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

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TO WHOM IT MAY CONCERN

I certify that the thesis entitled "STUDIES ON ECOLOGICAL IMPLICATIONS OF VARIED LAND USE PATTERNS IN THE NORTH-EASTERN HILL REGIONS OF INDIA" submitted by Shri Anil Kumar, for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of Ph.D. degree. This work has not been submitted for any degree of any other University.

(Signature of the Supervisor)

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DEDICATED TO

MY GRAND PARENTS

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CHAPTERS

PREFACE

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 for 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 nitrogen cycling (Bornemisza, 1982) and nitrogen 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; Pimentèl & 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 Austratian 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 foodstuff 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.

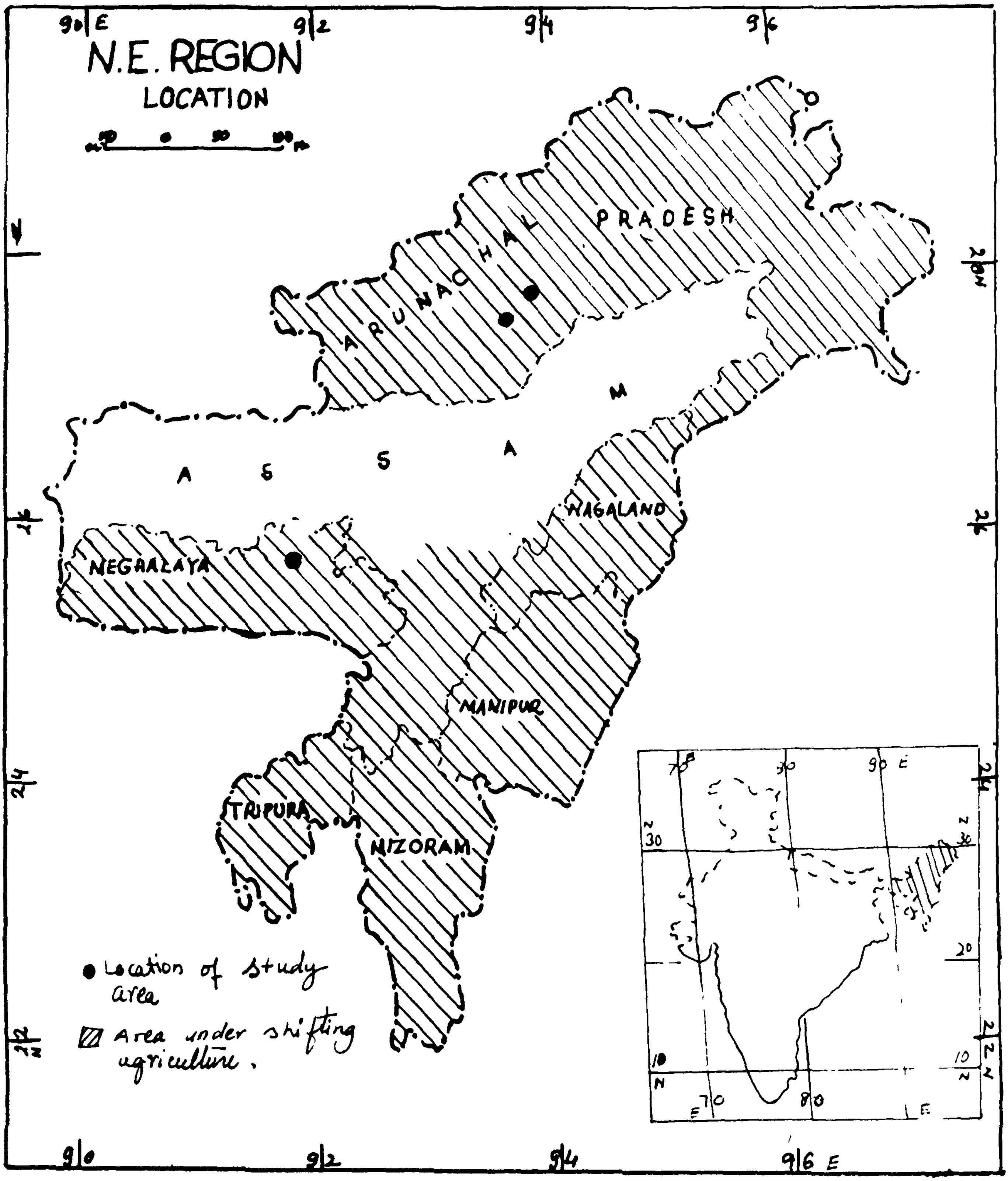
For over a third of the world's population located in the developing countries, fuelwood which is a scarce commodity, is a major problem of daily life. According to Eckholm (1975), no less than one and a half billion people in developing countries derive atleast 90% of their energy needs from wood and 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
ARUNACHAL PRADESH
ASSAM
NEGHALAYA
NAGALAND
MANIPUR
TRIPURA
NIZORAM
● Location of study area
▨ Area under shifting agriculture.
90 E
92
94
96 E
28 N
26
24
22 N
70
80
90 E
30
20
10
N
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.

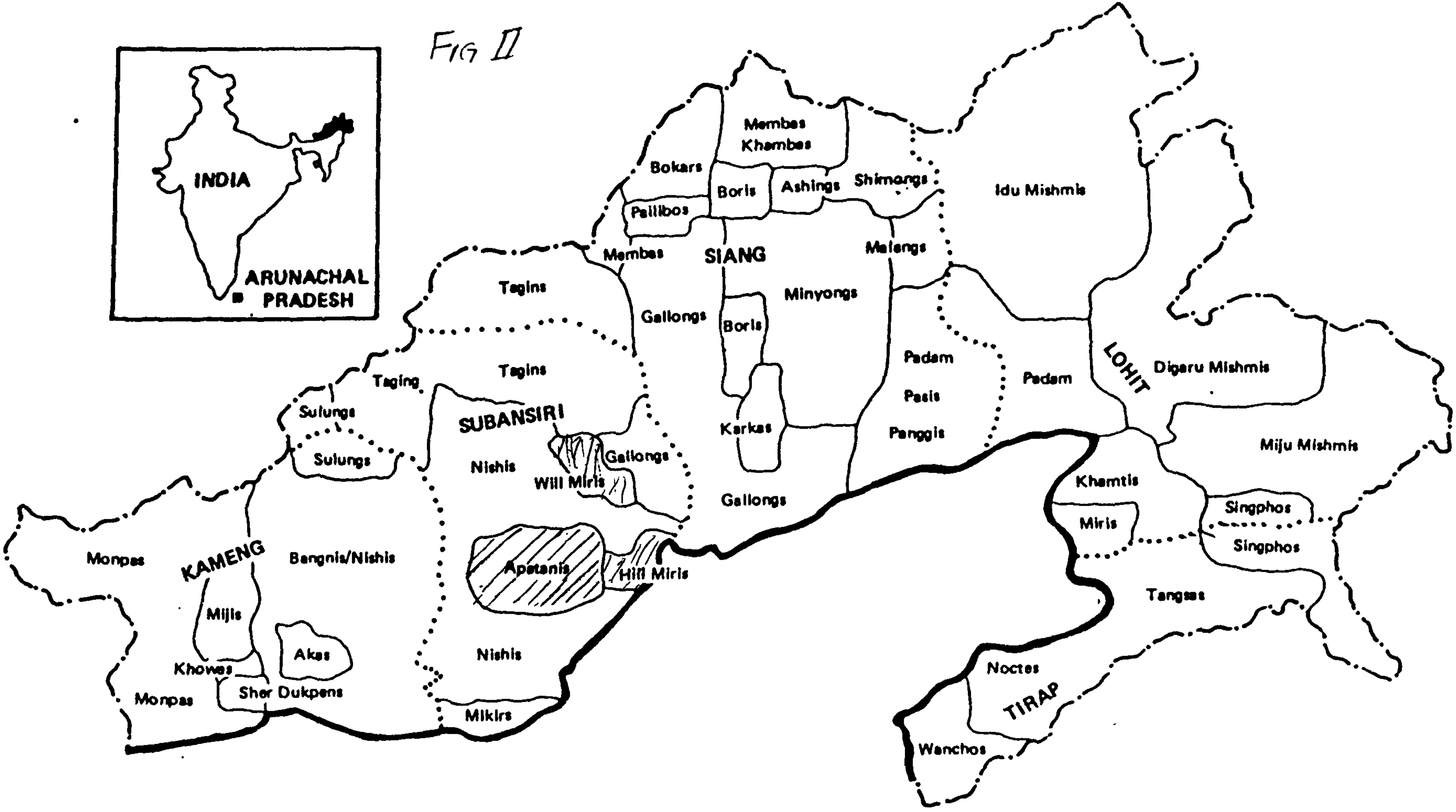
The Present Work:

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 Arunchal 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., 1980; 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 Arunchal 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.

CHAPTERS

CHAPTER 1

ECONOMIC YIELD AND ENERGY EFFICIENCY OF PLANTATION/CASH CROP ECOSYSTEMS IN MEGHALAYA IN NORTH-EAST INDIA.

INTRODUCTION

Though shifting agriculture is the chief land use system in the north-eastern hill region of India (Ramakrishnan <u>et</u>.<u>al</u>.,1981 a ; b; Ramakrishnan, 1985 a), the shortening of the shifting agriculture cycle (time lag between two successive cropping at the same site), because of population pressure and reduction in the land area, has resulted in distortions in terms of ecology (Ramakrishnan, 1985 c) and economic returns to the farmer (Toky & Ramakrishnan, 1981a ; Mishra & Ramakrishnan, 1981). Therefore, there has been attempts to have a shift in land use towards plantation and cash crops (Ramakrishnan, 1985c). Of the crops considered here, tea and coffee are new introductions whereas ginger and pineapple are traditional crops under shifting agriculture. These are raised on bench terraces. Since these cash crops are important as an alternative to shifting agriculture (Ramakrishnan, 1984a,1985c), the present study deals with comparative analysis of this economic and ecological efficiencies, in Meghalaya in north-eastern India.

STUDY AREA AND CLIMATE

The present study was done around Nayabunglow ($25^{0}45'$ N and $91^{0}54'$ E) at an altitude of 910 m in the Khasi hills of Meghalaya, about 30 km north of Shillong. The climate is typically monsoonic with more than 80% of the total annual rainfall of 180 cm occurring during May to September. The monsoon is followed by winter; March and April represent a brief dry period. The mean monthly maximum and minimum temperatures during the monsoon were $28.6^{0}c$ and $17.1^{0}c$ respectively, and for the winter they were $21.3^{0}c$ and $3.9^{0}c$, respectively.

DISCRIPTION OF THE LAND USE SYSTEMS

Coffee (*Coffea arabica*) plantation was done on terraces in early sixties by Governmental agencies. The plantation was raised with a spacing of 3x2 m is not very successful. *Schima wallichii* and *Bauhinia purpurea* are two important shade tree species used. Average plant height of coffee is 1.5 m. Seed picking (dark reddish) is done in December- January. Pruning of the plant is done soon after. Weeding is done once, followed by application of pesticides in September- October. Inorganic fertilizer (N&P - 5:3) is applied twice in a year at the rate of 155 kg ha^{-1}.

Transplantion of tea (Camellia sinensis) was done on slopes (60x90 cm distance) during the year, 1978 using one year old saplings. Albizzia odoratissima is the important shade tree species along with Albizzia chinensis, planted at distances of 3x5 m. Trimming of the bush at 75 cm height is done in February. Plucking of tea leaves is done during April-October, at 10-day intervals. Weeding is done three times during the rainy season. Apart from weedicides/pesticides applications, inorganic fertilizer (NPK-2:1:2) is used twice in a year at the rate of 555 kg ha^{-1}. The freshly plucked tea leaves are sold at the rate of Rs. 1.50 kg^{-1}.

Ginger (Zingiber officinale) is traditionally cultivated on terraces. After preparation of the land into ridges and furrows and after repairing the old terraces, sewing is done in April at distances of 20x30 cm following an application of organic manure at the rate of 720 kg ha^{-1} before crop sowing. Inorganic fertilizer (NPK -1:1:1) is applied twice in a year at the rate of 500 kg ha^{-1}. Harvesting of the rhizome is done in December- January.

Pineapple (Ananas comosus) plantations are being cultivated on terraces for the last six years. This alongwith rhizome and tuber crops (*Colocasia antiquorum*, *Curcuma longa* and *Manihot esculentus*) are sown in March and harvested during the following December. Two harvests of pineapple are done from the same field, once in July-August (monsoon variety) and another in December-January (winter variety). Weeding is done twice in June and December. Weed biomass and old pineapple plant biomass are put back into the plot as organic manure.

METHODS OF STUDY

Coffee, tea, pineapple with other crops and ginger plantations were selected at Nayabunglow, in Meghalaya in north-east India. In each plantation, three plots of 50 m^2 were identified.

Vegetation analysis was based on twenty 1 m^2 quadrats for herbs and twenty 10 m^2 quadrats for shrubs and trees placed at random in each plot. The importance value indices (IVI) which is an integrated measure of relative frequency, relative density and relative basal area of the species and calculated (Curtis, 1959).

Labour cost was calculated on the basis of prevailing rates (Rs. 12 day^{-1}). The cost of manure, chemical fertilizers, seeds, pesticides and weedicides were calculated according to the prevailing market price. The monetary output was calculated on the basis of the prevailing market price for each item. The economic efficiency was measured as monetary output/input ratio.

The labour hours expended for each activity was recorded separately. The total energy consumed was apportioned to each activity (Leach, 1976), according to the relative duration or the basis of grauping, involving either sedentary, moderate or heavy work. Per hour energy expenditure was calculated as (i) 0.418 MJ for sedentary work, 0.488 MJ for moderate work and 0.679 MJ for heavy work for an adult male and (ii) 0.331MJ for sedentary work, 0.383 MJ for moderate work and 0.523 MJ for heavy work for an adult female (Gopalan et.al.,1978). Energy input through chemical fertilizers was calculated on the basis of fossil fuel energy that is required to manufacture the fertilizer (Table 1.1). The fossil fuel equivalents given in Table 1.1, were used to calculate

Table 1.1. Energy Values (MJ kg^{-1} dry weight) for different component considered in the plantation/ cash crop ecosystems.

Items	Moisture (%)	Average energy value
Coffee seed[1]	25.7	17.03
Leafy materials[2]	46.8	13.77
Pineapple fruit[2]	60.0	2.20
Rhizome and tuber crops[2]	70.0	13.77
Production cost[3]		
N	-	76.98
P_2O_5	-	13.95
K_2O	-	9.66
Weedicides[4]	-	148.11
Pesticides[5]	-	100.00
Replacement cost		
Organic manure[6]	80.0	1.28

[1] Mitchell, 1979.

