STUDIES ON ECOLOGICAL IMPLICATIONS OF VARIED LAND USE PATTERNS IN THE NORTH—EASTERN HILL REGIONS OF INDIA

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MY GRAND PARENTS

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CONTENTS

PREFACE

Shifting agriculture (locally called jhum) is the chief land use system of the tribals of the north-eastern hill region of India. This is a land use system still prevalent in the humid tropics all over the world. With rapid deterioration in this land use practice with shortening of the shifting agriculture cycle (length of the fallow phase between two successive croppings on the same site), there is need, not only to look at possibilites of redeveloping this system through agricultural inputs and through diversion to other land use practices such as valley cultivation which depends upon nutrient wash-out from the hill slopes and therefore is self sustainable. Diversification to plantation/cash crop systems is another possibility. During the present study, therefore, all these land use systems have been evaluated considering shifting agriculture of the hill Miris, highly sophisticated wet rice cultivation of the Apatanis and the Government sponsored Plantation/cash crop cultivation introduced for the Khasi tribe in north-east India.

The thesis starts with a General Introduction surveying the literature pertaining to the work. The results are presented in the subsequent six chapters, two dealing with ecology of plantation/cash crops of the khasis of Meghalaya, the next three chapters deal with the ecology of wet rice cultivation of the Apatanis and the one following deals with the shifting agriculture system of the hill Miris, both of Arunanchal Pradesh.

Though the key element in all the six chapters is the land use system, it was most appropriate to link it with the functions of animal husbandry and domestic sector of the village. Each of these six chapters has its own Dicussion of results followed by summing up done in a following chapter on General Discussion. The literature cited is all presented towards the end.

GENERAL INTRODUCTION

Tropical rain-forests of the world constitute an important heritage for prosperity and have both academic and applicational values (Gomez-Pompa et.al., 1972; Raven, 1981). Apart from the fact 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 functioning 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 unconventional kinds. The need is accentuated increasingly by the rapid growth of human population particularly in the tropics (Raven, 1976).

The tropical rain-forests of India are restricted to two major geographical zones of the country, the western Ghats of south-western peninsular India and the north-eastern region (Ramakrishnan et.al., 1981a; Toky and Ramakrishnan, 1983a). However much of these forests have already been damaged considerably. The destruction is chiefly related to: (i) excessive timber extraction, (ii) agricultural practices and, (iii) other developmental activities.

Half of the world population is engaged in agriculture, the vast majority is in the tropics and the sub-tropics. Their agricultural practices are highly diverse, ranging from peasant and tenant small plots (shifting cultivation through to wet rice culture) to plantation export crops (Grigg, 1969; 1974; Duckham and Masefield, 1970; Manshard, 1974; Ruthenberg, 1976). From an ecological prospective, farming entails a rearrangement of the ecosystem, usually leading to increased productivity of useful materials. Its origin can be traced back at least to 8,000 years (Helback, 1959; Mac Neish, 1964; Ucko and Dimbleby, 1969). There were at least five, and probably more, independent centres of origin of farming systems (Zeuner, 1963; Sauer, 1965; Chang, 1970; Harlan, 1971). Most agriculture practices involve clearing of land and the establishment of such less mature ecosystems as annual crops (Anderson, 1952; Smith, 1974). Productivity depends on modification of the environment (e.g. soil preparation, irrigation and weeding) and on genetic changes that accompany domestication of animals and plants (Parodi, 1938; Epstein, 1955; Schwanitz, 1966).

Choosing policies for agricultural development requires the use of information about the existing farming situation. The collection of information presupposes the ordering of the great number of phenomena which can be observed in a given rural area into entities which are meaningful in terms of development, and these entities are systems, i.e. sets of related elements. System theory is therefore employed as the guideline for farm-system description and analysis (Dent and Anderson, 1971; Emery and Frist, 1971; Bertanlanffy, 1973).

LAND USE PATTERNS

Agroecosystems:

Shifting agriculture (slash and burn agriculture locally called 'Jhum') is the chief land use indigenous to the humid tropics of Africa, Asia and Latin America (Harrory, 1949; Schlippe, 1956; Worthington, 1958; Carneiro, 1960; Nye and Greenland, 1960). More than 240 million people living at or near the subsistence level practice shifting agriculture. They cultivate small patches of cleared land in the tropical forests, which are for the most part located on the poorer soils (UNESCO, 1978). Fields are cut out of secondary (usually) or primary forests leaving only the largest trees standing. Felled vegetation is burnt at the onset of rains, and the crops (seed and root) are planted with a minimum soil preparation. After one or two harvests, the plot is abondoned, or a third cropping may take place before the site is allowed to regenerate a vegetative cover (FAO, 1957). Although the yearly plots of shifting agricultures are small (1-2 ha) the total land tied up in shifting agriculture is enormous because of lengthy follow period (time lag between two successive cropping on the same plot). It is estimated that shifting agriculture in the tropics tie up twice the area (33 million km^2) used by temperate continuous cropping systems (Manshard, 1974).

