.7	1.46	19.31	1.74	9.75	1.49	56.43	22.25

[1] Rs. 5501 was through grain and Rs. 833 through rice straw.

RESULTS

Agriculture sub-system

With the shortening of the jhum cycle, the Khasis emphasize exclusively upon tuber and rhizome crops, particularly ginger which give maximum returns to the farmer (Table 5.5). This contrasts with longer cycles where vegetables are also important. The economic yield declined with the shortening of the jhum cycle. The return under valley cultivation was minimal. Pine apple cultivation done on slopes gave very high returns.

The major input into all agroecosystem is labour followed by seed (Table 5.6). This input increased under longer jhum cycles. Valley cultivation required lower labour input, both human and bullock; the former was more. Labour input for pine apple cultivation was lowest. Some inorganic fertilizer was used for valley cultivation. Though energy input increased with increase in the length of the jhum cycle, the output too improved, with sharply improved efficiencies. The energy efficiency of pine apple cultivation was the highest compared to all others.

With a greater emphasis on maize in the kitchen garden of the Nepalis, this gave maximum returns to the farmers (Table 5.7). The yield under valley cultivation was very low

Table 5.7. a^{-1}yr^{-1} and Rs. ha^{-1}yr^{-1}

ferent agroecosystems of

the Nepalis in Nayabunglow in north-east India

	Kg ha^{-1}yr^{-1}	Rs. ha^{-1}yr^{-1}
Kitchen garden		
Grains and legume		
Zea mays	4074	6110
Eleusine coracana[1]	3453	5180
Vigna sinensis	17	986
Leafy and fruit vegetables		
Momordica dioica	12	330
Cucurbita maxima	86	3063
Cucumis sativus	26	3190
Hibiscus sabdariffa	25	203
Capsicum frutesence	12	260
Valley		
Oryza sativa	3120	5460
Fodder		
Pennisetum purpurea	1640	1450

[1]This species was in pure stands during second cropping.

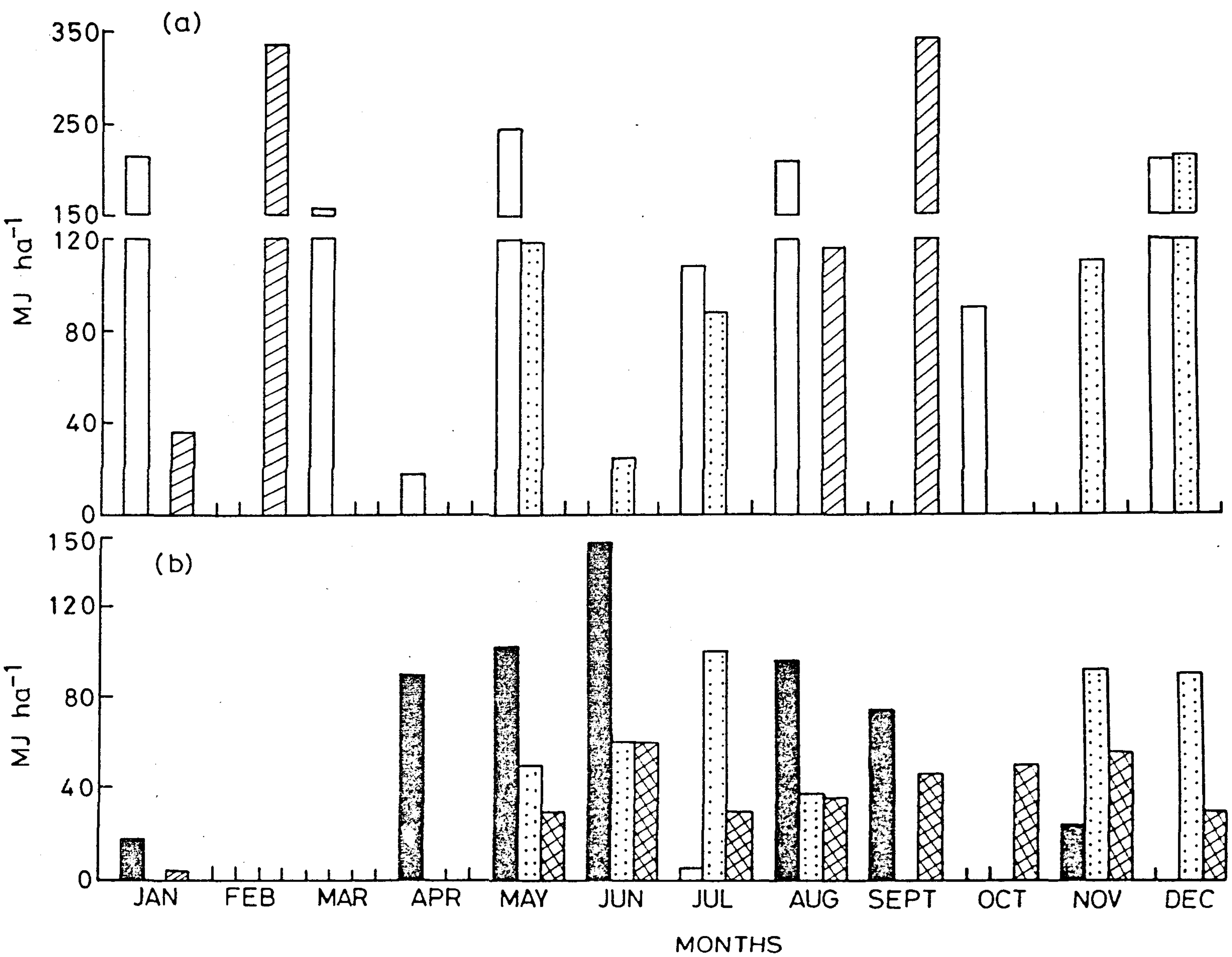
Table 5.8. Energy (MJ $ha^{-1}yr^{-1}$) and monetary (Rs. $ha^{-1}yr^{-1}$) efficiencies of different agroecosystems of Nepalis in Nayabunglow in north-east India. Values in the parantheses are for the second crop