[2] Gopalan et.al., 1978

[3] Pimentel et.al., 1973

[4] Avlani and Chancellor, 1975

[5] Leach and Slesser, 1973

[6] Percentage of N, P_2O_5 and K_2O in organic manure was 1.3, 1.2 and 1.2 respectively.

the replacement cost of organic manure in terms of fossil fuel energy. The input of energy through seed was calculated on the basis of total energy expended to produce that fraction of crop yield. For calculating the output of energy under the four land use systems, the total economic yield of the various crops was converted into megajoules of energy by multiplying with standard values of various crops as given in Table 1.1 .

The energy efficiencies were calculated as the output/non-solar input ratio, output/solar input ratio and output/labour hour ratio. Two energy intensities: labour input/yield ratio (minutes kg^{-1}) and yield/non-solar energy input ratio (kg MJ^{-1}) were also calculated.

All the results were compared and contrasted with shifting agriculture under a 10-year cycle, based on the data of Toky & Ramakrishnan (1981a&1982).

RESULTS

A total vegetation analysis of the weeds and crops done together at the peak period of August (Table 1.2) suggests that ginger, followed by pineapple with other crops had more weed intensity compared to tea ; coffee had the least

Table 1.2. Important Value Indices (IVI) of Vegetation in Different Plantation/ Cash Crop Ecosystems.

Species	Coffee	Tea	Pineapple with other crops.	Ginger
Weeds.				
Ageratum Conyzoides L.	18.8	40.1	43.1	95.0
Bidens pilosa Hook.F	-	-	5.8	7.4
Borreria articularis (L.F.) Will.	20.2	64.1	81.8	80.9
Commelina nudiflora L.	11.4	12.6	5.5	11.5
Crossocephallum crepidioides (Benth)L.				
Cynodon dactylon L.	-	-	-	5.4
Cyperus globosus All.	-	-	9.3	12.6
Eupatorium odoratum L.	36.3	-	6.0	-
Galinsoga parviflora Cav.	-	-	5.0	5.8
Imperata cylindrica P. Beauv.	-	-	5.6	-
Mimosa pudica L.	-	-	6.0	-
Panicum maximum Jacq.	15.3	7.0	40.1	-
Pteridium equilinm (L) Kuhn ex Decken	9.7	8.0	-	-
Saccharum arundinaceum Hook F.	10.9	15.9	-	-
Respective crop	89.5	95.7	75.0[1]	48.2
Trees.				
Albizzia odoratissima Benth	-	32.76	-	-
Bauhinia purpurea L.	20.3	-	-	-
Erythrina indica L.	6.6	-	-	-
Schima wallichii (DC)Korth	16.3	-	-	-
Others[2]	38.0	23.0	11.0	19.0

---

[1] 65.4 for Pineapple and 9.6 for rhizome and tuber crops.

[2] IVI below five.

Table 1.3. Cost of Production (Rs. $ha^{-1}yr^{-1}$) of Different Plantation/Cash Crop Ecosystems.

Inputs		Coffee	Tea	Pine-apple with other crops.	Ginger
1.	Labour	1694	11844	2896	8745
(i)	Field preparation	-	-	-	2200
(ii)	Sowing	-	-	325	1100
(iii)	Fertilizer application	525	880	-	825
(iv)	Weeding	320	1320	1625	3520
(v)	Plant protection (Chemical Spray)	165	220	-	-
(vi)	Harvesting	200	9072	946	1100
(vii)	Pruning	484	352	-	-
2.	Organic manure	-	-	-	2500
3.	Inorganic manure	760	1725	-	1375
4.	Pesticides/ weedicids	300	745	-	-
5.	Seed	-	-	200[1]	6225
	Total	2754	14314	3096	18845

---

[1] Cost of rhizome and tuber crops.

Table 1.4. Economic Efficiencies of Different Plantation/Cash Crop Ecosystems and a 10-year shifting agriculture ecosystem.

	Coffee	Tea	Pineapple with other crops	Ginger	10-year shifting agriculture
Input	2754	14314	3096	18845	1830
Output	4560	37125	12090[2]	42435	3354
Net return	1806	22811	8994	23590	1524
Output/ input ratio	1.66	2.59	3.90	2.25	1.83

[1] Toky and Ramakrishnan, 1981a.

2. Rs.9093 for pineapple and Rs. 2997 for other crops.

weed intensity. The weed intensity in tea plantation is checked through weedicides and in coffee, it is biologically suppressed to some degree by the dense canopy of the coffee plant and shade trees. Amongst the weeds, Borreria articularis and Ageratum conyzoides were two more dominent weeds.

Cost of production was maximum for ginger followed by tea (Table 1.3). Of the inputs, labour cost was the highest for tea followed by ginger. Since tea, coffee and pineapple with other crops field preparations are done once when cultivation starts, the cost is not recurring. It may be mentioned that tea is raised on the slopes but pineapple cultivation is done on terraces. Except for pineapple with other crops inorganic fertilizer was applied and this was minimal for coffee. Seed input was required every year for zhizome and tuber crops in pineapple and ginger only.

Though the output from ginger was maximum compared to other crops, followed by tea, the input for these two crops are also high (Table 1.4). With low input into pineapple with other crop and a relatively high return from it, the efficiency is maximum for this crop. A comparison of the output/input ratio of the plantation crops with a shifting agriculture under a 10-year cycle suggests that all

Fig. 1.1 Monthly labour energy distribution pattern in different plantation/ cash crop ecosystems: (a) Tea; (b) Ginger; (c) Coffee; (d) Pineapple with other crops.

Fig. 1.1

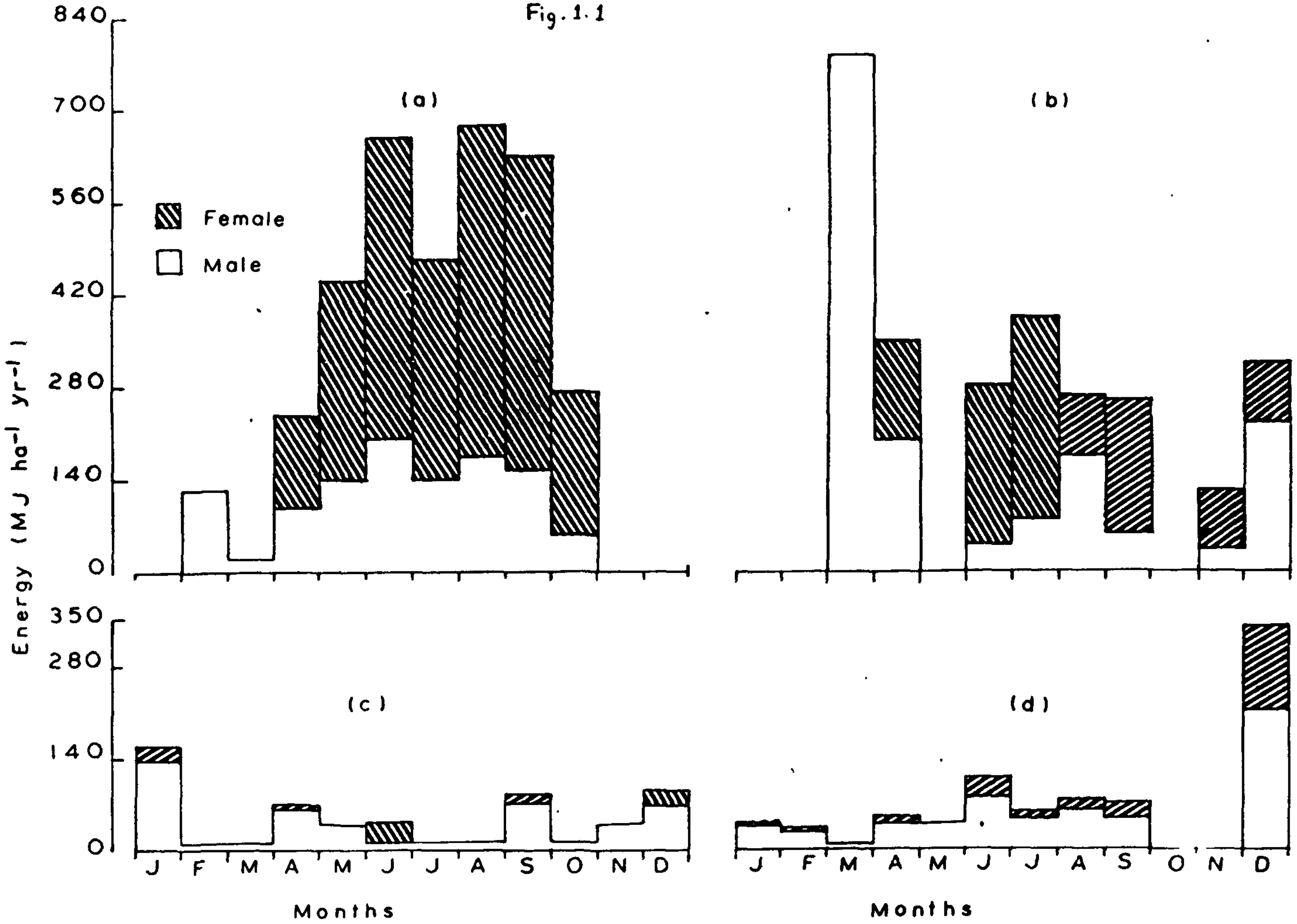

(a)
(b)
(c)
(d)
▨ Female
☐ Male
Energy (MJ ha⁻¹ yr⁻¹)
840
700
560
420
280
140
0
350
280
140
0
J F M A M J J A S O N D
J F M A M J J A S O N D
Months
Months

Table 1.5. Energy Input (MJ $ha^{-1}yr^{-1}$) in Different Plantation/Cash Crop Ecosystems.

Inputs	Coffee	Tea	Pineapple with other crops	Ginger
1. Labour	574	3537	808	2776
(i). Field preparation	-	-	-	781
(ii). Sowing	-	-	81	348
(iii) Fertilizer application	180	283	-	268
(iv) Weeding	99	385	459	1014
(v) Plant protection (Chemical Spray)	59	78	-	-
(vi) Harvesting	64	2666	268	365
(vii) Pruning	172	125	-	-
2. Organic manure	-	-	-	922
3. Inorganic fertilizer	8261	14978	-	9958
4. Pesticides/ weedicides	20	910	-	-
5. Seed	-	-	165[1]	198
Total	8855	19425	973	13854

[1] energy value for rhizome and tuber crops.

Table 1.6. Energy Sources and Efficiencies of Different Plantation/ Cash Crop Ecosystems and a 10-year shifting agriculture ecosystem. Labour Hour Expended is Given in Parentheses.

Production system	Coffee	Tea	Pineapple with other crops	Ginger	10-year shifting agriculture
Input $ha^{-1}yr^{-1}$					
1. Solar incident[2]	$33x10^6$	$33x10^6$	$33x10^6$	$33x10^6$	$33x10^6$
2. Non-solar energy	8855	19425	973	13854	1302
3. Labour energy	574 (1232)	3537 (8616)	808 (1784)	2776 (6760)	569 (1220)
Output $ha^{-1}yr^{-1}$					
Crop energy harvested	8450	181310	17085	33392	56655
Yield, Kg.	496	13167	3164[3]	2425	3305
Efficiencies					
Energy output/solar output	$2.6x10^{-4}$	$54.9x10^{-4}$	$5.2x10^{-4}$	$10.1x10^{-4}$	$17.2x10^{-4}$
Energy output/non-solar input	0.95	9.33	17.56	2.41	43.51
Energy output/labour hour	6.86	21.04	9.48	4.94	46.44
Intensities					
Labour input/yield (minutes Kg^{-1})	148.98	39.26	33.83	167.25	22.15
Yield/non-solar energy input ($Kg.MJ^{-1}$)	0.06	0.68	3.25	0.17	2.54

---

1. Toky and Ramakrishnan, 1982.
2. Spedding, 1982.
3. 2290 kg pineapple fruit and 275 kg rhizome and tuber crops

of them favourably compare with the latter except coffee.

More labour energy was expended for tea and ginge than for coffee and pineapple with other crops (Fig.1.1) Further, in the former two, the contribution by the female was much more (69% for tea and 43% for ginger) than the males, unlike in coffee and pineapple with other crops.

Energy input for tea was maximum and that for pineapple with other crops was minimum. For coffee, tea and ginger, the major energy input was through inorganic fertilizers, followed by labour input (Table 1.5).

The energy efficiency (output/input ratio), considering non-solar input was maximum for pineapple with other crops but much less than for cropping under a 10-year shifting agriculture cycle (Table 1.6). If solar energy input is considered tea was more efficient than shifting agriculture system, coffee being least efficient in both cases. Energy output per unit labour input was maximum for shifting agriculture followed by tea plantation. Labour input for unit production was maximum for ginger followed by coffee and the least for shifting agriculture agroecosystem. Yield per unit non-solar energy input was high for pineapple with other crops followed by shifting agriculture.

DISCUSSION

Shifting agriculture which is the most prevalent land use in north-east India, is becoming more and more untenable in view of the distortions that have come about due to shortening of agriculture cycle in the recent past, with adverse effect on the economic returns to the farmer (Ramakrishnan, (1984a,1985a). It is in this context that the introduction of plantation/ cash crops became important for the north-eastern hill region (Ramakrishnan, 1985 c). The result presented here for the yield patterns under four different plantation/cash crops and their comparison with mixed cropping under shifting agriculture with a 10-year shifting agriculture cycle suggests that the monetary output from the latter was low, which was even more so from the point of view of net return. Economic efficiency in terms of monetary return per unit rupee invested is an important factor for the success of any agroecosystem. It has been suggested that with the application of modern technology, the potential for food production in the humid tropics is almost unlimited, but that exploitation of this potential will take place only as fast as the necessary guarantees of profit are made to the farmers (Buol and Sanchez, 1978; Meerman and Cochrane, 1982). However, the biological productivity in the humid tropics may drastically go down on a long term basis after conversion of natural vegetation into crop-lands (Dickinson, 1972; Leith, 1976). It is in this context the feasibility of plantation/cash crop economy with substantial input of inorganic fertilizers has to be viewed. A shift towards permanent cultivation should consider, therefore, combining food crops with tree species as part of an agroforestry system (Watson, 1983; Ramakrishnan, 1987a,b). A generally poor return for coffee at this elevation is suggestive of its unsuitability for the ecological conditions prevailing here. Ginger and tea obviously are cash crops which are well suited for the region. One way of improving the economic efficiency of the system may be through mixed cropping, which would also ensure sustained yield on a long term basis (McConnell and Dharmapala, 1978; Okigbo & Greenland, 1976).

While monetary output/input analysis is suggestive of the economic efficiency of this system, energy output/input analysis is an indication of the ecological efficiency of the system (Rappaport, 1971;

Ramakrishnan, 1987 b). Though the efficiency of the shifting agriculture system in terms of non-solar input is much higher than in all the plantation/cash crops considered here, the energy efficiency of the shifting agricuture system connot be considered in isolation but need to be discussed in relation to land use pattern, or else energy efficiency values *per se*. could lead to distorted comparison. If land is not a limiting resource, then the greater solar input to a large area of shifting agriculture system with a large cycle could be used to offset imported energy and this would ensure harmony of the long cycle with the environment, at the same time ensuring rational returns for the farmer. The 10-year cycle, therefore, would need a correction factor of 1/10 to make comparisons valid with other systems considered here. Thus the effective output from shifting agriculture would decrease drastically (Toky and Ramakrishnan, 1982). Though the energy output from ginger is very low, the economic return are very high suggesting that energy efficiency has to be considered along with economic efficiency of the system for its effective evaluation. With a high inorganic fertilizer input into all plantation/cash crops except pineapple with other crops the efficiency of these sedentary systems, have come down drastically. However, efficient recycling of resources with emphasis on organic manure would contribute to better ecological efficiency of these plantation/cash crops.

