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

SUPRAVA PATNAIK
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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

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 no 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 <u>in situ</u>, 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 agroecosystem 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 Ramakrishnan, 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 of 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 cyćling.

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 herticultural 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 boundary . 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°45''N 91°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.

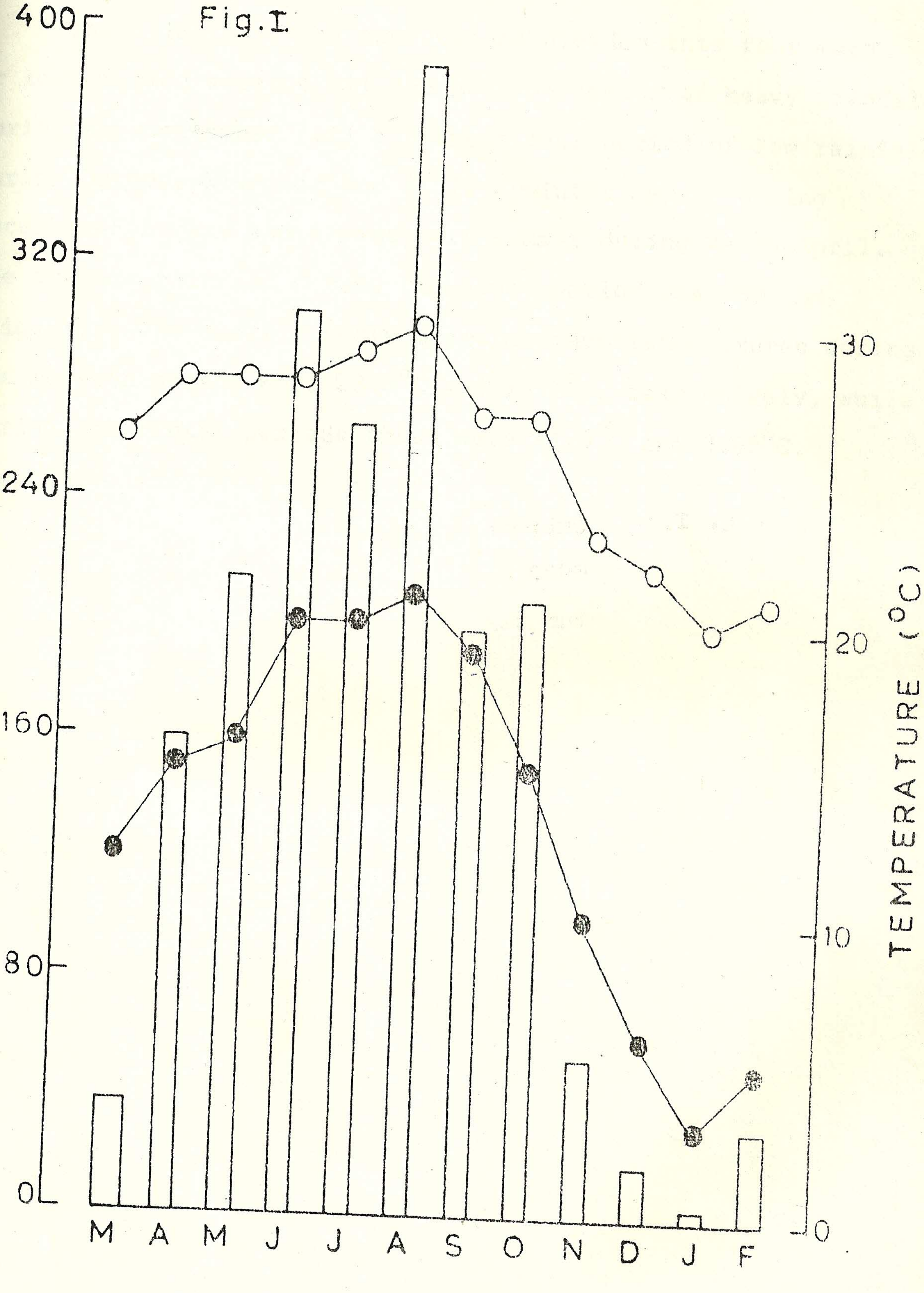

Fig.I
400
320
240
160
80
0
RAIN FALL (mm)
30
20
10
0
TEMPERATURE (°C)
M A M J J A S O N D J F

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.