Shifting agriculture in the north-east India is by far the most important factor in the conversion of tropical rain-forests. This practice though with many subtle variations (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981; Ramakrishnan, 1983, 1984a), basically involves slashing of the forest often by clear-felling, burning dried slash and raising crops for one or two years on the temporarily nutrient rich soil. The plot is abondoned for natural regrowth during fallow phases before returning to the same plot after a few years.

Under biologically stable conditions, a shifting agriculture plot may not be reutilized for upto 70 years, but under increased pressure of limited land and increasing populations, fallow period have decreased to generally unacceptable levels, averaging perhaps less than 5 years (Bertlett, 1956; Corner, 1960; Brown, 1971). In the north-eastern region of India this has come down to 4-5 years from original 30-40 years (Ramakrishnan et.al., 1981a;b, Ramakrishnan, 1985a). This in turn has further accelerated the environmental degradation leading to desertification (Ramakrishnan, 1985b), limited recovery of soil fertility (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983a) and deminished economic returns (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981). Stripped of their vegetation cover, the soils of these shorter fallow fields are often highly erodable, particularly immediately after abandonment

(Cook, 1921; Clarke, 1966; Walter, 1971). Therefore, even though shifting agriculture traditionally is based on sound scientific principles (Ramakrishnan, 1984a) distortions have made this system untenable in the present form.

With a view to arresting and reclaiming the degraded forest areas the Governmental agencies in north-east India have introduced and encouraged terrace cultivation. Terraces are one of the oldest and most common type of soil conservation practices used for erosion control. They intercept run-off water before it becomes erosive and they conduct the water at a non-erosive velocity to a stable outlet. Terraces fill a niche in cropland conservation system that no other practice can, by controlling sheet, rill and gully erosion and channel erosion caused by concentrated flow on steeper and longer slopes.

However, particularly in the north-eastern region of India, replacement of shifting agriculture by intensive agricultural practices is probably not a realistic solution to this problem. As a solution to the problem, the Indian Council of Agriculture 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 claim 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. But even if run-off losses of soil and nutrients are reduced by terracing, as the soil is loose and porous the leaching of nutrients through percolation is high (Mishra & Ramakrishnan, 1983a). With respect to nitrogen and phosphorus, the fertility depletion is very rapid as was observed during the second year of cropping on the same plot in Meghalaya (Mishra & Ramakrishnan, 1983b). In fact, the physical and chemical qualities of the soil may get so much adversely altered 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. The maintenance cost for the terraces are heavy apart from the input need for heavy dose of inorganic fertilizers. Besides this, weed potential under terrace cultivation gets intensified when compared to a 10-year shifting agriculture cycle in the same area, adversely affecting crop returns (Mishra & Ramakrishnan, 1981).

Valley cultivation of rice is a viable land use practice since the valleys are self-sustaining systems, they are natural sinks for nutrient flow from the hills (Mishra & Ramakrishnan, 1981: Toky & Ramakrishnan 1982). Most of the irrigated land in the tropics (particularly most of the wet-rice areas) is still cultivated year after year without much manuring because rice like rye, cotton, maize and sugarcane is self-fertile so that even under permanent cultivation, yields rarely drop further after a minimum level of soil fertility has been reached (Rutherberg, 1967). According to Angladette (1966), soils improve their quality for wet-rice production with time because of the impounding of water and its influence on chemical processes in the soil. Recently it was found that rice rhizosphere could also fix considerable amounts of atmospheric nitrogen under flooded condition (Dart & Day, 1975). Valley lands are relatively more extensive in the north-eastern hills than in the Himalayan zone because of the more prevalent rolling hill topography, but still limited by topography.