	Kitchen garden		Valley		Fodder grass	
	Energy	Economy	Energy	Economy	Energy	Economy
Input total	4052(790)	4285(2696)	4623	2890	1601	1338
Human labour	431(763)	2040(2633)	427	1897	318	700
Bullock power	147	160	307	333	184	200
Seed	24(8)	132(50)	171	300	127	--
Organic manure	3450(19)	1953(13)	--	--	972	438
Inorganic fertilizer	--	--	3718	360	--	--
Output total	68813(56249)	14142(5180)	50825	6460[1]	25863	1450
Output/input ratio	17(71.2)	3.3(1.9)	11	2.2	16.2	1.1

[1]Rs. 5460 was through grains and Rs. 1000 through rice straw.

Fig. 5.1 Distribution pattern of labour over a year under different agroecosystems of the Khasis and the Nepalis in Meghalaya in north-east India

a, Khasis; b, Nepalis □ , 5-yr jhum cycle; ⊡ Valley cultivation; ▨ , Pine apple plantation; ▩ , Kitchen garden ; ■ , Fodder grass.


(a)
350
250
150
120
80
40
0
MJ ha-1
(b)
150
120
80
40
0
MJ ha-1
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC
MONTHS

compared to mixed cropping of kitchen garden. Pennisetum purpurea grown as fodder for cattle gave minimal returns compared to others.

The major input into the agroecosystem of the Nepalis was human labour along with some bullock power (Table 5.8). Manure input in the form of cow dung was maximum for the kitchen garden. Valley cultivation had only some inorganic fertilizer input. With higher economic and energy outputs from the kitchen garden, the economic and energy efficiencies of this system for the mixed cropping was higher than the valley cultivation. Fodder grass cultivation has a very low economic efficiency. The energy efficiency of the second cropping of Eleusine coracana was very high, though the economic efficiency was lower.

For the Khasis, the labour distribution for jhum was uniformly destributed during the year (Fig. 5.1). Valley cultivation had labour input during two months in a year, one during crop introduction and another during harvest after three months. Pine apple also had labour input during two months once for weeding and another for harvest. It may be noted that pine apple was already introduced into the site earlier. Much of the labour input into different agroecosystems are uniformly distributed during April to December by the Nepalis, January to March is relatively free.

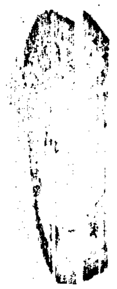


Table 5.9. *Energy output/input ratio* (MJ yr^{-1} $animal^{-1}$) for different animal husbandry systems of the Khasis and the Nepalis in Nayabunglow in north-east India

	Khasis		Nepalis			
	Swine	Poultry	Milking cow	Bullock	Goat	Poultry
Input total	6718	4203	38093	38093	5358	4221
Labour	47	5	1092	1092	35	23
Feed	4440	297	11907	11907	1545	892
Fire Wood	1597	--	7985	7985	1198	--
Fodder	--	--	6782	6782	2159	--
Grazing/browging/scavanging	634	3901	10327	10327	421	3306
Output total	750	197	6722	902	237	176
Dung	106	161	583	583	146	147
Milk	--	--	6139	--	--	--
Meat	644	6	--	--	91	5
Egg	--	29	--	--	--	24
Draught power	--	--	--	319	--	--
Output/input ratio	0.11	0.047	0.18	0.024	0.044	0.04

Table 5.10. Monetary output/input ratio (Rs. $yr^{-1}animal^{-1}$) of different animal husbandry systems of the Khasis and the Nepalis in Nayabunglow in north-east India

	Khasis		Nepalis			
	Swine	Poultry	Milking cow	Bullock	Goat	Poultry
Input total	660	87	2576	2576	354	102
Labour	228	23	915	915	152	20
Cattle feed	371	55	1577	1577	134	82
Firewood	61	-	84	84	68	-
Output total	1100	113	8976	916	415	87
Milk	--	-	8760	--	-	-
Draught power	--	-	--	700	-	-
Dung	50	11	216	216	23	9
Meat	1050	27	--	--	392	22
Egg	--	75	--	--	-	56
Output/input ratio	1.67	1.3	3.48	0.36	1.17	0.85

Animal husbandry sub-system

With higher input and output values for cattle husbandry the energy efficiency of this system of the Nepalis was highest followed by swine husbandry of the Khasis (Table 5.9). Bullock maintenance was more expensive as the labour derived from it was less. The feed for the animal husbandry was a major input. Cattle and goat maintenance also involved fodder, stall fed or obtained by the animal from the wild as well as fuelwood for cooking the feed. Cattle maintenance by the Nepalis was largely for milk production.

From an economic point of view, bullock maintenance was more expensive than cattle for milking (Table 5.10). Poultry husbandry of Khasis was economically more efficient than that of the Nepalis. Swine husbandry had a high economic efficiency next only to cattle husbandry for milking.