A major disadvantage of the plantation/cash crops such as tea and ginger is the heavier labour input that often involves employed labour from outside the village ecosystem boundary. This is often costly and has also implications of import of labour even from outside the region. Given the socio-economical and socio-political framework in which the traditional society operates, it may be desirable to stabilize shifting agriculture with a 10-year cycle or even redevelop shifting agriculture under a 5-year cycle so as to ensure self-sufficiency in the village (Ramakrishnan 1987 a). It may not be desirable to consider plantation/cash crops, at this stage, that connot be handled by the family unit with labour input from within. It is in this context a mixed land use pattern which considers redeveloped shifting agriculture along with small units of plantation/horticulture crops for a family organized on a co-operative basis (Ramakrishnan, 1984b) become relevent.

SUMMARY

The present study deals with the economic and energy analysis of coffee, tea, ginger and pineapple with other crops, and these are contrasted with shifting agriculture under a 10-year cycle in north-eastern India. Though ginger gave maximum monetary return, followed by tea, the output/input ratio was higher for pineapple with other crops. Coffee is not successful in the area. Shifting agriculture had a high energy efficiency of 43.5 with least efficiency for coffee. The implications of these results for land use redevelopment in the region are discussed.

CHAPTER 2

NUTRIENT BUDGET OF PLANTATION/CASH CROP ECOSYSTEMS IN MEGHALAYA IN NORTH-EAST INDIA.

INTRODUCTION

In north-east India, shifting agriculture (Jhum) is the traditional land use system of the tribal communities (Ramakrishnan, 1985a). With shortering of the shifting agriculture cycle (time lag between two successive cropping on the same site) from a longer 20 years or more to a shorter 4-5 years, partly because of population pressure and partly due to reduced land availability for agriculture (Ramakrishnan, 1985b) this land use system has become distorted and less tenable in the present form. Therefore, there have been attempts from various Governmental agencies to introduce plantation/cash crops as a replacement to shifting agriculture. These alternatives have had only a limited acceptance amongst the tribal communities, partly for ecological reasons (Ramakrishnan, 1984a) and partly for social reasons (Ramakrishnan, 1985b). The viability of any land use, system would be partly based upon its economic efficiency (Chapter 1) and partly for sustainable soil fertility for continued use of the land. In this context, an analysis of the nutrient budget of the land use becomes important. This study, therefore, is a comparative study of four plantation/cash crop systems, coffee, tea ginger and mixed system of pineapple with other crops.

METHODS OF STUDY

Coffee, tea, pineapple with other crops and ginger plots were identified at Nayabunglow, in Meghalaya in north-eastern India. In each plantation three replicate plots were identified soil (0-7cm) was sampled on two occassions, in March 1985 and in December, 1985, (February 1986 in case of coffee).

The amount of organic and inorganic fertilizer used, material removed from the ecosystem as economic yield through crop harvest, biomass removed through pruning and weed removal and there two components put back into the system were calculated on the basis of three 10 m^2 guadrat samples from each plot.

Litterfall in coffee and tea plantations were estimated using ten randomly placed $1m^2$ litter traps in each plot (Newbould, 1967). Monthly estimation of litterfall (except during monsoon when collection were made at 15 days intervals) was made by collecting the litter and sorting out into leaf and non-leaf components. The litter was oven-dried at 80^{0}c and stored for chemical analysis.

Stemflow of shade trees in coffee and tea plantations was sampled (with three replicates for each tree species) using a spiral polythene gutter of 6 cm diameter fitted on each stem and sealed with paraffir-wax, at a height of 1.5 m above the ground level on the tree trunk. A plastic funnel was attached to the two cut ends of the guther and connected to a polythene container of 5 ℓ capacity. A nylon filter 1mm mesh size was placed on the mouth of the funnel to prevent entry of extraneous matter.

[illegible]

Throughfall from coffee and tea plantations alone (nine replicates) and incident rainfall were collected in polythene containers, the mouth of each being fitted with 20 cm diameter funnel which was provided with 1mm mesh nylon filter to prevent entry of foreign matter.

For studies pertaining to sediment and water loss due to erosion and run-off, the loss from a confined area of 1x10m was collected in large collectors and sampled periodically for chemical analysis. For the study of percolation loss of water, Zero-tension lysimeters were employed (Buckman and Brady, 1960). Soil was cut vertically in each plot 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 ($30x30x15cm^3$) 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 results are based on twelve observations in each plot.

After analysing the fresh soil/water samples for NO_3-N and PO_4-P soon after collection, the water samples were preserved in polythene jars for subsequent analysis.

Air dried soil samples were passed through 2 mm sieve and kept in glass jars for subsequent analysis. Over-dried and grcnnd plant samples were stored in glass jars. The samples were analysed by standard procedures (Allen, <u>et.al</u>.1974). Thus NO_3-N was estimated by phenol- disulphonic acid method and PO_4-P and total phosphorus were estimated by molybdenum-blue methed. Total nitrogen was estimated by micro-kjhldahl method. Calcium

Table 2.1. Mean concentration of nutrientss ± S E in o-7 cm soil profile of different plantation/cash crop ecosystems. Values in parentheses represent nutrient concentration after crop harvest.

Elements	Coffee	Tea	Pineapple with other crops.	Ginger
C (%)	4.5 ± 0.09 (3.5 ± 0.10)	3.9 ± 0.07 (3.2 ± 0.07)	2.1 ± 0.07 (1.8 ± 0.06)	2.0 ± 0.10 (1.9 ± 0.09)
N (%)	0.3 ± 0.01 (0.3 ± 0.02)	0.2 ± 0.01 (0.2 ± 0.007)	0.4 ± 0.02 (0.3 ± 0.01)	0.2 ± 0.006 (0.3 ± 0.01)
P (mg 100 g^{-1})	0.07 ± 0.005 (0.10 ± 0.008)	0.18 ± 0.01 (0.22 ± 0.01)	0.06 ± 0.002 (0.05 ± 0.004)	0.11 ± 0.01 (0.17 ± 0.01)
K (mg $100g^{-1}$)	12.5 ± 0.8 (9.0 ± 0.06)	16.0 ± 0.10 (16.0 ± 0.08)	15.5 ± 0.15 (15.5 ± 0.10)	20.0 ± 0.6 (21.5 ± 0.08)
Ca (mg $100g^{-1}$)	48.5 ± 1.2 (38.0 ± 0.9)	57.6 ± 2.5 (46.0 ± 1.1)	34.9 ± 1.6 (23.3 ± 0.8)	67.8 ± 3.5 (50.2 ± 3.3)
Mg (mg $100g^{-1}$)	20.8 ± 2.0 (20.9 ± 1.8)	46.0 ± 2.2 (35.0 ± 1.3)	15.5 ± 0.8 (15.5 ± 0.6)	35.3 ± 3.3 (44.3 ± 2.7)

Table 2.2. Weed biomass ± S E (kg ha^{-1}yr^{-1}) recycled into different plantation/cash crop ecosystems.

Weed species	Coffee	Tea	Pineapple with other crops.	Ginger
Borreria articularis	136 ± 13	1288 ± 101	895 ± 86	2688 ± 175
Ageratum conyzoides	116 ± 11	532 ± 44	784 ± 75	5406 ± 371
Eupatorium odoratum	562 ± 43	0	33 ± 4	0
Panicum maximum	135 ± 10	41 ± 4	1319 ± 116	0
Others	258 ± 25	967 ± 88	947 ± 86	931 ± 78
Total	1207 ± 102	2828 ± 237	3978 ± 361	9025 ± 624

and magnesium were analysed by EDTA titration method while potassium was analysed by flame-emission method. Soil extraction for cations was carried out with 1N ammonium acetate at pH 7.

Input and output of the nutrients in the water were calculated on the basis of the amount of input/output through water and concentration of nutrients in it.

RESULTS

The concentration in the surface soil layers vary considerably from one system to another, both just before (March) and soon after harvest of the produce (February in case of a coffee and December in case of others) (Table 2.1).

Weed biomass recycled was significantly higher ($P < 0.05$) under ginger compared to others; this was least under coffee (Table 2.2). The contribution by <u>Borreria articularis</u> and <u>Ageratum conyzoides</u> was more than that by other weeds.

The nutrient input through weeds followed the general pattern as the biomass (Table 2.3),

Table 2.3. Total input of nutrients ± S E (kg ha^{-1}yr^{-1}) through weed biomass recycled into different plantation/cash ecosystems.

Elements	Coffee	Tea	Pineapple with other crops	Ginger
N	26.2 ± 2.29	91.75 ± 7.69	100.9 ± 9.05	295.7 ± 20.18
P	1.97 ± 0.18	7.49 ± 0.61	7.55 ± 0.73	19.1 ± 1.31
K	13.6 ± 1.17	44.6 ± 3.74	54.5 ± 4.94	123.8 ± 8.52
Ca	12.9 ± 1.09	32.4 ± 2.7	49.0 ± 4.44	136.3 ± 9.30
Mg	9.8 ± 0.86	26.6 ± 2.2	32.6 ± 2.96	98.3 ± 6.75

Fig. 2.1 Monthly litter production in coffee plantation. ○———○, Coffee leaf; ●———●, Coffee stem; △———△, *S. wallichii* leaf; ▲———▲, *S. wallichii* stem; □———□, *Bauhinia purpurea* leaf; ■———■, *B. purpurea* stem; ○------○, other trees.

Fig. 2.1

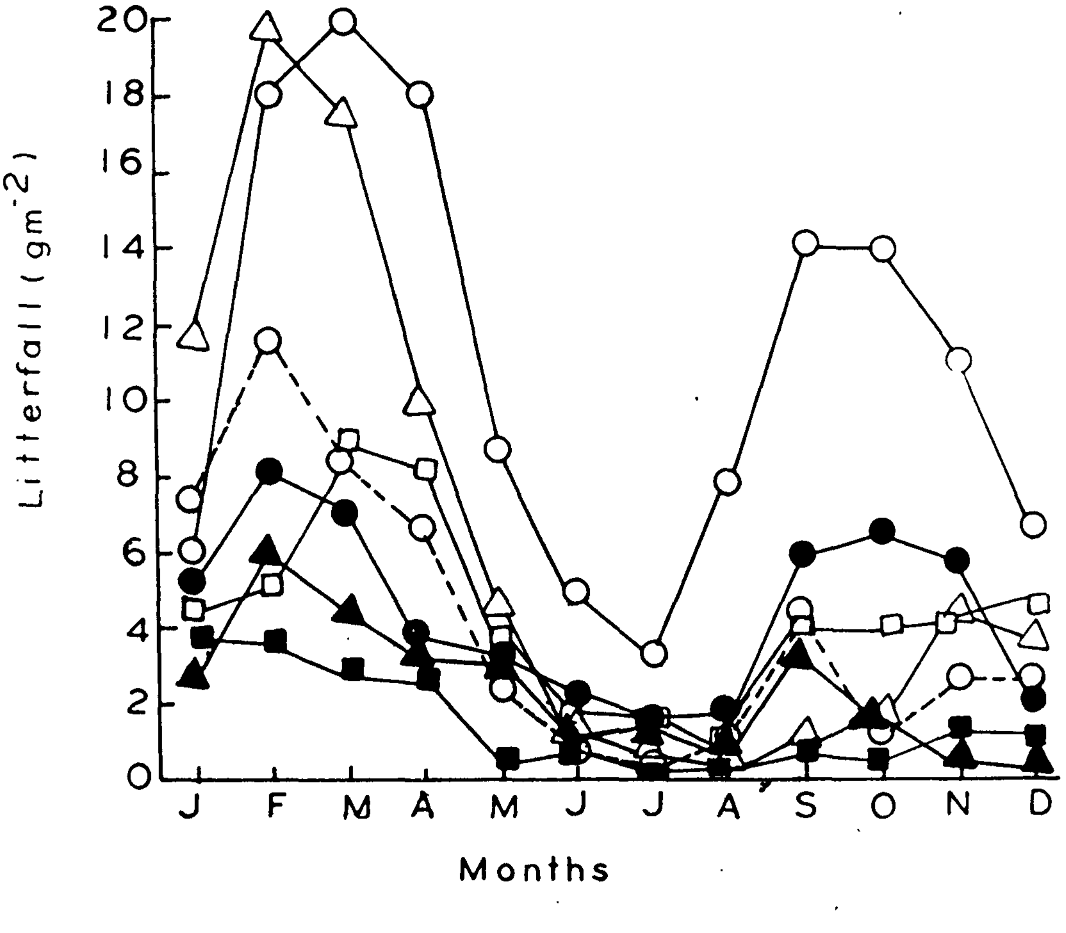
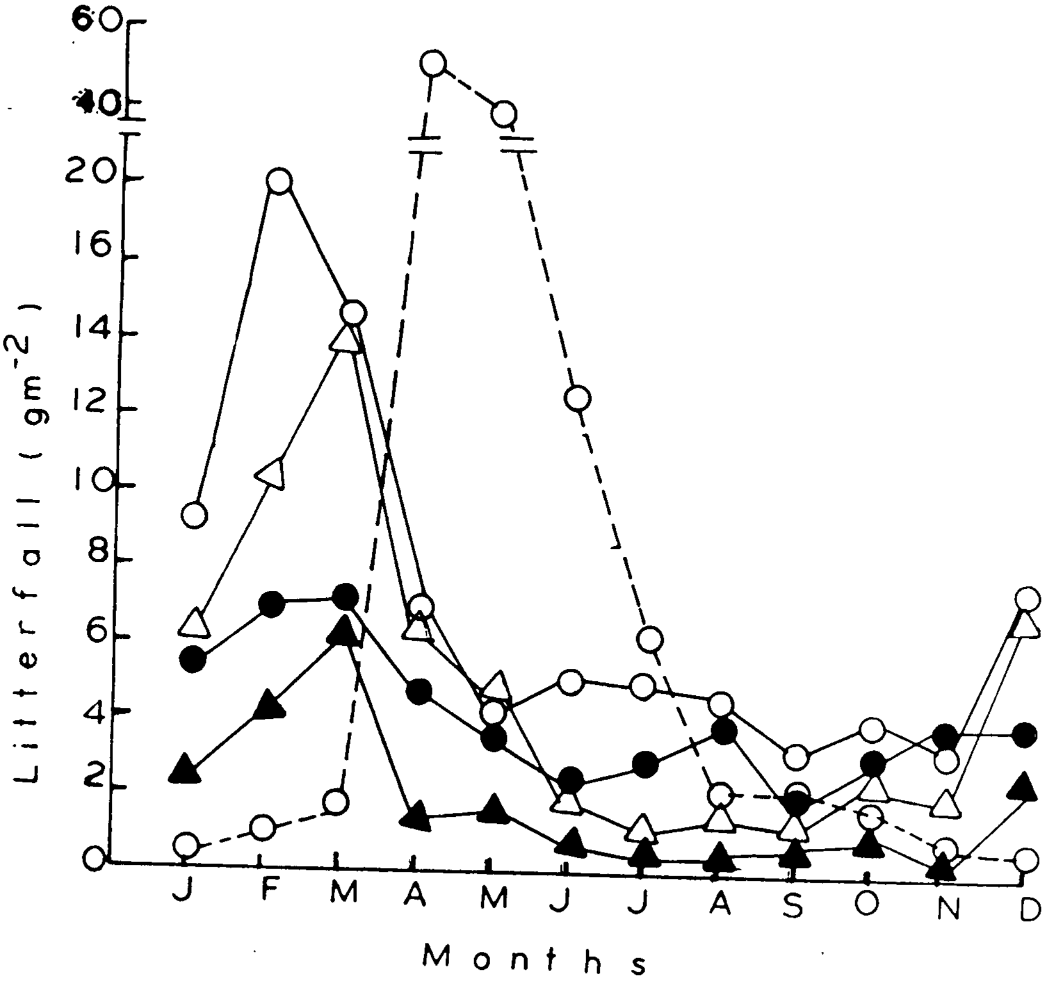


Fig. 2.2 Monthly litter production in tea plantation. ○------○, tea leaf (young); ○———○, tea leaf (mature); ●———●, tea stem; △———△, *A. odoratissima* leaf; ▲———▲, *A. odoratissima* stem.