In areas where rice fields retain water for 3 to 8 months in a year, rice-cum-fish culture has often provided an additional supply of fish crop. The antiquity of rice field fish culture in south-east Asia has only recently been established (Ardiwinata, 1957; Pongsuwana, 1962; Coche, 1967). In India rice-cum-fish culture has been described in detail by Hora (1951), Chacko and Ganapati (1952) and Iyenger (1953, 1962). Iyenger (1953) through his experimental studies at Hasserghata fish farm, Karnataka, and Visweswaraya canal farm reported an average fish yield of 112 $kgha^{-1}$ after 3-4 months of rearing in rice fields. Experiments on rice-cum-fish culture at Hebbal, Karnataka (Muddanna et.al., 1970: cited by Jhingran, 1982) and at Arupatkiodai, Tanjore district, Tamil Nadu (Devaraj and Natarajan, 1973: cited by Jhingran, 1982) resulted in varying yields ranging from 17.5 to 152.5 kg ha^{-1} in 71 days and 240 kg ha^{-1} in 9 months, respectively. Hickling (1961) reported that in Java and Madagascar the fish yield from rice field was 28 to 50 kg ha^{-1} in 100 days.

Economic Yield and Weed Problem Under Agriculture:

The immediate cause for the rotation of fields under shifting agriculture in the successive years of cultivation was decrease in economic yield. In the British Honduras, Charter (1941) found the yield of maize on peasant milpas was about 1000-800, 800-600, 600-400 kg ha^{-1} in successive years. Steggerda (1941) estimated that the yield in second year, in the Yucatan Peninsula (Mexico), is only about 80% as high as in the first year. Grist (1953) estimated that the yield of paddy in successive years of cultivation was to the tune of 1500-2000, 1200-800 kg ha^{-1}. In the central Peten, Cowgill (1961) found second year milpa yields to be only 71% as high as compared to the first year.

In north-east India there was much confusion regarding the yields of crops from hill agroecosystems, until work was initiated by Ramakrishnan and his co-workers (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981). The Agroeconomic Research Centre, Jorhat (Assam) conducted surveys on shifting agriculture yield of rice and concluded that the average yield of 800-900 kg ha^{-1} in Garo hills, Mizoram and Arunachal Pradesh. On the other hand, the rice yield under shifting agriculture in Tripura was reported to be around 1200 kg ha^{-1} (Mishra, 1976). In a recent survey of the socio-economy of the shifting agriculture, Aurora et.al. (1977) concluded that the yield of rice under shifting agriculture and dry land cultivation on terraces are not significantly different under comparable situations. A study from Burnihat (Sahu, 1978) on rice yield gave yearly outputs under terrace cultivation 738 kg ha^{-1} and with shifting agriculture 853 kg ha^{-1}. According to Indian Council of Agricultural Research (Borthakur et. al., 1978) the yield under shifting agriculture is very low (190 kg ha^{-1}) compared to terrace cultivation (1860 kg ha^{-1}). However, more precise comparative estimates of the yield under different shifting agriculture cycles at low and high elevations of this land use vis-a-vis sedentary farming such as terrace and valley cultivation (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981) showed that (i) a longer cycle gives better yield than a short cycle, (ii) a 10-year cycle is economically viable, (iii) though terrace cultivation gives as much as return to the farmer as shifting agriculture under 10 year cycle, a major fraction of input for the farmer is through inorganic fertilizer while labour is the chief input into shifting agriculture.

Weeds are a major cause of declining yield under shifting agriculture in many parts of the world and include *Eupatorium odoratum* in Thailand (Zinke et.al., 1978) and *Imperata cyclindrica* in Sarwak (Freeman, 1955) and all these and others in north-east India (Saxena and Ramakrishnan, 1984).

Cutting *et.al.*, (1959) estimated that the yield of maize in Nyasaland was 4284 kg ha^{-1} when weeded four week after germination, but attain only 3217 kg ha^{-1} when weeded six weeks after germination. Toky and Ramakrishnan (1981a) and Mishra and Ramakrishnan (1981) reported that under shorter shifting agriculture cycles the weed problem was severe due to arrested succession by exotic weeds in north-east India.

Recently weeds have been viewed as an useful component in agroecosystems and may be expected to play an important role in agricultural management of the future. Obviously one of the important roles of the weeds in the cropland 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 Gliessman, 1982). Swamy (1986), from north-east India have reported that traditional weeding (involves retention of a certain proportion of weed biomass *in situ*) and this has little effect on the economic yield potential of the crop 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.

Plantation/Cash Crop System :

It has been suggested that with the application of modern technology the potential for food production in the humid tropics is almost unlimited, but the exploitation of this potential will take place only as fast as the necessary guarantees of profit are made to farmers (Buol & Sanchez, 1978; Meerman & Cochrane, 1982).