Domestic sub-system

Both the Khasis and the Nepalis had more land under valley than under other landuse systems (Table 5.11). The jhum plot of the Khasis was small partly due to this and partly because of its own merit the output from the valley system was markedly higher. On a unit area basis, kitchen garden yielded more than the valley system. Both the communities consumed half or more

Table 5.11. Comparative analysis of production and consumption pattern (MJ yr^{-1}) from agriculture of a Khasi and a Nepali family in Nayabunglow in north-east India. (Value in the parantheses are for the second crop)

	Khasis		Nepalis		
	5-Yr jhum	Valley	Valley	Kitchen garden	Fodder
Size of the area (ha)	0.07	0.6	0.6	0.3 (0.15)	0.1
Economic yield	1063	28677	30495	20644 (8437)	2830
Utilization					
Seed	292	1303	1042	361 (163)	244
Human consumption	59	13039	14206	6058 (489)	--
Animal consumption	--	--	--	12278	2586
Export	681	--	--	1947 (7785)	--
Land revenue	--	14335	15247	--	--
By product yield	--	11038	12161	--	--
Utilization					
Animal consumption	31	--	12161	--	--
Export	--	11038	--	--	--
Import					
Inorganic fertilizer	--	2125	2231	--	--
Human labour	--	133	141	-- (14)	--
Bullock power	--	295	--	--	--

Table 5.12. Comparative analysis of production and consumption patterns (Rs. yr^{-1}) from agriculture of a Khasi and Nepali family in Nayabunglow in north-east India

	Khasis	Nepalis
Area (ha)	0.67	1.0
Inputs total	2994	4918
Human labour		
Inside	1446	2665
Outside	780	788
Animal labour		
Inside	--	310
Outside	320	--
Inorganic fertilizer	170	216
Organic manure	--	719
Seed	278	220
Output total	4237	8529
Consumption		
Human	1509	2689
Animal	47	1948
Export	254	2152
Revenue	1650	1805

of the production from the land as food with a small fraction of it kept aside as seed. While the Nepalis use major fraction of the economic yield from the kitchen garden as feed for the animal husbandry, the Khasis use only a small fraction of the by products for this purpose. The Khasis export the by product as cattle feed whereas the Nepalis use it for feeding their own cattle. About half the production from the valley cultivation is given to the land owner as rent for the land. Inorganic fertilizer is used for valley cultivation by both the communities. Both the communities hire labour from outside to meet part of the requirement for the agricultural operations for the valley cultivation, the Khasis in addition also hire bullock from the Nepalis for ploughing the land. The fodder cultivation done by the Nepalis meet part of the requirement for their animal husbandry system.

The major input into the agricultural system of both the communities was labour, and a major proportion is contributed by family itself (Table 5.12). The input into the agricultural system per family and on a unit area basis was higher for the Nepalis than for the Khasis. This difference between the two communities was more pronounced for the Nepalis. Further the Nepalis are able to export more of their agricultural produce after a higher consumption within the family and after paying the land revenue. The Khasis consume only a small fraction

Table 5.13. Comparative analysis of production and consumption patterns (MJ yr^{-1}) from animal husbandry of a Khasi and a Nepali family in Nayabunglow in north-east India

	Khasis	Nepalis
Number of animals		
Cattle	--	8
Goat	--	6
Pig	1	--
Poultry	4	1
Production		
Milk	--	12278
Meat	668	551
Egg	29	24
Dung	750	5687
Draught power	--	638
Consumption		
Egg	29	24
Milk	--	2046
Export to market		
Milk	--	10232
Egg	--	--
Meat	644	546
Dung	750	4000
Import from market		
Feed	3547	5700
Import from forest		
Fodder	--	64463
Firewood	3194	71068

Table 5.14. Comparative analysis of monetary production and consumption pattern from animal husbandry (Rs yr^{-1}) of a Khasi and a Nepali family in Nayabunglow in north-east India

	Khasis	Nepalis
Inputs total	972	22834
Human labour	320	8252
Fire wood	61	1080
Cattle feed	591	13502
Outputs total	1552	23225
Human consumption	300	2998
Draught power	--	1400
Export	1252	16958
Revenue	--	69
Loan	--	1800

Table 5.15. Food consumption pattern ($Capita^{-1} yr^{-1}$) by the Khasi and the Nepali in north-east India. Values in parantheses are the standard requirements

Category	Khasis		Nepalis	
	Energy (MJ)	Protein (Kg)	Energy (MJ)	Protein (Kg)
Plant originated food				
Grains	4580	19	4758	22
Pulses	165	2	513	6
Green vegetables and tubers	105	0.1	145	0.13
Fruit	53	0.5	9	0.005
Mustard oil	1.2	--	242	--
Animal originated food				
Milk	--	--	369	3.0
Egg	4	0.2	3.4	0.14
Fish	53	0.5	13	0.2
Meat	7	0.7	2.3	0.13
Total	4968(4211)	23(20.08)	6054(4211)	31.6(20.0

of the production from the animal husbandry and most of it is exported (Table 5.13). The Nepalis consume 17% of the milk production. The eggs and partly meat are consumed within the family itself. The Khasis export all the dung collected whereas the Nepalis use 70% within the family, exporting the remainder. Some feed is purchased from the market. The Nepalis collect fodder from the forest whereas both the communities obtain firewood from the forest for cooking the feed for the animals. The Nepalis consume about 22 times more firewood per family than Khasis, for preparing the animal feed.