Fig. 2.2



60
40
20
16
14
12
10
8
6
4
2
0
Litterfall (gm^{-2})
J
F
M
A
M
J
J
A
S
O
N
D
Months

Table 2.4. Litterfall ± S E (kg ha^{-1} yr^{-1}) and nutrient input ± S E (kg ha^{-1}yr^{-1}) through it in coffee plantation.

Plant component	Litterfall	N	P	K	Ca	Mg
Coffea arabica leaf	1337±157	40.0±0.16	1.4±0.16	10.8±1.26	15.7±1.83	11.0±1.29
non-leaf	53±74	13.3±1.73	0.26±0.03	2.4±0.33	5.1±0.71	3.4±0.47
Schima wallichii leaf	756±87	16.5±1.89	0.6±0.07	4.8±0.55	3.9±0.44	1.1±0.12
non-leaf	189±20	2.7±0.28	0.11±0.01	1.0±0.11	2.8±0.29	0.4±0.04
Bauhinia parpurea leaf	496±67	14.1±1.90	0.9±0.12	4.1±0.55	8.0±1.08	4.4±0.59
non-leaf	172±16	1.7±0.15	0.01±0.00	0.7±0.06	2.3±0.21	1.3±0.11
Other trees leaf	401±34	8.3±0.70	0.6±0.05	2.6±0.22	5.5±0.46	2.7±0.23
non-leaf	90±9	1.1±0.10	0.03±0.00	0.3±0.03	0.5±0.05	0.5±0.05
Total	3494±464	97.7±11.4	3.9±0.04	26.7±3.1	43.8±5.1	24.8±2.9

Table 2.5. Litterfall ± 1 S E (kg ha^{-1}yr^{-1}) and nutrient input ± S E (kg^{-1}ha^{-1}y) through it in tea plantation.

Plant component	Litterfall	N	P	K	Ca	Mg
Camellia sinensis leaf (young)	1205 ± 143	40.6 ± 4.83	2.2 + 0.26	7.9 ± 0.94	12.5+1.43	10.3+1.23
leaf (mature)	895 ± 86	25.1 ± 2.40	1.3 ± 0.12	4.3 ± 0.41	7.8±0.75	5.4±0.51
non-leaf	475 ± 46	13.0 ± 1.24	0.5 ± 0.04	4.9 ± 0.46	3.5±0.34	3.5±0.34
A. odoratissima leaf.	576 ± 59	17.2 ± 1.75	0.5 ± 0.05	6.3 ± 0.64	7.7±0.78	3.4±0.35
non-leaf	202 ± 20	4.2 ± 0.42	0.2 ± 0.02	1.8 ± 0.17	2.1±0.21	2.1±0.21
Total	3353 ± 354	100.1 ± 10.64	4.7 ± 0.49	25.2 ± 2.62	33.6±3.51	24.7±2.64

with maximum nutrient input through weeds into ginger and least for coffee. The input under ginger was 9 to 11 times more (11.3times for N, 9.7 times for P, 9.1 times for K, 10.6 times for Ca and 10 times for mg) than under coffee. The inputs of nitrogen, potassium and calcium were very high under all plantation/cash crops.

Monthly litterfall in coffee (Fig.2.1) and tea (Fig. 2.2) plantations peaked during February-March, with an additional peaking in coffee in September- October. In tea plantations young leaf fall peaked in April during the plucking time.

The litterfall from coffee bushes and nutrients released to the soil through it was more compared to Schima wallichii or Bauhinia purpurea, that are inter-grown (Table 2.4). However, the litter and nutrient contribution by all the total tree components inter-grown between coffee was higher than that through the coffee plants.

The contribution of litter in the tea plantation through tea leaf was higher than that through Albizzia odoratissima, a shade plant (Table 2.5). Nutrient input through Albizzia odoratissima represented

Table 2.6. Input of nutrients ± S E (kg ha^{-1}yr^{-1}) through stemflow, throughfall and precipation in coffee and tea (in parenthesis) plantation.

Category Cm.	Water input	NO_3-N	PO_4^-P	K	Ca	Mg
Stemflow	13.2 ± 1.2	0.08 ± 0.01	0.01 ± 0.00	0.84 ± 0.08	0.37 ±0.03	0.18 ± 0.02
	(6.8 ± 0.6)	(0.03 ± 0.00)	(0.00 -)	(0.33 ± 0.03	(0.11 ±0.01)	(0.11 ± 0.02)
Throughfall	125.7 ± 11.3	0.56 ± 0.05	0.06 ± 0.05	4.52 ± 0.41	2.63 ±0.74	2.39 ± 0.21
	(142.3 ± 9.4)	(0.49 ± 0.03)	(0.04 ± 00	(4.26 ± 0.28)	(2.13 ±0.14)	(3.13 ± 0.14)
Directfall[1]	176	0.44	0.04	1.76	0.79	0.97

[1] For pineapple with other crops and ginger.

15% to 32% of the total (21.3% for N, 14.9% for P, 32.1% for K, 29.2% for Ca and 22.5% for mg) through litter. The nutrient input through small twigs was substantial being about 1/5 of the total leaffall for tea and about $\frac{1}{3}$ of the total leaffall of *Albizzia odoratissima*.

Though litterfall under coffee was more than under tea, the latter had slightly high nitrogen and phosphorus input to the soil through litter compared to the farmer as shown by a comparision between Table 2.4 and 2.5.

About 21% of the total rainfall for coffee and 15% for tea were intercepted by canopy (Table 2.6). The stemflow under coffee plantation was more than under tea and due reverse was true for throughfall. While this difference in stemflow between the two plantation crops is reflected in the nutrient quatity, the throughfall nutrient levels were not significantly different between tea and coffee. The direct fall input occurred only in ginger and pineapple with other crops, but not in coffee and tea and the quantity of nutrients were generally much lower than that reached the ground level under coffee and tea plantations.

Table 2.7. Total loss of water (cm) and sediment (mt.ha^{-1}yr^{-1}) from different cash crop ecosystems ± S E values.

Category of loss	Coffee	Tea	Pineapple with other crops	Ginger
Run-off water	33.6 ± 1.70	73.6 ± 3.86	47.6 ± 2.94	58.9 ± 2.53
Percolation water	21.1 ± 1.03	13.4 ± 0.89	17.1 ± 0.97	35.9 ± 2.39
Sediment	1.37 ± 0.09	2.52 ± 0.19	0.54 ± 0.04	20.84 ± 1.49

Annual precipilation = 176 cm.

Table 2.8. Total loss of nutrients ± S E (kg $ha^{-1}yr^{-1}$) in run-off and percolation water from different cash crop ecosystem. Values in parentheses are for percolation losses.

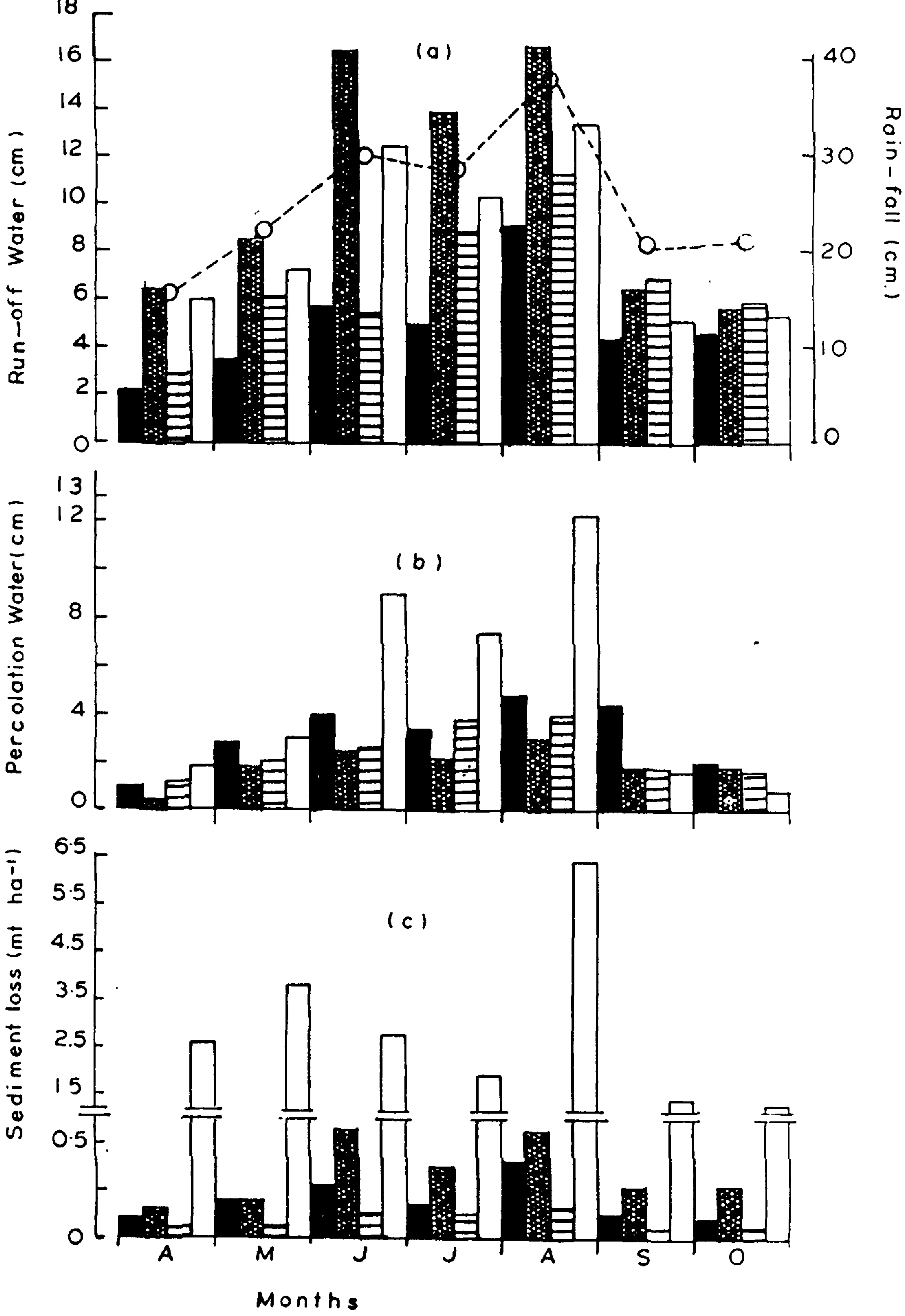
Element	Coffee	Tea	Pineapple with other crops	Ginger
NO_3 -N	3.03 ± 0.18 (3.80 ± 0.17)	6.61 ± 1.20 (2.20 ± 0.14)	1.05 ± 0.08 (2.28 ± 0.13)	6.10 ± 0.35 (8.38 ± 0.44
PO_4 -P	0.59 ± 0.03 (0.22 ± 0.02)	2.56 ± 0.15 (0.30 ± 0.02)	0.61 ± 0.04 (0.19 ± 0.01)	1.68 ± 0.07 (1.0 ± 0.05)
K	22.01 ± 0.96 (9.45 ± 0.35)	54.67 ± 1.61 (5.90 ± 0.35)	15,15 ± 0.68 (3.80 ± 0.22)	41.03 ± 1.57 (15.86 ± 1.02)
Ca	10.83 ± 0.64 (3.84 ± 0.17)	26.0 ± 1.36 (3.0 ± 0.21)	8.01 ± 0.48 (2.33 ± 0.12)	12.94 ± 0.56 6.36 ± 0.40
Mg	8.97 ± 0.41 (2.33 ± 0.11)	36.94 ± 1.95 (4.55 ± 0.25)	6.32 ± 0.40 (1.62 ± 0.17)	10.86 ± 0.49 (5.58 ± 0.35)

Table 2.9. Total loss of nutrients ± S E (kg $ha^{-1}year^{-1}$) through sediment from different plantation/cash crop ecosystems.

Element	Coffee	Tea	Pineapple with other crops	Ginger
NO_3-N	0.01 ± 0.001	0.02 ± 0.002	ND	0.19 ± 0.01
Total N.	0.24 ± 0.02	0.58 ± 0.04	0.06 ± 0.003	3.74 ± 0.26
PO_4^-P	0.02 ± 0.001	0.02 ± 0.001	0.005 ± 0 ±	0.22 ± 0.002
K	0.78 ± 0.06	2.68 ± 0.12	0.45 ± 0.03	16.41 ± 1.12
Ca	1.53 ± 0.11	1.19 ± 0.08	0.30 ± 0.02	13.46 ± 0.95
Mg	0.96 ± 0.07	2.13 ± 0.18	0.24 ± 0.02	9.10 ± 0.64

Fig. 2.3 Pattern of water and sediment loss during the monsoon season from a hectare of land under different plantation/cash crop ecosystems. ■ , Coffee; ▩ Tea; ≡ Pineapple with other crops; □ Ginger.