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 pressures by engendered population increase on the 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; Adeyoju, 1980; Doyen, 1980; Kaul, 1980; Wiersum, 1980). The potential value of trees as multiuse components of tropical agricultural systems has been appreciated for many years (Douglas and Hart, 1976) while, in developed countries, the integration of trees with agriculture is common, and concerns farmers, foresters, planners and even landscape artists (Cunningham et.at., 1978; Pierre, 1980; Stewart, 1978). In the humid tropics, trees represent the climax vegetation and traditionally, they have provided food, shelter and fuel (Earl, 1975). Since they do not require soil cultivation, and can continue photosynthesis virtually throughout the year, tree food crops are far more 'energy efficient' than annual crops (Bowers, 1982). Stands of economically useful local or exotic species can be used as stable successors to native forests, or to rehabiliate land that has been degraded through inappropriate cropping (Weaver, 1980; Nair, 1982).

Agroforestry Systems may vary widely in both intensity and species composition, depending upon local soil and climatic circumstances (Maydell, 1979; Nair, 1982).

If shifting agriculture is to be replaced by a life style based on agrogorestry, there are many traditional multicropping systems, involing tree crops, that can serve as models(Watson, 1983). They are typified by the Kandy Gardens of Sri Lanka (Mc Connell & Dharmapala, 1978), the Indonesian homesteads (Harwood & Price, 1976), the Nigerian Compound farms (Okigbo & Greenland, 1976) the South Indian home gardens (Sundarraj & 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. Such systems provide varied income and food supply, and have supported a stable and satisfying lifestyle far generations.

In the noth-eastern region of India a shift towards plantation/cash crop system have been suggested to reduce the pressure from shifting agriculture (Ramakrishnan, 1984 a; 1987 a). Apart from providing export-oriented economy(Ruthenberg 1976 ; Andreae 1980), the perennial plant cover would protect soil more effectively.

NUTRIENT BUDGETING UNDER DIFFERENT LAND USE PATTERNS.

The long term success of shifting agriculture depends upon the recovery and maintenance of soil fertility. If the nutrient lost or displaced during the short period of cultivation are approximately balanced by those replaced during the fallow period, the system could continue indefinetly. The maintenance of soil fertility in hot, humid and high rainfall area 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 weeds. This in turn results in reduced crop yield under short cycles (Nye & Greenland, 1960; Watters, 1971; Toky & Ramakrishnan, 1981 a; Mishra & Ramakrishnan, 1981).

When the forests are cleared and the debris is burnt, all the cations are released on the surface soil as ash. Heavy losses of carbon, nitrogen and sulphur occur due to volatilization during the burn (Nye & Greenland, 1960; De las sales & Folster, 1976 Ramakrishnan & Toky, 1981, Mishra & Ramakrishnan, 1983 b, 1984). For phosphorus though, there are no obvious mechanisms of volatilization, losses, are reported through convenction via particulates to the atmosphere (Freedman, 1981). There are conflicting reports on addition of phosphorus through fire (Nye & Greenland, 1960; Stark 1971; Stromgaard, 1984) and others suggesting some losses from the system (Harwod & Jackson, 1975; Ashton, 1976; Mishra & Ramakrishnan, 1983a). Liyod (1971) reported massive losses for phosphorus through fire. Swamy and Ramakrishnan (1987b) reported that the nitrogen and phoshorus losses due to fire under a 5 year shifting agriculture cycle at lower elevation of Meghalaya was 550 kg ha^{-1} and 7.2 kg ha^{-1} respectively.

The total concentration of cations in the soil solution depends upon the total concentration of anions. A high level of nitrate ion due to increased biological activity (Ahlgren & Ahlgren, 1965; Wells, 1971) balances a corresponding concentration of nutrient cations in the soil solution and therefore heavy losses through water occur (Bormann _et.al_, 1968; Lewis Jr. 1974). According to Bormann _et.al_. (1968) and Likens _et.al_. (1978), quantitative importance of nitrification would determine the quality and quantity of cations flushed from the deforested system. The amount of nutrient losses also largely depend upon the quality and quantity of nutrient release from litter (Singh & Ramakrishnan, 1982a; Ram 1986.).

The loss of water through run-off and percolation, and consequent loss of sediment, increases with the shortening of shifting agriculture cycle. This may be partly related to poor physical characteristic of the soil, and also particularly to poorer crop-cover (Toky& Ramakrishnan, 1981b). Toky and Ramakrishnan (1981b) reported that the shortening of shifting agriculture 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.

Hydrological studies under terrace agroecosystem showed that run-off and sediment losses were markedly reduced due to terracing (Mishra & Ramakrishnan, 1983a) but percolation losses were found to be high. During the second year of cropping on the same terrace rapid depletions of the soil fertility were observed (Mishra & Ramakrishnan, 1983b).