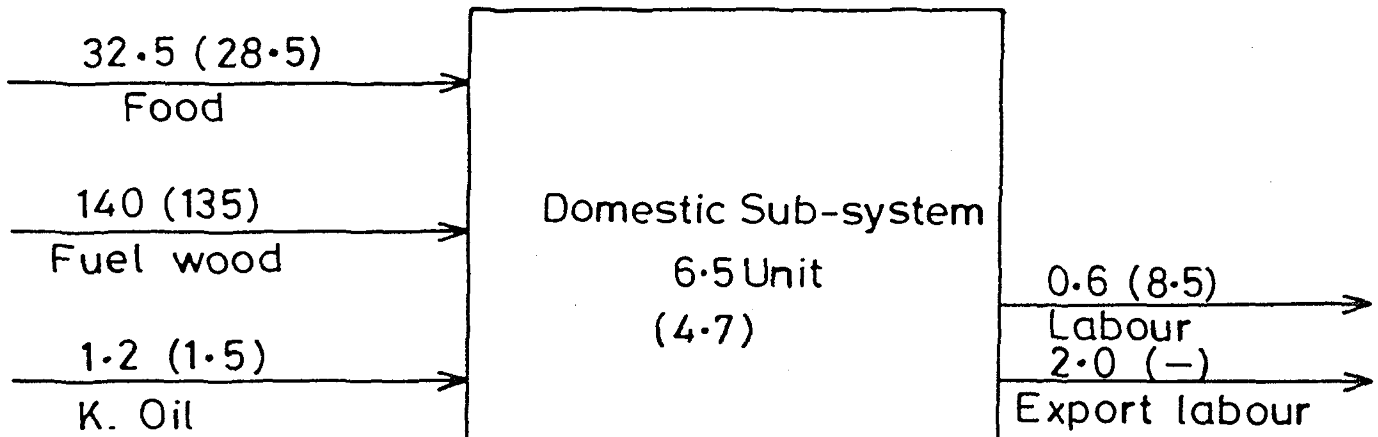
Cattle feed is one of the major monetary input into the animal husbandry of both communities followed by labour (Table 5.14) Nepalis had much higher output about 15 times more than the Khasis from their animal husbandry, a major part of the production is exported. The Nepalis also pay revenue to the Khasis for using the forest for grazing and pay the loan from the Bank.

In general, the intake of energy and protein from plant sources was more than from animal sources, the grains contribute a major proportion of the total (Table 5.15). The intake of legumes, mustard oil and vegetables was more for the Nepalis than for the Khasis, where as the intake of fruits, fish and meat was more for the latter. Milk is consumed only by the Nepalis. The energy and protein intake by both communities was more than the standard requirements for an Indian adult; this

Table 5.16. Import of food from the market by the Khasi and Nepali families (Rs. yr^{-1}) in Nayabunglow in north-east India

	Khasis	Nepalis
Family unit	6.5	4.7
Plant originated food		
Grains	2937	1875
Pulses	178	1593
Green vegetables and tubers	545	332
Fruits	285	170
Mustard oil	221	585
Animal originated food		
Fish	650	500
Meat	559	568
Total	5375	5623

Fig. 5.2 Comparative energy input and output analysis (MJ X 10^3 family^{-1}yr^{-1}) of domestic sub-system of two communities in Nayabunglow in north-east India. (Values in the parantheses are for Nepalis)



Output : Input ratio 0·02 (0·05)

Table 5.17. Comparative analysis of export and import (Rs. yr^{-1} $family^{-1}$) by the two communities in Nayabunglow in north-east India

	Khasis	Nepalis
Import from market		
Food	5375	5623
Kerosene oil	46	58
Import from the forest	1779	1714
House rent	--	50
Export labour	1600	--

was more obvious for the Nepalis import more food from the market than Khasis (Table 5.16).

With a comparatively smaller family unit for the Nepalis, the input of energy into their domestic system is about the same as for the Khasis (Fig. 5.2). The output of energy in the form of labour by the Khasis, however, was lesser than that by the Nepalis. Further, the Nepalis use labour energy within their own domestic sector where as the Khasis use much less.

Khasis and Nepalis depend on the market for food and Kerosene oil (Table 5.17). The Khasis alone export labour.

DISCUSSION

Agriculture sub-system

The Khasis do slash and burn agriculture (jhum) under cycle lengths of 5-10 yrs, five year being the more common cycle length. Earlier studies show that the jhum system can be effective only if it had a minimal cycle length of atleast 10 yrs (Ramakrishnan, 1984) and therefore it is reasonable to expect the decline in the economic and energy efficiencies of this system under shorter jhum cycle. Such a decline in yield may be related to reduced soil fertility (Nye and Greenland, 1960; Ramakrishnan and Toky, 1981) and increased weed potential (Zinke *et al*., 1978; Saxena and Ramakrishnan, 1984a).

Though the economic output from valley cultivation was lower than under jhum, it had the major advantage of being a system sustainable on a year to year basis, unlike the former. With much of the hill slopes being under a 5-yr jhum cycle, the wash-out of nutrients into the valleys would be low and this entails use of some fertilizers. However, pine apple cultivation has very high economic and ecologic efficiencies and therefore it is practised widely by the tribals.

Mixed cropping is an important feature of jhum under all cycle with diversity in economic yield. The shift in emphasis on tuber/root crops under short jhum cycles may be because of the higher returns under this category of species inspite of low soil fertility as suggested through earlier studies (Toky and Ramakrishnan, 1981a; Ramakrishnan, 1984).

Short term alternatives to jhum may be through intensified valley cultivation with more crops harvested in a year from the same plot or through plantation/horticultural crops such as pine apple suggested for north-east (Ramakrishnan, 1985a) and for other regions (Ruthenburg, 1976) under slash and burn agriculture.

Nepalis are basically cattle farmers who came into this area as immigrants. As they are not permitted to own land in rural areas for agriculture, they hire the lands from the Khasi landlords of the town and do valley cultivation of rice and/or have kitchen garden on land owned by the local Khasis. The mixed cropping under kitchen garden with two croppings done in a year and giving more emphasis on grains and vegetables is very efficient both in energy and economic terms. Like many other home gardens organized vertically in different layers, it is a highly productive system (Mitchell, 1979). However, the land under kitchen garden for a family is limited ranging from 0.3 to 0.5 ha. The Nepalis however, emphasize more on valley cultivation. Though the output from valley cultivation of Nepalis is close to that of the Khasis, the efficiency is higher because of much reduced labour input by the former. As fodder resources and grazing lands for the cattle of the Nepalis are limited, they cultivate the fodder grass, Pennisetum purpurea in small plots of 0.1 to 0.3 ha. which contributes to about 5% of their requirement, the rest being obtained from the forest.