Fig 2.3


(a)
Run-off Water (cm)
0
2
4
6
8
10
12
14
16
18
Rain-fall (cm.)
0
10
20
30
40
(b)
Percolation Water (cm)
0
4
8
12
13
(c)
Sediment loss (mt ha-1)
0
0·5
1·5
2.5
3·5
4.5
5·5
6·5
A
M
J
J
A
S
O
Months

Run-off water was maximum in tea ($P < 0.05$) followed by ginger, pineapple with other crops and least for coffee (Table 2.7). On the other hand, percolation water was maximum in ginger and minimum in tea ($P < 0.05$). Sediment loss was very high in ginger ($P < 0.05$) compared to all other crops, with least value for pineapple with other crops. The loss pattern closely followed the monthly rainfall pattern with maximum values between June- August and with decline on either side (Fig. 2.3).

The run-off loss of nutrients was maximum in tea and minimum in pineapple with other crops, the other two falling in between (Table 2.8). On the other hand, nutrient load in the percolation water was maximum in ginger and minimum in pineapple with other crops. The monthly pattern of nutrient output through run- off and percolation water did not show any clear-cut pattern but only suggested that the losses increased sharply after fertilizer addition. Therefore the detailed data is not presented here.

Nutrient losses through sediment was significantly high ($P < 0.05$) in ginger compared to all others (Table 2.9). Least losses occurred in pineapple with other crops.

entry]

Table 2.10. Crop yield (kg ha^{-1}yr^{-1}) and nutrient output ± S E. (kg ha^{-1}yr^{-1}) from crop harvest. Values in parentheses are for losses due to pruning.

Crop	Yield	N	P	K	Ca	Mg
Coffee	496 ± 35 (875 ± 62)	11.9 ± 0.84 (53.7 ± 3.80)	0.9 ± 0.07 (1.0 ± 0.05)	8.9±0.63 (16.2±1.30)	2.0+ 0.14 (22.5± 1.03)	3.7±0.26 (12.1±0.21)
Tea	1316 ±956) (437 ± 38)	316 ±22.94) (28.0 ± 2.52)	10.7 ± 0.77 (1.7 ± 0.88)	123.8±9.1 (9.6±0.40)	154.1±11.85) (11.5± 0.73)	125.1±9.08 (9.0±0.28)
pineapple with other crops.	3165 ±267	90.2 ± 7.61	4.1 ± 0.35	46.5±3.92	17.4± 1.47	16.8±1.42
Ginger	2425 ± 186	72.5 ± 5.56	1.9 ± 0.15	34.7±2.7	10.2± 0.78	17.0±1.30

Table 2.11. Input-output analysis of nitrogen and phosphorus (in parentheses) (kg ha^{-1} yr^{-1}) in plantation/cash crop ecosystems.

	Coffee	Tea	Pineapple with other crops	Ginger
Input				
Precipitation	0	0	0.44 (0.04)	0.44 (0.04)
Stemflow and throughfall.	0.64 (0.06)	0.52 (0.03)	0	0
Fertilizer	96.64 (58.88)	160.0 (80)	0	108.36 (107.64)
Weed put back	26.2 (1.97)	91.75 (7.49)	100.9 (7.55)	295.7 (19.1)
Litterfall	97.7 (3.9)	100.1 (4.7)	0	0
Crop residue	0	0	50.6 (4.5)	12.01 (0.76)
Pruning	15.66 (0.57)	28.0 (1.7)	0	0
Total (a)	236.8 (65.4)	380.4 (93.9)	151.9 (12.1)	416.5 (127.5)
Output				
Run-off	3.03 (0.59)	6.61 (2.56)	1.05 (0.61)	6.1 (1.68)
Percolation	3.80 (0.22)	2.28 (0.30)	2.28 (0.19)	8.38 (1.0)
Sediment	0.24 (0.02)	0.58 (0.02)	0.06 (0.005)	3.74 (0.22)
Crop removal	11.90 (0.94)	316 (10.66)	90.20 (4.14)	72.50 (1.92)
Litterfall	97.7 (3.9)	100.1 (4.7)	0	0
Weed removal	26.2 (1.97)	91.75 (7.49)	100.9 (7.55)	295.7 (19.1)
Pruning	53.67 (1.01)	27.95 (1.65)	0	0
Total (b)	196.6 (8.7)	545.3 (27.2)	194.4 (12.5)	386.4 (23.9)
Difference (a-b)	40.2 (56.7)	- 164.9 (66.7)	- 42.5 (-0.4)	30.1 (103.6)

Table 2.12. Input-output analysis of cations (kg $ha^{-1}yr^{-1}$) plantation/cash crop ecosystems.

		Coffee			Tea			Pineapple with other crops			Ginger		
		K	Ca	Mg	K	Ca	Mg	K	Ca	Mg.	K	Ca	Mg
	Inputs												
1.	Precipitation	0	0	0	0	0	0	1.76	0.79	0.97	1.76	0.79	0.97
2.	Stemflow and throughfall	5.36	3.0	2.57	4.59	2.24	3.24	-	-	-	-	-	-
3.	Fertilizers	-	-	-	160	-	-	-	-	-	107.6	10.1	12.2
4.	Weed put back	13.6	12.9	9.8	44.6	32.6	26.6	54.5	49.8	32.6	123.8	136.3	98.3
5.	Litterfall	26.7	43.8	24.8	25.8	33.6	24.7	-	-	-	-	-	-
6.	Crop residue	-	-	-	-	-	-	22.4	12.3	11.5	7.09	2.57	4.72
7.	Pruning	9.2	8.3	8.0	9.6	11.45	8.0	-	-	-	-	-	-
	Total (a)	54.9	68.0	45.2	244	79.9	63.5	78.7	62.9	45.1	240.3	149.8	116.2
	Output												
1.	Run-off	22.01	10.83	8.97	54.67	26.0	36.94	15.15	8.01	6.32	41.03	12.94	10.86
2.	Percolation	9.45	3.84	2.33	5.90	3.0	4.55	3.8	2.33	1.62	15.86	6.36	5.58
3.	Sediment	0.78	1.53	0.96	2.68	1.19	2.13	0.45	0.30	0.24	16.41	13.46	9.10
4.	Weed removal	13.6	12.9	9.8	44.6	32.6	26.6	54.5	49.8	32.6	123.8	136.3	98.3
5.	Crop removal	8.9	2.0	3.7	123.8	154.1	125.1	46.5	17.4	16.8	34.7	10.2	17.0
6.	Litterfall	26.7	43.8	24.8	25.2	33.6	24.7	-	-	-	-	-	-
7.	Pruning	16.2	12.1	12.1	9.6	11.45	9.0	-	-	-	-	-	-
	Total (b)	97.6	87.4	62.6	266.4	261.9	229.1	120.4	77.8	57.6	231.8	179.2	140.8
	Difference (a-b)	-42.7	-19.4	-17.4	-22.4	- 182.0	-165.6	- 41.7	-14.9	-12.5	+ 8.5	-29.4	-24.6

The total quantity of nutrients removed due to crop harvest was markedly higher ($P < 0.05$) under tea plantation, followed by pineapple with other crops (Table 2.10). In coffee plantation, the nutrient lost due to pruning was about one and half to two times more than in tea.

The input/output analysis of cropping systems with respect to nitrogen and phosphorus are shown in Table 2.11. Tea and pineapple with other crops showed greater output of nitrogen compared to input whereas the reverse was true for coffee and ginger. Phosphorus input was generally higher than due output in all systems except pineapple with other crops where input and output almost equalled.

Cations input/output pattern showed that the output always exceeded input in all the systems except ginger where potassium output was less than input (Table 2.12). Net loss was minimal for potassium under tea and maximal for coffee, closely followed by pineapple with other crops. Loss of calcium and magnesium was maximum under tea plantation than in others.

DISCUSSION

All the plantation/cash crops (coffee, tea ginger and pineapple with other crops) are raised on terraces except tea that is raised on slopes. Except for pineapple with other crops, all the other three crop systems receive inorganic fertilizer. Ginger, in addition, also received organic manure as an additional input. Pineapple with other crops on the other hand received none. Due to differences in cultural practices and also because of use of weedicides in tea, weed potential in the crop ecosystems differed significantly. Dense canopy with heavy shade under coffee and absence of fertilizer use under pineapple with other crops, both caused reduced weed potential in these compared to ginger which with heavy fertlizer application of the soil promoted weed growth.

In traditional shifting agriculture system weed biomass is recycled into agroecosystem after removal thus contributing to nutrient conservation in the system (Chacon & Gleissman, 1982; Mishra & Ramakrishnan, 1984; Swamy, 1986). Following this traditional use of weed by the shifting agriculture farmers, even in these sedentary plantation/cash crop systems, the weed biomass is put back as mulch, which was more in ginger than in others. Apart from nutrient release during decomposition of the weed biomass the surface mulch also helps in preventing soil and nutrient losses through run-off (Toky & Ramakrishnan, 1981b; Mishra & Ramakrishnan, 1983a)

Nutrient recycling in coffee and tea plantation is also because of litterfall from there two species as well as from the shade tree species such as naturally occurring Schima wallichii and Bauhinia purpurea in coffee plantation and planted Albizzia odoratissima in tea plantation.

Leaffall in coffee is largely from mature leaves occurring through out the year with maximum fall during February- March. Leaffall in Schima wallichii and Bauhinia purpurea also peaked during February- March. On the other hand, leaffall in tea was both through young leaves during plucking (maximum in April) and through mature leaffall which peaked during February. A seasonal trend where litterfall peaked during the dry reason was also found in other tropical rain forests (Nye, 1961; Klinge & Rodrigues, loss. Even in coffee and tea plantations the losses could be substantial. This would seem to suggest that a multiple cropping system with a vertically layered crop mixture as in home gardens (Maikhuri, 1987) may be more appropriate to conserve nutrient in the system. With a high concentration of nutrients in the leaves, the output of nutrients from tea was substantial,compared to others. Coffee plantation is not very successful in this area and therefore the economic yield was low (Chapter- 1) and the consequent low output of nutrients through crop harvest.

Nitrogen and phosphorus budgets in plantation/ cash crop systems showed differences from the shifting agriculture thus, the loss of nitrogen after a year of cropping was far less than under shifting agriculture (Mishra & Ramakrishnan, 1984; Swamy & Ramakrishnan, 1986a). Coffee even showed a net gain in nitrogen. Except in pineapple with other crops, a net gain in phosphorus occurred in all the systems whilst under shifting agriculture losses were shown (Swamy & Ramakrishnan, 1986a). Unlike under shifting agriculture where a net gain in cations occurred (Swamy & Ramakrishn 1986b) because of its release through ash, under the

1968). However the contribution of nutrient by the young leaves of tea was more than through mature ones.

Precipitation is an important source of nutrient input into forested ecosystem (Nye, 1961; Likens et.al., 1977; Swank and Henderson, 1976). The amount of water coming as throughfall and stemflow would depend largely on the canopy structure. Thus, coffee plantation had more quantities of water channelized through it than tea. Apart from canopy structure, the coffee plantation was older (25years) than tea (6 years).

The total amount of nutrients in stemflow in both was relatively low despite the higher concentrations, than in throughfall. This is due to the fact that the stemflow water was only a smaller proportion of the precipitation and hence its role as pathway for nutrient transfer was relatively minor (Monokaran, 1979). Such a higher throughfall percentage was also reported by other workers (Ovington, 1962; Eaton et.al., 1970; Foster and Gessel, 1972).

Amongst all the elements potassium, a monovalent cation, was more mobile (Tokey et.al.,1958;

Gosz *et.al*., 1975). The order of leaching of elements through throughfall and stemflow was $K > \frac{Ca}{mg} > NO_3\text{-}N > PO_4\text{-}P$.

With coffee, pineapple with other crops and ginger being grown on terraces, the losses through run-off water was relatively lower than tea grown on slopes. However, losses from ginger grown on terraces prepared into ridges and farrows was more because of the poor physical quatity of the soil which was frequently disturbed. Frequent disturbances also occured in pineapple mixed with other crops. However, since the pineapple plants were closely planted along the margin of the terrace, and the other crops in middle, the former acted as a check to loss of sediment and nutrients.

In earlier studies on shifting agriculture system done on steep slopes of 30-40^{0}angle, it was shown that percolation losses of nutrients from the system could be substantial going upto as much as 50% of the total (Mishra & Ramakrishnan, 1983a; Toky & Ramakrishnan, 1981b). With terracing under mixed cropping with pineapple or under ginger the percolation losses of nitrogen, phosphorus and potassium could vary from $\frac{1}{3}$ to as high as two times of the run-off plantation/cash crops there was consistently net loss from the system. The ultimate nutrient status of the soil in March before the crop growth phase and in December (February in case of coffee) after crop harvest is a consequence of the balances achieved after accounting the inputs and outputs from the system. That is one of the reasons why no distinct patterns in soil nutrient levels could be recognized between the crop systems or for the different elements.

With weed biomass being put back into the system, not only the nutrients are conserved but the weed biomass also protected the nutrients from loss through water. A major difficulty with the plantation/cash crop ecosystems, however, is the need for a heavy input of inorganic fertilizers. The possibilities of effective recycling of resources in there ecosystems need to be explored.

SUMMARY

The four plantation/cash crop systems had differening weed potential related to cultural practices. The input of nutrients into these ecosystems differed depending upon the weed biomass put back, the litterfall and input of nutrients from external sources. In the case of coffee and tea, throughfall and stemflow inputs also occurred. The losses from the system varied depending upon the plant cover, harvesting procedures and the fertilizer inputs, with gain or loss from the system at the end of a cropping year. The significance of there results are discussed.

CHAPTER 3

ECONOMIC YIELD AND ENERGY EFFICIENCY OF AGROECOSYSTEMS OF THE APATANI TRIBE OF ARUNACHAL PRADESH IN NORTH-EAST INDIA.

INTRODUCTION

Small farmers in the wet tropics concentrate upon rice cultivation to obtain their basic food needs because rice, like sugarcane, maize and tuber crops is one with aparticularly high calorie content (Finck, 1970). These traditional systems based on technology developed over many, generations (Schultz, 1964) are often energy efficient as shown through many studies done in different parts of world (Rappaport, 1971; Steinhart and Steinhart, 1974) and as also shown through many of our studies in north-east India (Mishra and Ramakrishnan, 1981; Toky and Ramakrishnan, 1982). Though mechanization of agriculture has increased production potential of site (Pimentel et.al., 1974; FAO, 1977), They are inefficient in terms of energy use and are based largely on fossil fuel energy inputs and less labour intensive, and therefore could leave to unemployment or underemployment in developing countries where labour is cheap and abundant (National Productivity Council , 1973).

Wet cultivation of rice in irrigated valleys and on slightly terraced land around the valleys is a traditional and important land use system along with dry cultivation of millet on rolling dry hill tops practised by the Apatanis in Arunachal Pradesh in north-east India. These agroecosystems are fundamentaly different from those of other tribes of north-east India who practice traditionally shifting agriculture (Ramakrishnan _et_._al_.,1981a; Ramakrishnan, 1984a) This settled form of agriculture has often been quoted by the Governmental agencies in the region as an example for adoption by the shifting agriculture farmers of the region and as an alternative land use system. However this agriculture has not found acceptance from other tribal communities as a possible alternative strategy.