Plantation are simplified versions of forested ecosystems. The total ecosystem approach for quantifying nutrient budget and cycling in the northern hardwood forest has been successfully done by Bormann and Likens, (1967). Several studies have demonstrated that rainfall may remove substantial amounts of nutrients from the foliage in horticultural plants (Leclere & Breazeale, 1908, Mes, 1954; Tukey & Amling, 1958). Others have reported that rain water which passes through the tree crown contain higher quantities of various nutrients than the rainfall collected in adjacent openings (Will, 1955, 1959; Voigt, 1960; Rahman, 1969; Cole et.al. , 1967; Singh & Ramakrishnan, 1982). Measurements of nutrients in throughfall and stemflow water have been done by many workers (Madgwick & Ovington, 1959; Likens et.al., 1971; Eaton et.al., 1973). Most of the studies suggest that throughfall contribution to nutrient cycling have received much attention than the contribution by stemflow.

The amount and quality of litter has long been considered to be of vital importance for exchange of organic and inorganic materials between living organisms and the soil. In tropical forests of Africa, nutrient contents of litter have been studied by many workers (Laudelaout & Meyer, 1954; Bernehard, 1970; Egunjobi, 1974). Studies on nutrient contents of litterfall in humid sub-tropical montane forests are available from north- east India (Singh & Ramakrishnan, 1982a; Das & Ramakrishnan, 1985).

Among the soil nutrients taken up by the coffee plant, nitrogen is the most important. Studies are available on nilrogen cycling (Bornemisza, 1982) and nilrogen losses in coffee, plantations (Carvajal, 1959; Cooil & Fukunaga, 1959; Kupper, 1976). Role of organic matter and effect of plant cover on soil conservation practices in coffee plantations have also been studied by Suarez de Castro & Rodriguez (1955a,b). However, information on nutrient budgeting in plantation crop systems is limited. The plantation crop introduced into the hill areas of north-east India has received little attention.

ENERGETICS

Agroecosystems :

The usefulness of energetic analysis in agriculture has been questioned by many researchers. 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 other's approach (Georgescu- Roegen, 1979). Others, more favourably disposed consider the energetic view as compatiable 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 fertilzer 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 in terms of human time and labour inputs but are highly inefficient from overall energy point of view, as 5to10 units of fuel energy are required to produce one unit of food energy (Steinhart & Steinhart, 1974). Where as shifting agriculture has been held up as a model of productive efficiency where 5 to 50 units of food energy are harvested for each unit of energy input into the system (Rappaport, 1971; Steinhart & Steinhart, 1974; Mishra & Ramakrishnan, 1981; Toky & Ramakrishnan, 1982). Rappaport (1971) provides relatively complete information on the energy expenditure of the Tsembaga people of new Guinea highlands. According to him, the farmers obtained an average of 16 food calories for each calorie 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 system (Greenland, 1975; Revelle, 1976; Mutsaers et. al., 1981; Ramakrishnan, 1985c), which has been considered as the most evolved system for the forested areas of the humid tropics (Conklin, 1957; Carneiro, 1960; Nye & Greenland, 1960; Walters, 1971; Ramakrishnan, 1984a).

Terrace cultivation in north-east India was found to be energetically inefficient (6.7)

(Toky & Ramakrishnan, 1982) due to heavy input of fertilizers every year besides labour input for terracing. This system is comparable to comparatively more modern Indian agricultural systems where 9 units of food energy is harvested for each unit of fossil fuel energy input into the system (Mitchell, 1979). However, terrace cultivation was found to be better than most industrialized western agricultural systems, where only 1 or 2 units of food energy is harvested for each unit of input (Spedding, 1975; Spedding & Walsingham, 1976; Leach, 1976; Pimentel & Pimentel, 1979).

Valley cultivation, which needs very little nutrient input because of natural drainage into these systems from adjoining hill slopes, is energetically efficient in north-east India (Mishra & Ramakrishnan, 1981).

Animal Husbandry System:

Population growth rates indicate that by year 2000, 60% more food will be required to meet the requirement of the world population (FAO 1977). In a world already suffering from widespread 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. 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).

Traditional farmers consider animal husbandry as an essential activity along with agriculture for the persistence of the system and welfare of the family (Rappaport, 1971; Ramakrishnan, 1984a, Queirez et.al; 1986). The energy efficiency of cattle (for meat) was found to be very low (less than 1) (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 & Brigstocke, 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 Tsembage 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 x 10^2MJ over a 10-yr period for 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 Australtian nutritional anthropologist, suggested that killing of swine in smaller numbers at more frequent intervals would be more efficient from a nutritional and ecological point of view.