The agroecosystems of both the communities are labour intensive with an energy efficiency ranging between 9.7 to 71.2. These systems compare favourably with the traditional Indian agriculture systems of the plains which has an energy output/input ratio of 9 (Mitchell, 1979). One of the major strengths of these agroecosystems lie in the high energy efficiency of these compared to industrialized agroecosystems which have energy efficiency values of less than one (Spedding, 1975; Leach, 1976; Pimentel and Pimentel, 1979). Besides, with labour being more uniformly distributed through out the year, the farmers find much time for leisure and cultural activities which form an important aspect in the life of the Khasis in particular.

Animal husbandry sub-system

Animal husbandry is an important activity of the two farming communities under consideration here. With slash and burn agriculture as the major agricultural activity for the Khasis, swine husbandry and poultry are the only two animal husbandry systems of this tribe. Such a close linkage between slash and burn agriculture and swine husbandry and even poultry is well recognized in the region (Mishra and Ramakrishnan, 1982; Maikhuri, 1987) and all the world over. The chief advantage of this linkage lies in that the waste products from agriculture is recycled into swine husbandry as it is largely detritus based. Even the feed that is given to pigs are agricultural products unfit for human consumption. Even poultry involves very little input, as grain fed to the birds largely depend upon grazing and scavanging. The cost of maintenance is minimal.

Unlike the Khasis, the Nepalis being sedentary agriculture farmers and with greater dependence on cattle for milk emphasize this along with bullocks for draught power and some goats and poultry. Their requirement for cow dung manure is high and a sizeable fraction of it is also sold in the market. The input into the system is substantial unlike swine husbandry or poultry.

However, the output from it is also high so that the economic and energy efficiencies are comparable with swine husbandry or even better.

Both the communities export a large fraction of the produce from animal husbandry system with little consumption from within their own village. Most of their meat requirements are met subsequently from the market.

Whereas the pigs and goats receive much of their food through stall feeding, other animals largely depend upon grazing/ browsing/scavanging. Confinement feeding provides some advantage like the energy (feeding) cost of foraging and disease recycling are eliminated, ''least cost'' rationing allows optimum use of other food stuffs (by products and wastes) (Dean et al., 1972). Like swine husbandry, poultry has also high economic and energy efficiencies.

It is usually societies with large population densities and/or small proportion of grazing land that emphasize upon confinement feeding. Thus, swines and poultry require a much greater portion of grain in the diets than the ruminants and thus are more competitive with humans, but they have reasonably high feeding efficiency of over 30% of plant protein converted into animal protein with 80% of human edible returns (Loomis, 1984).

The Nepalis depend upon forests to meet their fodder needs. Fodder denotes plant materials fresh or dry, which is consumed by the livestock as food and is taken to include material grazed, browsed or gathered. However, with declining forest resources and reduced access to the forest resources for these immigrant community, they tend to depend largely upon Pennisetum purpurea raised in plots hired from the tribals.

Domestic sub-system

In general, in the Khasi hills of Meghalaya the land is owned by the community; the individual family holdings are regulated through village headman. However, in Nayabunglow which is close to the city of Shillong the land tenure pattern has undergone some changes because of the purchase of valley lands and a few hill slopes by the Khasis living in the town who subsequently have leased out the same to the local Khasis and Nepalis for cultivation. As a consequences these owners obtain revenue from the land which is 50% of the total produce from valley cultivation. Therefore, valley cultivation, though it is an economically viable system, the actual benefit to the farmer is considerably reduced. Unlike the animal husbandry system where the emphasis is on export, the agricultural production is largely consumed within the family itself.

Unlike valley cultivation, the hills for jhum belong to the community and the jhum farmers get the land on payment of nominal fee to the village headman. The plots belong to the farmer as long as he cultivates it. Therefore the ownership here is an incipient one. All the production from jhum that the Khasi farmer obtains is his own.

Though the two communities export all that is produced from animal husbandry, they obtain almost an equal amount of meat from the market. Though the food consumed by both the communities is of plant origin, the Khasis consume three times more meat than the Nepalis. However, the Nepalis, unlike the Khasis consume substantial quantities of milk. Their energy and protein requirements are met completely and in fact, they obtain much more than their standard requirements (Ranjhan, 1979). However, the energy efficiency of domestic sector is very low.

One of the important reasons for this is high consumption of fuelwood energy. According to a calculation the energy obtained through fuelwood is 7.6 times more in developing countries compared to the developed societies (Stout, et al., 1979). This is because of energy inefficient cooking stoves (Donovan, 1981; Fox, 1984). For the future, one ought to consider possibilities of energy efficient stoves to replace the inefficient open types now used by them. This would help in checking to some extent the large-scale conversion of rainforests occuring now (Ramakrishnan, 1985).

A low land : man ratio, rapidly declining economic return from agriculture, high revenue to the absentee landlord, rapidly declining forest resources, all adversely affect the economy of both the Khasis and the Nepalis. Khasis compensate for this to some extent through export of labour and in extreme cases by migration to the city in search of work.

SUMMARY

This study deals with the village ecosystem function of pical Khasi and Nepali villages at Nayabunglow at an elevation of 960 m in Meghalaya in north-east India. The Khasis practise chiefly jhum under 5-yr cycle though some valley cultivation of rice and pine apple cultivation on hill slopes are done. Pine apple plantation was most profitable and energy efficient. The Nepalis have kitchen garden, valley cultivation of rice and fodder grass (Pennisetum purpurea) for cattle. Kitchen garden was the most efficient of all the three.

Swine husbandry and poultry are two main components of the animal husbandry sub-system of the Khasis. Nepalis are basically cattle farmers. From an energy point of view, cattle husbandry of the Nepalis was efficient followed by swine husbandry of the Khasis. From economic point of view swine husbandry had a high economic efficiency next to cattle husbandry for milk production.

Both the communities consumed half or more of the production from the land as food with small fraction of it kept aside as seed. About half the production from the valley cultivation was given to the land owner as rent.