The present study, therefore was initiated in this context to evaluate:
(i) The organization of the cropping system,
(ii) The ecological and economic efficiencies of the system through energy and monetary analysis,
(iii) The factors that make this land use system sustainable on a long term basis and, (iv) The inapplicability of this as an alternative land use for shifting agriculture.

STUDY AREA AND CLIMATE

This study was done at Ziro (27^{0}36'N 93'49 E) of the lower Subansiri District at an elevation of 1572 m in Arunachal Pradesh. The climate is typical monsoonic with about 75% of the total annual rainfall (1758 mm) occurring during May to September. Monsoon is followed by a relatively dry winter, March and April representing the brief dry summer season. Average monthly maximum and minimum temperatures during the summer months were 24.1'C and 12.7'C where as they were 17.0'C and 2.8'C respectively during the winter.

DESCRIPTION OF ARGOECOSYSTEMS

Wet rice cultivation:

Two varieties of rice are grown by the Apatanis as part of the wet cultivation of rice in the valley system. Late variety of rice alone but mostly associated with pisciculture as an integrated system is located in the valleys closer to the village. Along the periphery of the valley with slightly formed terraces early rice variety but without pisciculture could occur. Millet

(*Eleusine coracana*) grown along with rice is confined to bunds (partitions) between the plots or in plots on hill tops.

Preperation of the land in the Apatani village starts from February with surface application of rice husk derived from the previous cropping year. The existing water channels are repaired by the community as a collective effort. Water from the hill slopes and from the village itself is channelized. Handtilling is followed by levelling ground after filling up the plot with water, only where early variety of rice is sown. Rice seedlings are transplanted in April- May from nursery beds raised separately during March-April. Simultaneously, seeds of millet (*Eleusine coracona*) are dibbled along the bund (partitions) between the plots. Fish fingerlings are introduced into the plots if it is a part of the agricultural system. Weeding is done at regular monthly intervals and water flow is controlled through manipulation of bamboo sluice.

While early variety of rice and millet are harvested during August-September itself, The late variety where grown is harvested only in October. However, fish culture along with late rice variety is harvested in August.

Dry millet cultivation:

Millet cultivation on hill tops recieve an application of organic manure. Before the seed is dibbled at regular intervals in the month of May. Weeding is done twice, first after 15-days after sowing and then once again in June-July. Harvesting is completed by August-September.

Kitchen garden:

A mixture of crops are grown together in the kitchen garden. After an initial application of organic manure in the plot in February, potato is sown while other tu~~y~~ber crops are sown in March. *Zea mays* and *Eleusine coracana* seeds are dibbled in May after the onset of monsoon whereas vegetable and fruit crops are planted in June-July. Weeding is done 2-3 times during the cropping season. A sequential harvesting of crops starting with the harvest of potato in May extended upto November-December.

METHODS OF STUDY

Agriculture plots with cultivation of early and late variety of rice located within and outside the village boundary were selected. Millet cultivation under dry land cropping and kitchen garden plots were also selected. Each of these different categories had three replicate plots.

Density and basal area of crop plants were measured before crop harvest using twenty randomly placed $1m^2$ quadrates for rice and millet and $5m^2$ for the kitchen garden. Economic yield measurement are based on an average of 15 individuals of each crop species. Economic yield per hectare was then computed using the density values obtained for each crop species.

The monetary input-output analysis was done on the basis of prevailing rates of wages for labour, at the rate of Rs. 9 for the female and Rs. 11 for the male. The total economic yield was converted into rupees on the basis of prevailing market price. Economic efficiency was evaluated as output/input ratio.

Labour input in man.hours was recorded under each agroecosystem. 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 expenditures 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 calculate the labour energy input into the system (Gopalan et.at.,1978). The input of energy through seeds was calculated on the basis of total energy expended to produce that fraction of crop yield. The fossil fuel equivalents given in Table 3.1 were used to calculate the replacement cost of the organic manure in terms of fossil fuel energy. For calculating the output of energy under different agroecosystems the total economic yield of the various crops was converted into megajoules of energy by multiplying with standard values of various edible parts of crops as given in Table 3.1. The energy efficiency was calculated as the output/input ratio.

Plant components (edible and non-edible) were sampled separately during harvesting for

Table 3.1. Energy value for different items considered in agroecosystem.

Items	Energy value (MJ)
Grains[1]	16.31
Fruits	14.94
Leafy vegetables	13.77
Tuber and rhizome crops	13.77
Fish	4.7
Cost of production[2]	
N	79.99
P_2O_5	13.95
K_2O	9.97
Replacement cost[3]	
Rice husk	1.0
Organic manure	1.4

[1] Gopalan *et.al*., 1978.
[2] Pimentel *et.al*., 1973.
[3] Percentage of N, P_2O_5 and K_2O in the rice husk and organic manure was 1, 0.2 and 1.8 and 1.4, 1.2 and 1.2 respectively.

chemical analysis. Soil (0-7 cm) was also sampled from ten random points after the crop harvest. Available phosphorus was measured in fresh soil sample, colorimetrically, by ammonium molybdate.method after extraction with Bray and Kurtz's solution (1945). The soil was air dried, ground and passed through a 2 mm sieve, and stored in polythene jars for subsequent analysis. Elemental analysis was done following standard procedures (Allen et.al.,1974). Thus, organic carbon was determined by Walkey-Black method, nitrogen was estimated by micro-Kjeldaul method. Cations were extracted with IM ammonium acetate solution at PH 7. Potassium was estimated with flame-emmission method and calcium and megnesium by EDTA tritration. Oven dried plant samples were ground to powder and passed through a 0.5 m m sieve. After wet digestion with triple acid (Allen et. al., 1974) nitrogen, phosphorus and potassium were analysed as soil samples.

Table 3.2. Mean concentration of nutrients ± S.E. in 0-7 cm soil profile of different agroecosystems of Apatanis in north-east India.

Elements	Rice Within the village	 Outside the village	Kitchen garden	Millet
C (%)	2.3 ± 0.2	1.4 ± 0.09	2.2 ± 0.2	1.5 ± 0.09
N (%)	0.3 ± 0.02	0.2 ± 0.02	0.3 ± 0.03	0.2 ± 0.01
P(mg100g^{-1})	0.11± 0.01	0.09± 0.01	0.11± 0.01	0.07 ± 0.007
K (mg 100g^{-1})	25.0 ± 1.2	15.0 ± 0.8	17.5 ± 1.3	15.0 ± 1.0
Ca (mg 100g^{-1})	112.5 ± 9.4	67.5 ± 3.2	97.5 ± 6.8	57.5 ± 1.4
Mg (mg 100g^{-1})	32.5 ± 1.2	27.5 ± 0.8	42.5 ± 1.9	17.5 ± 0.8

Table 3.3. Density, basal area and mean economic yield ± S E of rice agroecosystem of Apatanis in north-east India. Values in parentheses are for *Eleusine coracama.*

Agroecosystem[1]	Density ($plant\ m^{-2}$)	Basal area ($cm^2 m^{-2}$)	Mean economic yield: $g\ plant^{-1}$	Mean economic yield: $kg\ ha^{-1}$
Within the village:				
Rice (late var.)[2]	32 (112)	400 (25.7)	12.7±0.4 (2.8±0.1)	4064±141 (102.5±3.7)
Outside the village:				
Rice (early var.)	48 (104)	216 (23.9)	7.2±0.3 (2.4±0.1)	3456±163 (129.5±5.9)
Rice (late var.)[2]	44 (112)	374 (25.7)	8.8±0.3 (2.8±0.1)	3872±152 (102.5±3.7)

[1] Average bund area ha^{-1} rice plot was 519 m^2 and 327 m^2 respectively in early and late varieties.

[2] Fish production where it was involved was 48 kg ha^{-1}.

RESULTS

A comparative study of soil nutrient status under different agroecosystems of the Apatani tribe showed significant differences depending upon the agroecosystem type (Table 3.2). The rice plots closer to the village were nutritionally richer ($P<0.05$) than those outside. The soil under kitchen garden was also nutritionally rich but only next to plots under rice closer to the village. The plots under millet cultivation had lower soil nutrient status ($P<0.05$) compared to kitchen garden.

Rice plots closer to the village had lower density and higher basal area compared to those outside (Table 3.3). The former had significantly higher ($P<0.05$) economic yield per plant as compared to those in plots outside the village. Total economic yield of the late variety of rice was not significantly different in plots within and outside the village. However, economic yield differed significantly ($P<0.05$) between early and late varieties. Economic yield of *Eleusine coracana* from bund was comparatively more in the plot of early variety of rice as compared to late variety. Pisciculture did not affact the yield of rice.

Table 3.4. Density, basal area and mean economic yield ± S.E. of kitchen garden and millet agroecosystem of Apatanis in north-east India.

Crop	Density (plants m^{-2})	Basal area (cm^2 m^{-2})	Mean economic yield g $plant^{-1}$	kg ha^{-1}
Kitchen garden				
Grain and seed				
Eleusine coracana	12	3.7	3.6 ± 0.2	432 ± 24
Zea mays	3.6	12.6	66.4 ± 3.2	2390 ± 115.2
Leafy and fruit vegetables				
Brassica oleracea	0.3	0.01	65.6 ± 6.2	196.8 ± 18.6
Capsicum frutesence	0.3	0.23	3.4 ± 0.2	10.2 ± 0.6
Cucurbita maxima	0.03	0.05	115.6 ± 8.4	34.7 ± 2.5
Cucumis sativa	0.03	0.05	98.9 ± 8.9	29.5 ± 2.7
Dolichos lablab	0.02	0.02	270 ± 22	54 ± 4.4
Lycopersicum esculentam	0.07	0.05	10.5 ± 1.0	7.4 ± 0.7
Solanum melongena	0.01	0.02	112 ± 8.6	11.2 ± 0.9
Tuber and rhizome crops				
Colocasia antiquorum	0.08	0.16	98.2 ± 5.4	78.6 ± 4.3
Manihot esculentus	0.04	0.02	546 ± 38.6	218 ± 15.3
Solanum tuberosum	0.6	1.06	46 ± 2.2	276 ± 13
Zingiber officinal	0.01	0.04	40.3 ± 1.3	4.3 ± 0.1
Millet Cultivation				
Eleusinecoracana	70	38.5	2.9 ± 0.2	2030 ± 140

Table 3.5. Cost-benefit analysis (Rs. ha^{-1} yr^{-1}) of rice agroecosystem of Apatanis in north-east India. Values in parentheses are for net return.

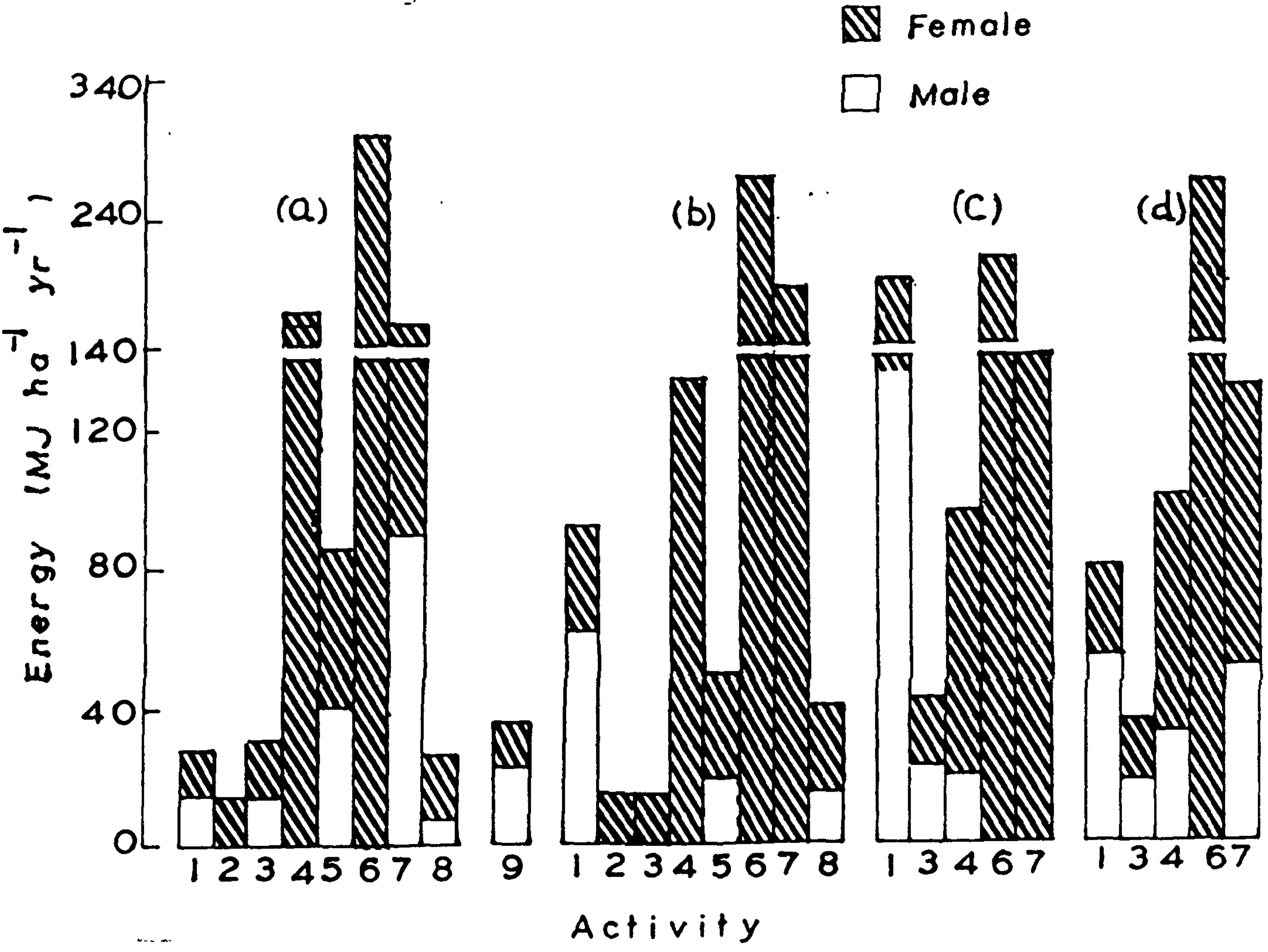
Production measures	Within the village	Outside the village	
	Late Var.	Early var.	Late var.
Input total: Rice	2481	2677	2899
Rice + millet	2551	2798	2969
Rice + millet + fish	2753	-	3171
Labour : Rice	2163	2337	2349
Millet	67	116	67
Fish	102	-	102
Organic manure	250	250	450
Seed: Rice	68	90	100
Millet	3	5	3
Fish	100	-	100
Output total: Rice	8941 (6460)	9603 (4946)	8518 (5619)
Rice + millet	9102 (6551)	7817 (5039)	8679 (5710)
Rice + millet + fish	10062 (7309)	-	9639 (6468)
Economic efficiency			
Rice	3.60	2.84	2.94
Rice + millet	3.57	2.79	2.92
Rice + millet + fish	3.65	-	3.04

Table 3.6. Cost- benefit analysis (Rs. $ha^{-1}yr^{-1}$) of kitchen garden and millet agroecosystem of Apatanis in north-east India.