Swine husbandry is an integral part of shifting agriculture in north-eastern region of India (Mishra & Ramakrishnan, 1982). In fact the tribal farmer of this region consume pigs not only as part of his normal diet but makes a feast of it during celebrations related to shifting agriculture procedures. Again the main region why swine husbandry is part of shifting agriculture system is because of its in expensive maintenance costs.

VILLAGE ECOSYSTEM

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 input-output analysis of a single tribe illustrating their responses to their environment, the work of Lee (1966) Rappaport (1971), and Mishra and Ramakrishnan (1982) are important. In Lee's study, the input-output approach to subsistence has shown that Kung Bushman in the Dobe area can derive an adequate living from only a modest expenditure of their time and effort. He estimated that the per capita yield of food-stuff was 8.95 MJ which was in excess of 0.69 MJ to their energy requirement per person per day. Rappaport (1971) described the importance of swine husbandry to the Tsembaga farmers in New Papua Guinea. Makhijani and Poole (1975) studied energy flow in a number of prototype villages in developing countries. He concluded that farmers in developing countries often use more energy per hectare than those in industrialized nations. His data showed that gross energy input per capita varied from 1.5×10^4 MJ per year in India to 6.5×10^4 MJ in Mexico. The efficiency of converting gross energy input into useful work was about 5% in India and 25% in Mexico, as a result of which twenty times more useful energy was available per person in a typical Mexican village. Revelle (1976) tabulated the use of energy in rural India. According to him, energy use per person in 1971 was 29.7 MJ day^{-1}, 3.3 times the energy in food consumed. More than 89% of this energy was from local sources, and less than 11% was from commercial sources. Briscoe (1979) through his study on a Bangladesh village (Ulipur) showed that about 10% of the total food intake of the population is accounted for by useful work. The most important sectoral activities are household work, agricultural work, and fishing which accounted for, 45%, 28% and 15% respectively of the total output of useful work. Although the energy system in Ulipur is frugal, with virtually all products and by-products being used for some purposes, the use of energy is inefficient. Sundarraj and Mitchell (1987) on the basis of detailed analysis of ecosystem function of a south Indian village concluded that this village operates very close to biological limits for biomass production, with a high intensity of biomass use (90%) which attests to the sophisticated management techniques followed by some of the rural communities in the region. One of the first few studies on village ecosystem from north-east India (Mishra and Ramakrishnan, 1982) showed that the per capita food production in the village exceeded the food energy consumed by the people (Khasis) by 16.64 MJ day^{-1}. This energy efficient village ecosystem is closely linked to their natural forested environment.