Both the communities meet their energy and protein needs from their production systems. The Khasis export a large fraction of their agricultural produce and both the communities sell the produce from animal husbandry in the market only to buy again that needed. The Khasis also export labour for cash income from outside. The significance of these observations are discussed.

GENERAL DISCUSSION

GENERAL DISCUSSION

Though terrace cultivation has been introduced from time to time to replace slash and burn agriculture (locally called as jhum), it has found little acceptance from the local people (Ramakrishnan, 1984). The tribals revert back to jhum as soon as Government subsidies given as incentives are withdrawn. Wherever terrace has been accepted it is largely by the immigrant Nepalis, as at Nayabunglow. This is because of the fact that the Nepalis are basically sedentary farmers and they have no accessibility to forest for jhum. Besides, being cattle farmers, they are able to use cow dung to supplement soil fertility of the terrace under continuous cropping. The Nepalis at Naya-Bunglow are dependent upon land leased out by the tribals living in the city at Shillong. These leased land could be used only for sedentary agriculture such as terracing.

A comparative study of terraces of different ages (cultivated for different time periods) show that the number of crop species were fewer in older terraces. The economic yield was maximum in younger terraces than the older ones. In a 4-yr old terrace farmer takes two crops unlike one cropping on the others. This may be related to the decline in physical properties of the soil on older terraces, the soil fertility status and increased weed potential of the site. Further the economic and energy efficiencies increased with decreasing age of the terrace.

Though the loss pattern of many of the elements through run-off and percolation on terraces did not differ much, it was interesting to note that the loss of a highly labile element such as potassium increased with increase in terrace age. Nitrate-nitrogen loss through run-off also increased significantly in older terraces. Besides, the maintainance cost of the terraces themselves increased as there was continuous damage along the periphery due to heavy wash-out under heavy rain.

Nutrient budget studies under 4-yr and 12-yr old terraces showed that the net loss of nitrogen and phosphorus from the system increased from older terraces. Nutrient removal through weed was more under 12-yr old terrace than under 4-yr old one and the reverse was true for that removed by crop. In a 4-yr old terrace where a second cropping is done, a shift of dicot to monocot weeds during second cropping was related to reduced nutrient availability as these C_4 grasses have been shown to have a high nutrient use efficiency (Saxena and Ramakrishnan, 1983; Saxena and Ramakrishnan, 1984b). Nutrient deficit particularly potassium was obvious under 12-yr old terrace.

When the terraces of different age groups were compared with jhum and valley, it was found out that jhum under a 7-yr cycle to be economically and energetically efficient than terraces of different age groups. Earlier studies had shown that jhum with a cycle length of 5 years is unviable and 10 years is the minimum cycle suggested (Ramakrishnan, 1984). Nitrogen and phosphorus recovered during the fallow phase of secondary succession in the jhum system. Such a recovery does not happen under terrace cultivation because of continuous cropping. therefore, under terraces nitrogen and phosphorus can be maintained effectively only through tighter recycling of organic resources or input through inorganic fertilizer. Valley cultivation done by both communities was found to be self-sustainable, as also reported elsewhere (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981).

In the village ecosystem studies, we considered three sub-systems : (i) agricultural sub-system (ii) animal husbandry sub-system and (iii) domestic sub-system, for both the Khasis and the Nepalis, coexisting in the same area at Naya Bungalow.

The Khasis do jhum, valley and pine apple plantation. The economic yield from the jhum system declined with the shortening of the jhum cycle (Toky and Ramakrishnan, 1981a). The energy input increased with the increase in length of jhum cycle but output too improved with sharply improved efficiencies (Toky and Ramakrishnan, 1981a). Pine apple plantation on the hill slopes gave very high returns and it had the highest energy efficiency compared to all others.

Nepalis do kitchen garden, valley and fodder grass (for cattle) cultivation. Kitchen garden was found to be economically and energetically efficient, giving better returns to the farmer. The yield of valley cultivation was low compared to mixed cropping of kitchen garden. *Pennisetum purpurea* grown as fodder grass for cattle gave minimum returns to the farmer.

With slash and burn agriculture as the major activity of the Khasis, swine and poultry are the two of their major husbandry systems. The chief advantage of the linkage between slash and burn agriculture, swine husbandry and poultry lies in the waste products from the agriculture being recycled into swine husbandry, as it is detritus based. Input into poultry husbandry was minimal being largely dependent on grazing and scavanging by the birds.

Nepalis being sedentary farmers and with greater dependence on cattle for milk emphasize this along with bullock for draught power and some goats and poultry. The input into the system is substantial, unlike swine husbandry or poultry. However, the output from it was also high so that the economic and energy efficiencies were comparable with swine husbandry or even better.

Since the valley land of the Khasis and the Nepalis were leased out by the Khasis living in town, these land-lords obtain revenue which is 50% of the total agricultural produce. Therefore, though it was an economically viable activity, the actual benefit to the farmer was considerably reduced. Unlike valley cultivation, the hills for jhum belong to the community and the jhum farmer get the land on payment of a nominal fee to the village headman. All the production from the jhum that the Khasi farmer obtains is his own. The Nepalis who are immigrants donot have accessibility into forest for jhum and they depend on kitchen garden and do fodder grass cultivation for cattle, besides valley cultivation.

The two communities export most of the produce from animal husbandry and obtain meat for their consumption from market. Per capita food consumption was more for Nepal s. The energy efficiency of the domestic sub-system was low for both the communities. High fuelwood consumption with low energy efficiency for cooking stoves were observed.

With a locally high population pressure, availability of land is limited. Therefore, the Khasis in this area emphasize on jhum under a 5-yr cycle, which gives minimal returns to the farmer. The pine apple plantation found most profitable by the Khasis. offers possibilities for diversification and as an alternative to jhum. Valley cultivation also offers scope for improvement through more intense cropping systems.