Production measures	Kitchen garden	Millet cultivation.
Input Total	3162	2212
Labour	2580	1992
Organic manure	350	100
Seed	232	120
Output Total	10524	3350
Grain and seed	7882	3350
Leafy and fruit vegetables.	1081	-
Tuber and rhizome crops	1561	-
Economic efficiency	3.33	1.51

Fig. 3.1 Allocation pattern of labour for different activities under different agroecosystems of Apatanis in north-east India: a, rice (late var) cultivation outside the village; b, rice (early var) cultivation outside the village; c, kitchen garden and d, millet cultivation. 1, Field preparation; 2, Nursery; 3, Fertilizer; 4, Sowing; 5, Irrigation; 6, Weeding; 7, Harvesting and threshing; 8, Millet cultivation on bund of rice plots and 9, Pisciculture.

Fig. 3.1


Female
Male
Energy (MJ ha^{-1} yr^{-1})
340
240
140
120
80
40
0
(a)
(b)
(c)
(d)
1 2 3 4 5 6 7 8
9
1 2 3 4 5 6 7 8
1 3 4 6 7
1 3 4 6 7
Activity

The chief emphasis in the kitchen garden was on grain and seed crops, accounting for about 75% of total yield (Table 3.4). Mean economic yield per plant of Eleusine coracana was significantly lower ($P<0.05$) under monoculture than in the kitchen garden.

Late variety of rice grown within the village had lesser organic manure input, whereas the input was higher for the late variety cultivated outside the village (Table 3.5). Millet and fish are additional outputs from this system. The economic efficiency of rice cultivated within the village was higher than that outside.

The economic output from kitchen garden was very high and was comparable to rice cultivated with pisciculture within the village (Table 3.6). The yield from millet cultivation was lower, with lower economic efficiency. The economic efficiency of kitchen garden was comparable with rice cultivated within the village.

Labour energy input by females was generally more than by males (Fig.3.1). Weeding done by females contibuted to about 30-40% of the total energy input. Energy input for land preparation was higher for the early variety of rice involving hand ploughing. Fencing by males involved higher labour input for kitchen garden. Energy expended

Table 3.7. Energy input-output pattern ($MJ\ ha^{-1} yr^{-1}$) and efficiency of rice agroecosystem of Apatanis in north-east India.

Production measures.		Within the village	Outside the village	
		Late var.	Early var.	Late
Input total:	Rice	846.5	904.5	1027.5
	Rice+millet	870.2	946.0	1051.5
	Rice+millet+fish	906.6	-	1087.9
Labour:	Rice	713	769	786
	Millet	23	40	23
	fish	36	-	36
Organic manure		125	125	225
Seed :	Rice	8.5	10.5	16.5
	Millet	0.7	1.5	1.0
	Fish	0.4	-	0.4
Output total :	Rice	66284	56367	63152
	Rice+millet	67956	58480	64824
	Rice+millet+fish	68182	-	65050
Energy efficiency				
Output/input ratio				
	Rice	78.3	62.3	61.5
	Rice+millet	78.1	61.8	61.6
	Rice+millet+fish	75.2	-	59.8
Output/labour hour				
	Rice	35.6	27.6	31.2
	Rice+millet	35.4	27.4	31.2
	Rice+millet+fish	34.1	-	30.1

Table 3.8. Energy input-output pattern (MJ $ha^{-1} yr^{-1}$) and efficiency of kitchen garden and millet agroecosystem of Apatanis in north-east India.

Production measures		Kitchen garden	Millet cultiv
Energy input:	Total	1774	1037
	Labour	687	643
	Organic manure	1050	336
	Seed	37	58
Energy output:	Total	58873	33109
	Grain and seed	46027	-
	Leafy and fruit vegetables	4906	-
	Tuber and rhizome crops	7940	-
Energy efficiency			
	Output/input ratio.	33.2	31.9
	Output/labour hour.		19.5

for harvesting was more for the early variety with total contribution through females where as the contribution for the harvest of the late variety was almost the same between males and females.

With lesser energy input for rice cultivated within the village, the output from it equalled that of the late variety outside the village but was higher than that for the early variety (Table 3.7). With additional output through millet in all cases and through fish in late varieties of rice cultivated both within and outside the village the energy output improved. The energy efficiency of rice cultivation was very high (60-78) and this declined only slightly, when millet and fish are included. The energy efficiency of rice cultivated within the village boundary was higher than that of others. The output per labour hour, however, was minimal for early variety grown outside the village.

For a marginally higher energy input into kitchen garden the output was relatively more compared to millet (Table 3.8). While the energy

Table 3.9 Nitrogen, Phosphorus and potassium loss (Kg. ha^{-1} yr.$^{-1}$) due to Crop harvest in different agroecosystems of Apatanis in north-east India

	Within the village Rice (late variety)			Outside the village, Rice						Kitchen gargen			Millet cultivation		
				early variety			late variety								
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Inputs															
Non-edible	51.9	4.3	49.2	69.8	5.8	94.1	42.5	3.4	39.6	80	12.1	199.2	57.1	7.7	84.4
Rice husk	1.0	0.8	2.3	1.0	0.8	2.3	2.3	1.8	4.1	0	0	0	0	0	0
Organic manure	0	0	0	0	0	0	0	0	0	10.4	9.0	9.0	3.4	2.9	2.9
Total (a)	52.9	5.1	51.5	70.8	6.6	96.4	44.8	5.2	43.7	90.4	21.1	208.2	60.5	10.6	87.3
Output															
Crop harvest Edible	41.0	3.4	46.6	34.4	2.9	39.5	39.0	3.2	44.3	40.3	8.5	151.5	31.2	3.2	44.7
Non-edible	61.6	5.1	57.9	69.8	5.8	94.1	50.1	4.0	46.6	100.2	16.4	221.3	67.2	9.1	112.5
Total (b)	102.6	8.5	104.5	104.2	8.7	133.6	89.1	7.2	90.9	140.5	24.9	372.8	98.4	12.3	157.2
Net loss (a-b)	49.7	3.4	53.0	33.4	2.1	37.2	44.3	2.0	47.2	50.1	3.8	164.6	37.9	1.7	69.9

efficiency was more or less similar, the output per labour hour was higher for the former.

Nitrogen, phosphorus and potassium budgets of the agroecosystems are given in Table 3.9. The non-edible component of the crop in all cases and rice husk in the case of rice cultivation alone, are recycled as inputs into the systems. Input of nutrients through organic manure was only for millet cultivation and kitchen garden. The net loss through crop harvest was maximum through kitchen garden for nitrogen, phosphorus and potassium followed by rice cultivated within the village, the exception to this was potassium where the net loss through crop harvest was higher for millet than that for rice cultivated within the village.

DISCUSSION

Unlike most of the other tribal communities of north-east India, Apatanis have evolved sedentary agriculture chiefly in the form of wet rice cultivation in their extensive valley lands. Valley land agriculture is one of the important land use system even amongst tribals with shifting agriculture (Jhum) as the major land use, though this is restricted elsewhere because of topography. The chief advantage of this land use is because of the nutrients wash-out from the hill slopes during the rains. When crop is harvest considerable quantities of nutrients are lost through economic yield (Rosswall and Paustian, 1984; Swamy and Ramakrishnan, 1978a;b) and must be replaced for sustainable yield. One of the ways in which this is done by Apatanis is through recycling of crop residues (Jones, 1976), as shown here. Moreover the wash-out of nutrients from hill slopes and from organic wastes generated in the village also contribute to replenishment of the lost nutrients before the next cropping. Thus about 30-50 kg. of nitrogen lost during one cropping season may be replaced through soil nitrification processes (Patrick & Mahapatra, 1968). The amount of potassium lost from rice cropping is substantial (about 40-50 kg.), even more in the kitchen garden system (165 kg). Perhaps only input from outside during the fallow period could replace whatever is lost.

Irrigation farming such as wet cultivation of rice require cooperation of several farmers and communal work to maintain, and improve the water delivery system (Ruthenburg, 1976). In the absence of a disciplined schedule and scale of water distribution among the beneficiaries, very often economic returns could decline drastically. The Apatanis with cooperative management of the water delivery system under the overall supervision of the village head man, have optimized water use in their rice fields.

Apatanis make best use of their irrigated land by planting early and late ripening varieties of rice. Early ripening variety is sown farther away from the village where disturbance by animals and poorer irrigation facilities could be major constraints. On the other hand, closer to the village where conditions are more favourable late ripening variety is preferred. The yield from rice is supplemented by cultivation of <u>Eleusine coracana</u> on the elevated bunds between the rice plots and through pisciculture along with late variety of rice because of more assured water supply. With a production of about 50 kg of fish providing additional income of about Rs.1000 - which is equivalent to the cost of about 450-500 kg. of rice, pisciculture compares favourably with similar systems from Java and Madagaskar (Hickling, 1961).

Kitchen garden is an important component of the Apatani village in that it meets all the varied food requirements of the community through mixed cropping. In the traditional societies of north-east India under shifting agriculture this function is performed through mixed cropping under shifting agriculture itself (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981).

With human labour as the major input and with very little organic manure use, the Apatanis obtain high energy output as crop yield. The efficiency of the system expressed as output/input ratio is very high (60-78) for rice cultivation unlike what was reported earlier for the Khasis (Mishra and Ramakrishnan, 1981) and the Garos (Toky and Ramakrishnan, 1982) in Meghalaya in north-east India (3-48) and a value of about 9 for traditional Indian agricultural system (Mitchell, 1979) and traditional rice cultivation elsewhere in the Philippines (Nguu and Palis, 1977). Compared to the energy efficiency of millet cultivation and kitchen garden the values are more than double for rice. Such a high energy efficiency with a reasonable monetary efficiency of about 3 makes the rice system of the Apatanis one of the effective models of traditional agriculture, particularly when it is realised that human labour is a free input being largely obtained from within the family itself and for specific tasks through cooperative effort. A high energy efficiency obtained here is ever greater than what has been recorded for shifting agriculture in north-east India (Mishra and Ramakrishnan, 1981; Toky and Ramakrishnan, 1982) and elsewhere (Rappaport, 1971; Steinhart & Steinhart, 1974). With 27-35 MJ units of energy output per labour hour, this system compares favourably with similar systems of China (Dazhong and Pimentel, 1984) and even more modern agriculture of industrialised societies (Leach, 1976) such as United Kingdom with an output of 40 MJ units.

SUMMARY

Apatanis of Arunachal Pradesh in north-east India practice valley cultivation of rice which also extends along the periphery through gently formed terraces. Close to village late variety of rice is grown where as outside the village boundary it may either be early or late variety. Late variety of rice is often associated with pisciculture. With minimal inputs of organic manure as rice husk the quantity of which is higher in the peripheral plots and with tight recycling of domestic liquid waste into the plots within the village boundary, this system is self sustainable and have exceptionally high energy and economic efficiencies. Dry land cultivation of millet and mixed cropping in kitchen gardens contribute towards diverse needs of this community.

CHAPTER 4

ECONOMIC AND ENERGY EFFICIENCY OF ANIMAL HUSBANDRY SYSTEM OF THE APATANI TRIBE OF ARUNACHAL PRADESH IN NORTH-EAST INDIA.

INTRODUCTION

Although a considerable attention has gone into identifying new plant species for food and fibre, animals (other than cattle) as a source of protein are often overlooked in developing countries (De Vos, 1977). Domestic animals provide several very important links in a predominantly solar economy . They function well on light energy, feeding mostly on plant tissues unsuitable for human consumption- grasses and crop by-products -supplemented with only small amount of grain (Odum,1971); they deliver the essential power for many farm tasks, recycle the valuable nutrients and finally are a critical source of protein for the population.

Animal husbandry system of Apatains comprising mithun (Bos frontalis), cattle, swine and poultry and fish culture is important, in their culture and diet. Though to a lesser extent than for the other traditional societies (Mishra & Ramakrishnan, 1982; Maikhuri, 1987). This is because of the emphasis on a better organized and efficient sedentary agriculture system. The objective of this study, therefore, is to access the role of animal husbandry in this tribal society and its role as a production system in the village.

METHODS OF STUDY

This study is based upon observations made on an Apatani village Hari at an elevation 1572 m in Arunachal Pradesh in north-east India for detailed observations on the economic and ecological budgeting of each category of animal, observations were made on 15 randomly identified families.

The total feed energy requirement of each category of animals till the age of slaughter was calculated on the basis of standard values given by Ranjhan (1977) (Table 4.1). The values thus obtained were divided by the age of animals to calculate the average feed energy intake per year. For grazing, it was assumed that energy consumed through this activity would be equal to the total energy requirement minus food energy given from home.

Daily dung production was measured thrice for each category of animals and based on three replicates. Chemical analysis of dung for nitrogen,

Table 4.1. Energy requirements for mithun and cattle (MJ day^{-1}); swine and poultry (MJ kg^{-1} feed). (Ranjhan, 1977).

Animals	Body wt/age	Energy requirement
Mithun	800 kg	101.3
	500 kg	69.4
	150 kg	36.4
Cattle	300 kg	57.3
	150 kg	35.1
Swine	5-20 kg	14.4
	20 kg or more	13.3
Poultry	0-8 week	10.0
	8-20 week	10.6
	20 week or more	11.5

Table 4.2 Concentration (%) of nitrogen, phosphorus and potassium and energy equivalents (MJ kg-1) of animal dung.

	N	P	K	Energy equivalent
Mithun	0.85	0.26	0.88	0.8
Cattle	0.76	0.26	0.83	0.7
Swine	1.2	0.57	1.2	1.1
Poultry	1.5	1.2	1.2	1.4

phosphorus and potassium was done by standard procedures given by Allen (1974). The fossil fuel equiralents given by Pimentel et.al.(1973); 80 MJ $kg^{-1}$for N, 13.9 MJ $kg^{-1}$for P and 9.7 MJ kg^{-1} for K, were used to calculate the replacement *cost of dung in terms of fossil fuel energy* equiralent (Table 4.2).