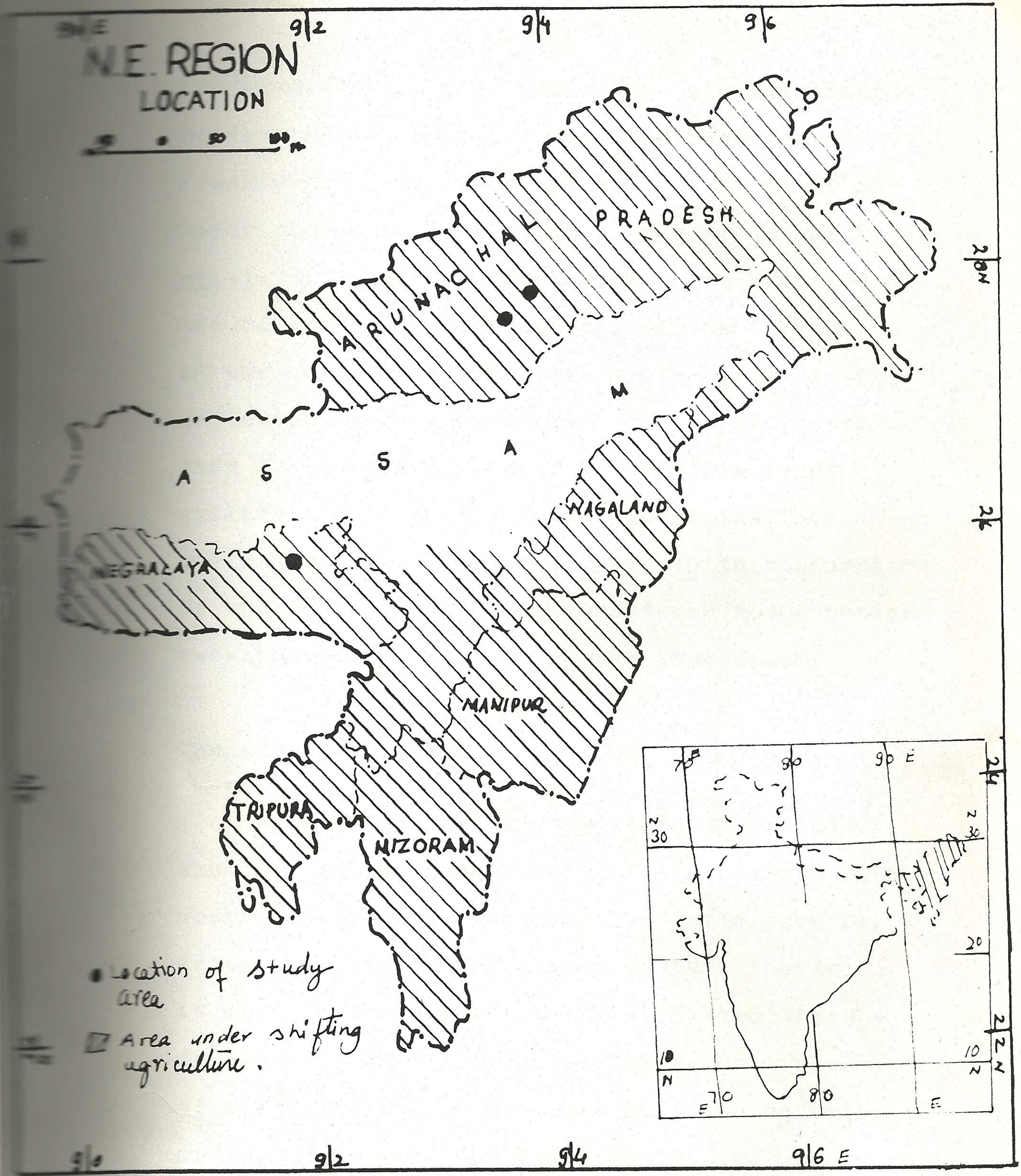
For over a third of the world's population located in the developing countries, fuelwood which is a scare commodity, is a major problem of daily life. According to Eckholm (1975), no less than one and a half billion people in developing countries derive atleast 90% of their energy needs from wood and charcoal; another one billion depend upon this for atleast 50% of their energy needs. Excessive use of fuel wood and ever increasing demands for it have caused fuel wood shortage in many developing countries (Pasca, 1981; Montelambert and Clement, 1983; Baidy, 1984). Most of

FIG. I. The area dominant under shifting agriculture in north-east India.

▨ , under shifting agriculture

● , study site

Fig I


N.E. REGION
LOCATION
92
94
96
ARUNACHAL PRADESH
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
Location of study area
Area under shifting agriculture.
96 E

the studies that have been done on deforestation in developing countries have indicated quite clearly that fuel wood extraction is one of the major causes for depletion of forests. Ramakrishnan et.al. (1981b) from north-east India reported that one of the major consequences of the shortening of the shifting agriculture cycle has been fast depletion of fuel wood resources in the region. This is aggravated due to low efficiency of utilization of fuel wood energy in the developing world (Leach, 1976), where per capita consumption of energy for cooking is considered to be between two-and-a-half times more than in the west.