The basic difference between the Khasis and the Nepalis lie in that only the latter has terrace cultivation, as their land available options are limited and that they are able to recycle cow dung into the terrace system. With a deeper soil profile, the Nepalis are able to sustain terraces for as many as 15 years, as noted by us, under continuous cropping. In weakly developed soils elsewhere, terraces are often abandoned after 6-8 years as the land gets totally desertified (Ramakrishnan, 1984). With jhum as the chief land use system the Khasis find swine husbandry and poultry compatible with their agriculture like other tribals in the region. For the Nepalis cattle farming can be an ecologically viable proposition only as long as they generate their own fodder through cultivation as they are now forced to do because inaccessibility to the forest. Otherwise, cattle farming with dependence on forests a: o e for fodder would lead to extensive deforestation and as has happened in the western Himalayas (Pandey and Singh, 1984).

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PLATES

Plate I. Terrace agroecosystem at Nayabunglow in north-east India

a) 1-yr old terrace

b) 4-yr old terrace

c) 12-yr old terrace

d) An abandoned terrace


a


b


c


d

Plate II. Cropping pattern in different agro ecosystems at Nayabunglow in north-east India

a) Mixed cropping on a 4-yr old terrace with Zea mays, Vigna sinensis Momordica dioica

b) Second cropping of Eleusine coracana on a 4-yr old terrace

c) Jhum under 5-yr cycle showing ginger and Colocasia antiquorum

d) Phaseolus vulgaris during the first cropping in a valley system.

a

b

c

d

Plate III. (a) Valley cultivation of rice by the Khasis at Nayabunglow in north-east India

(b) Pine apple cultivation by the Khasis in Nayabunglow in north-east India

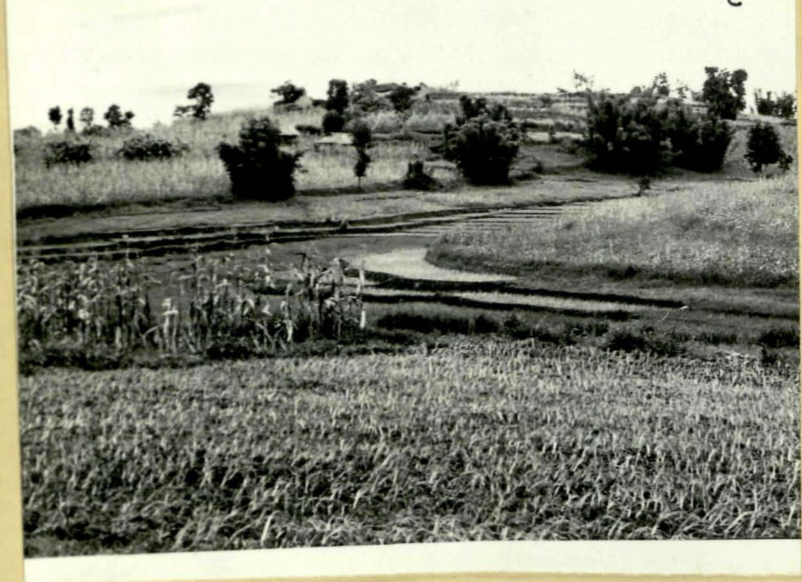
(c) Valley cultivation and kitchen garden of the Nepalis at Nayabunglow in north-east India

(d) A view of the market place showing ginger is ready for export.

a

b

c



d

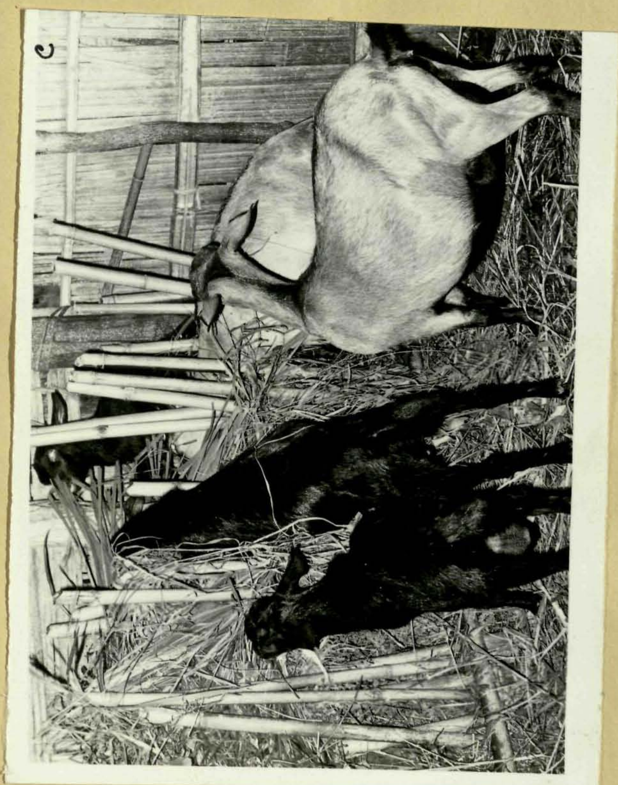
Plate IV. Facets of animal husbandry of the Khasis and the Nepalis at Nayabunglow in north-east India

a) Swine husbandry of the Khasis

b) Cattle husbandry of the Nepalis

c) Goat husbandry of the Nepalis.


b


c

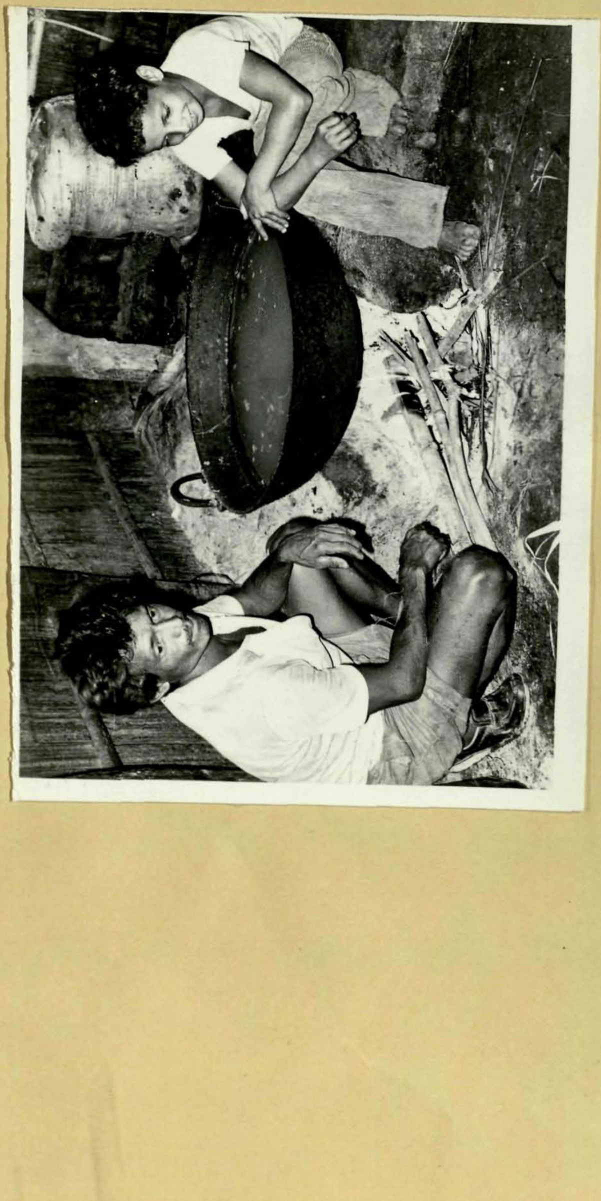

a

Plate V. Village activities of the Khasis and the Nepalis at Nayabunglow in north-east India

a) Fodder for the cattle brought in from the forest by the Nepalis

b) Feed (leaves of _Ipomoea_ _batatus_) for the swines being prepared by Khasi farmer

c) Concentrated feed of grains, crop residues and oil cake being prepared by a Nepalis farmer.



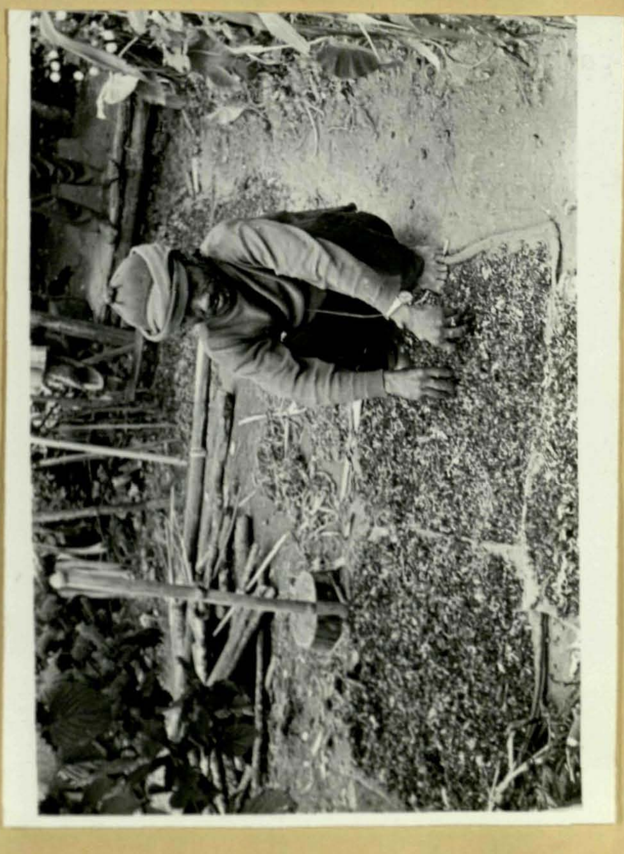
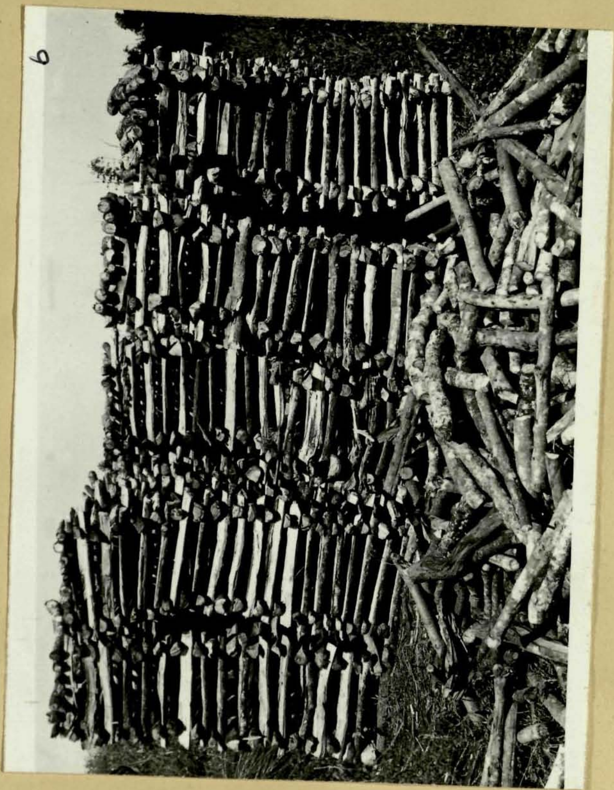


Plate VI. Fuel wood needs of the Khasis farmer is met from forest at Nayabunglow in north-east India

a) Fuel wood being brought in from forest

b) Fuel wood stacked by a Khasi farmer near the hut

c) A Khasi women cooking food on an open stove.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a