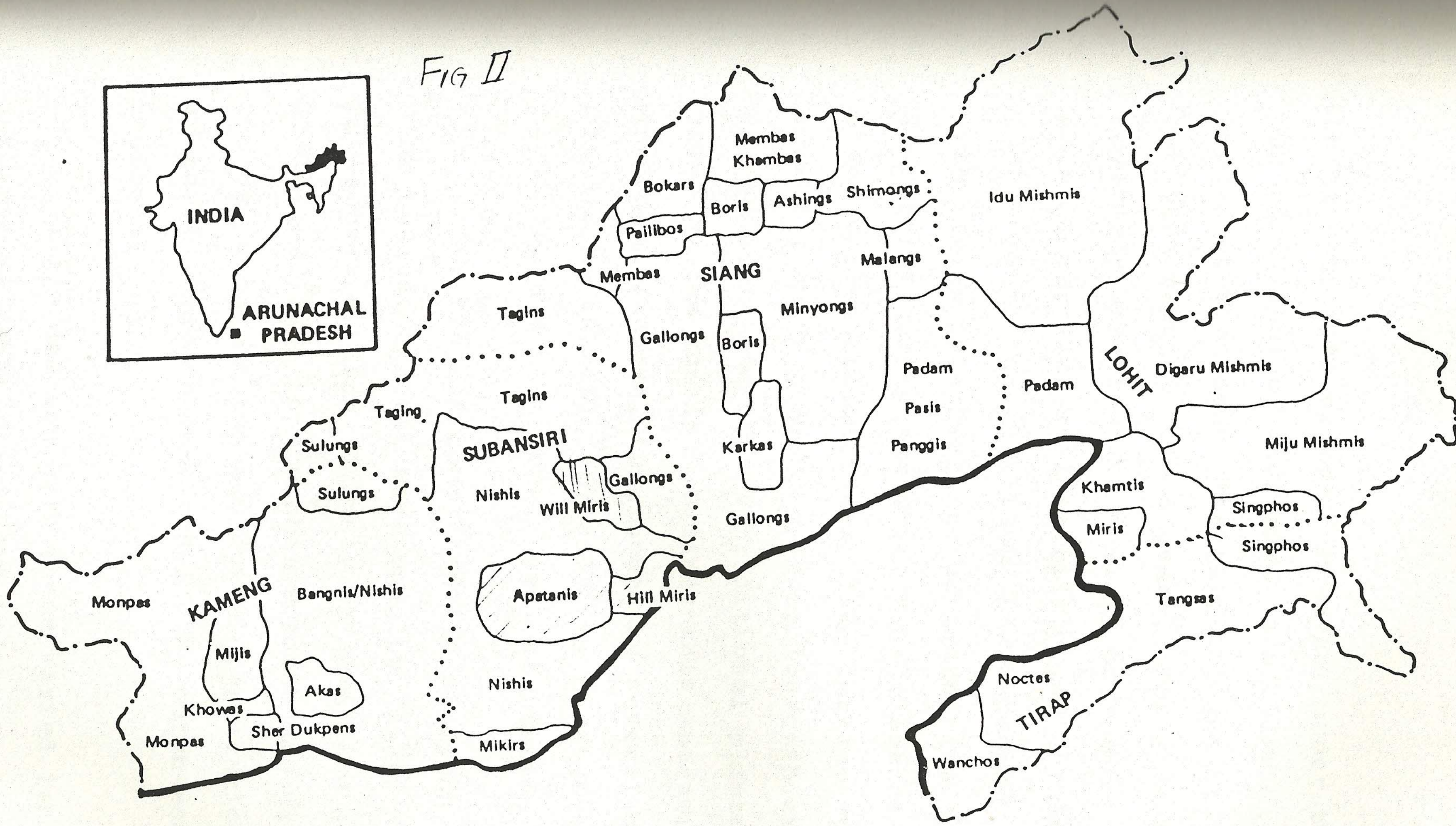
The Present Work:

Shifting agriculture (locally called Jhum) is a predominant form of agriculture in the north-eastern hill region of India (Figure I). After cultivation for a year or two, the land is left fallow, again to be cultivated after a few years. This time lapse before cultivation of the same site is called a shifting agriculture cycle. Formerly, the shifting agriculture cycle was fairly long, ranging from 20-30 years, which ensured that the system was self-sustaining and

Fig. II. Distribution of tribal groups in Arunachal Pradesh in north-east India.

Apatani and hill Miris

Fig II



ARUNACHAL PRADESH
DISTRIBUTION OF TRIBAL GROUPS

in harmony with nature. However, under the present day conditions of increased population pressure and reduced acreage, the shifting agriculture 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., 1981a; Ramakrishnan, 1985a) with a view to arresting and reclaiming the degraded forest areas the Governmental agencies have suggested varied alternatives; like terrace cultivation and/or a shift towards plantation/cash crops. Pineapple is one of the traditional plantation crop grown by the khasis. Besides this Apatani tribe of Arunachal Pradesh, surrounded by several other tribes practising shifting agriculture, have developed permanent and sustainable wet cultivation of rice (Fig II).

The present comprehensive study on the varied land use patterns at Naya bunglow (25°45'N 91°54'E) in Meghalaya, Ziro (27°36'N 93°49'E) and Raga (27°44'N93°51E) in Arunachal Pradesh are part of a broader study on the ecological implication analysis of these land use patterns in the north-eastern hill region of India.

While dealing with these varied land use patterns in Meghalaya and in Arunachal Pradesh, the linkages between land use, animal husbandry and domestic sectors have also been looked into in order to obtain a wider ecological prospective on the implications of the land use activities. It is hoped that this study would help in designing ecologically and economically viable land use systems in the region.