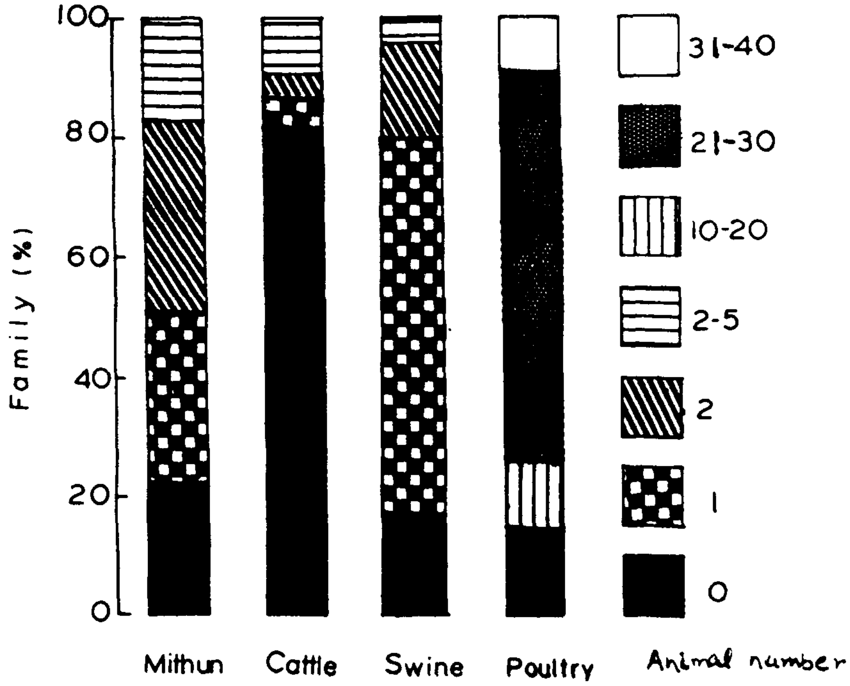
Total meat production for each category of animal was divided by the age of the animal to calculate average meat production per year. Labour cost for annual maintenance was calculated at the prevailing annual rates of wages Rs.300 and Rs.200 respectively for mithun and cattle. The economic yield of meat/egg based on the prevailing market rates. Economic efficiency was calculated as output/input ratio.

Labour energy input in man hours was recorded for each category of animal. Total food energy consumed was apportioned to each activity (Leach, 1976) according to relative duration on the basis of involving either sedentary or moderate work. Per hour energy expenditures of 0.418 MJ for sedentary work, 0.488 for moderate work for an adult male and 0.331 MJ for sedentary work, 0.383 MJ for moderate work for an adult female, were used to calculate the labour energy input into the system (Gopalan *et*.*al*.,1978). For calculating the energy output through meat and egg, the total quantity of each item was converted into megajaules of energy by multiplying with standard values given by Gopalan *et*.*al*., (1978) for mithun and cattle meat (17.2MJ kg^{-1}), poultry meat (4.56MJ kg^{-1}),and egg (7.2MJ kg^{-1}). These values were multiplied by 1.149 to calculate the heat of combustion (Mitchell,1979). A value of 17.1 MJ kg^{-1} was used for the pig meat (Ranjhan, 1977). The energy efficiency was calculated as output/input ratio.

Protein output from meat of each category of animal was calculated on the basis of standard values given by Gopalan *et*.*al*.,(1978) for mithun and cattle (79.2%), poultry (18.5%), egg (13.5%) and that given for pig meat (12%) by Ranjhan (1977). Protein energy output was then calculated by multiplying the quantity by 16.7 MJ kg^{-1}protein.

Fig. 4.1 Animal distribution pattern in an Apatani village in north-east India.

Fig. 4.1



100
80
60
40
20
0
Family (%)
Mithun
Cattle
Swine
Poultry
31-40
21-30
10-20
2-5
2
1
0
Animal number

Table 4.3 Production and consumption pattern of meat and egg in an Apatani village in north-east India, values in parentheses represent for juvenile animals .

	Animal number			Meat/egg production and consumption.	
Animals	Total	Died	Slaughtered	kg yr^{-1}	MJ yr^{-1}
Mithun	394 (262)	2 (6)	12 (8)	7224 (2112)	142746 (41733)
Cattle	76 (142)	6 (8)	36 (9)	9054 (945)	178907 (18673)
Swine	275 (177)	12 (3)	260 (160)	13780 (2160)	235638 (36936)
Poultry: meat.	2418 (6910)	87 (2974)	1426 (3341)	2495 (665)	13074 (3484)
egg[1]	65705	-	-	3811	31692

[1] Out of total egg production 1514 kg was exported from the village.

Table 4.4. Quanitity of nitrogen, phosphorus and potassium (kg animal^{-1}yr^{-1}) from animal dung of an Apatani village in north-east India. Values in parentheses represent total production (kg x10^3) of the village.

Animal		Dung	N	P	K
Mithun -	Mature	1587	13.5	4.1	13.9
	Juvenile	941	8.0	2.4	8.3
		(872)	(7.41)	(2.26)	(7.67)
Cattle	Mature	931	6.9	2.9	7.7
	Juvenile	602	4.5	1.9	4.9
		(156.44)	(1.18)	(.40)	(1.29)
Swine	Mature	156	1.8	0.9	1.8
	Juvenile	11	0.1	0.06	0.1
		(52.9)	(0.63)	(0.30)	(0.63)
Poultry	egg layers	16.4	0.3	0.2	0.2
	non-egg layers	4.8	0.07	0.05	0.05
		(25.2)	(0.38)	(0.30)	(0.30)

RESULTS

Mithun, swine and poultry are three major animal husbandry systems of Apatanis (Fig. 4.1). A larger number of farmers have 1 or 2 mithuns, pigs and about 10-30 birds. Cattle is not very common.

Though the average slaughtering age for mithuns, cattle, pigs and poultry was 7-yrs, 5-yrs and 6 to 12 months, respectively, some juveniles may also be slaughtered earlier (Table 4.3). Among the larger animals mithun were present in more numbers than pigs. However pigs contributed more towards meat production per year, followed by cattle and mithuns. While meat is consumed within the village, only eggs (about 40% of the total production) were exported.

With maximum dung production through mithun followed by cattle, pig and poultry the quantities of nutrients in them also followed a similar trend (Table 4.4) Per animal dung production of mithun was 1.65 times more than that by cattle.

The cost of maintaining animal husbandry was minimal and was chiefly as labour alone (Table 4.5). On an individual animal basis. mithun gave more monetary output followed by pig. The monetary

Table 4.5. Cost-benefit analysis (Rs. animal^{-1}yr^{-1}) of mature and juvenile (in parentheses) animals of an Apatani village in north-east India.

Production measures.	Mithun		Cattle		Swine		Poultry egg layers	Poultry non-egg layers	
Input total	300	(300)	200	(200)	190	(30)	19	6	(0)
Labour	300	(300)	200	(200)	0		0	0	
Feed	0	(0)	0	(0)	190	(30)	19	6	(0)
Output: Meat	1290	(1320)	750	(787)	1070	(297)	0	35	(5.0)
Egg	o		0		0		120	0	
Economic efficiency (output/input ratio)	4.30	(4.40)	3.75	(3.94)	5.63	(9.90)	6.30	5.80	(5.0)

Table 4.6. Energy input-output pattern (MJ animal^{-1}yr^{-1}) of mature and juvenile (in parentheses) animals of an Apatani village in north-east India.

Production measures	Mithun		Cattle		Swine		Poultry		
							egg layers	non-egg layers	
Input total	28789	(21912)	21226	(14768)	8112	(763)	418	137	(4.27)
Labour	61	(61)	47	(47)	60	(5)	13	4	(0.4)
Food	28728	(21851)	21179	(14721)	8052	(758)	405	133	(3.8)
Output total	2969	(2492)	1640	(1459)	1083	(243)	(81.2)	16	(1.6)
Meat	1699	(1739)	988	(1037)	911	(231)	0	7.9	(1.3)
Egg	0		0		0		58.2	0	
Dung	1270	(753)	652	(422)	172	(12)	23.0	8.1	(0.3)
Energy efficiency									
Output/input	0.10	(0.11)	0.08	(0.10)	0.13	(0.32)	0.19	0.12	(0.38)
Output (m+e)/ Labour energy	27.9	(28.5)	21.0	(22.1)	15.2	(46.2)	4.5	2.0	(3.3)

Table 4.7. Protien production (kg P animal^{-1}yr^{-1}) and efficiencies (MJ kg P-1and kg hr^{-1}) of mature and Juvenile (in parentheses) animals in an Apatani village in north-east India.

	Protien output				Protien efficiency			
Animal	kg		MJ		input/protien MJ kg P^{-1}		Protien/labour hr kg hr^{-1}	
Mithun	68.1	(69.5)	1610	(1643)	423	(315)	0.54	(0.55)
Cattle	39.6	(41.5)	936	(981)	536	(356)	0.41	(0.43)
Swine	6.4	(1.6)	151	(38)	1268	(477)	0.04	(0.12)
Poultry-egg.	0.93		22		449		0.03	
Meat.	0.4	(0.07)	9	(2)	456	(84)	0.03	(0.05)

value for dung is excluded here as it is never sold out. Swine husbandry and poultry had higher monetary efficiency followed by mithun; cattle had least efficiency.

Apart from labour energy, the feed input for the animals varied (Table 4.6). Mithuns and cattle were maintained exclusively through grazing and pigs depend upon domestic and human waste. Poultry had 60% grain feed from agriculture and the rest was through scavenging. With meat/egg as output along with dung, the energy efficiency was maximum for poultry and swine and least for cattle. However meat output per unit labour energy was maximum for mithun and minimum for poultry.

Protein output per animal varied depending upon size of animals, with maximum for mithun and minimum for poultry (Table 4.7). In terms of energy input per kg of protein production, mithun and poultry were more efficient than others; the efficiency of swine husbandry was least. Efficiency in terms of protein production per labour hour expended was maximum for mithun and cattle and minimum for swine husbandry and poultry.

DISCUSSION

The Apatanis of Arunachal Pradesh, like other traditional farmers in north-east India (Mishra & Ramakrishnan, 1982; Maikhuri, 1987) and elsewhere in Latin America (Queirez et.al., 1986) consider animal husbandry as an important activity along with agriculture. It is not only important as an economic activity but also is related to their social and religious life (Rappaport, 1968; Harris, 1966, Chavanduka, 1976). The slaughtering of traditional animal such as mithun, pig and poultry may often related to festivities and religious rites unlike cattle (as an introduction from outside in this area) that could be slaughtered at any time of the year. Unlike the tribes involved in shifting agriculture (Maikhuri, 1987), Apatanis emphasize lesser on animal husbandry, perhaps because of their emphasis upon a highly well organized and efficient wet rice cultivation as an sedentary agricultural activity (chapt. 3).

In any case, the animal husbandry system of the Apatanis is a minimal input system. The emphasis is more on mithuns because it is a highly priced animal and is socially important. Mithuns are cheap to maintain as long as forest resources are plenty for grazing. Under such a situation the economic efficiency is very high and the maintenance cost is almost absent, the mithuns freely grazing and living in the forest. Since these animals have strong territoriality they need no special care.

Swine husbandry is an important traditional husbandry practice as it is a detritus based system with minimal cost to the farmer. Waste material including human faeces and agricultural produce unfit for human consumption are used as feed for them. The traditional poultry system is partly based upon scavenging and partly by grains from agriculture.

Societies with large population densities and/or small portion of grazing lands emphasize confinement feeding of swine and poultry. These animals require a much greater portion of grain in their diets than the ruminants and thus are more competetive with humans, but they have reasonable feeding efficiency (over 30% of plant protein is converted into animal protein with 80% of human edible returns) (Loomis, 1984). 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 also has high economic and energy efficiencies.

The economic and energy efficiencies of larger animals are also related to the slaughtering age of the animals. Thus pigs maintained by Apatanis are slaughtered at yearly intervals. Therefore the cost of maintenance is reduced. This is unlike Tsembaga swine husbandry the new Guinea highlands (Rappaport, 1971) with only 1.5% return on food energy feed to pig meat energy, according to calculation of Pimentel & Pimentel (1979). This is because of a 10-yr slaughtering interval in case of the Tsembaga farmer. Thus pigs, poultry, pisciculture and the domestic sector of the village ecosystem all form an integrated and efficient recycling net work of system (Grau & Klein, 1957; Bolton, 1970; Loosli, 1974; Braude, 1976; Rao, 1977). Many animal production system tends to aggravate competetion for food between man and animals (Reid, 1973). But for the Apatanis the animal husbandry is complementary rather than competetive.

SUMMARY

Animal husbandry system of Apatanis of Arunachal Pradesh in north-east India involves mithun, cattle swine and poultry. Mithun and cattle graze in the forest with minimal labour cost pigs and poultry of the village consume agricultural by-products and do scavenging. Swine husbandry and poultry are more efficient than mithun and cattle husbandry. However, mithuns are important for social and religious reasons and are tenable if forest resources are abundant. Pisciculture is integrated into wet rice cultivation based on nutrient recycling of village waste.

CHAPTER 5

ENERGY FLOW THROUGH AN APATANI VILLAGE ECOSYSTEM OF ARUNACHAL PRADESH IN NORTH-EAST INDIA.

INTRODUCTION

Energy flow through a society or an ecosystem is a useful measure to describe ecosystem properties (Loucks & D'Allessio, 1975). In many traditional societies rural ecosystem function is based upon a tight recycling of resources within the village. However, only a few studies are available on energy flow through village ecosystems (Rappaport, 1971; Leach, 1976; Briscoe, 1979; Sundarraj & Mitchell, 1987). Revelle (1976) in his study on rural India suggested that energy use efficiency here is low and attributed this to the extreme poverty. Much of this energy use in rural India is for domestic cooking and heating (Makhijani & Poole, 1975). Wood and other vegetable matter, crop residues and cattle dung are the main domestic fuels. Sundarraj and Mitchell (1987) on the basis of detailed analysis of ecosystem function of a south Indian village concludes 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.

The north-eastern hill region of India is inhabited by a variety of linguistically insulated communities of diverse socio- economic and cultural backgrounds whose village ecosystem is closely linked to their natural forested environment. These communities largely depend upon forest farming, variously termed slash and burn agriculture, shifting agriculture or locally known as jhum. Some studies in energy flow through societies practising shifting agriculture (Jhum) are available (Mishra & Ramakrishnan, 1982). However, the Apatanis of north-east India constitute one of the very few tribes who traditionally practise only sedentary agriculture in the form of wet cultivation of rice in the valley lands. This self-sustaining agricultural system is largely based upon tight recycling of resources within the village itself. This study, therefore, looks at: (i) the linkages between agriculture, animal husbandry and domestic sub-systems in the village, (ii) the efficiency of resource use and recycling of resources within the village ecosystem, (iii) the economic efficiency of the village ecosystem and the extent to which it is self-sustainable and, (iv) the possibilities of improved management practises that are ecologically viable.

Table 5.1. Apatani Village Ecosystem Structure at Hari in north-east India (1984-85)

Number of households	418
Total population	2021
Adult male	626
Adult female	646
Adolescent 12-21 year	304
Children below 12 year	445
Total area under cultivation (ha)	
Rice cultivation	356
Kitchen garden	24
Millet cultivation	5
Bamboo garden	47
Total animal population	
Mithun	656
Cattle	218
Swine	452
Poultry	9328

VILLAGE STRUCTURE

'Hari is a large village situated in the Apatani plateau ($27^0 36'$N, $93^0 49'$E) at an elevation of 1572m with 418 families and a total population of 2021 (Table5.1). The average size of a family is about five, living in a large bamboo hut of 15x4 m floor area. The climate is monsoonic with over 75% of the total rainfall 1758 m m occurring during the monsoon period from May to September. The average maximum and minimum temperatures during the summer was 24.1^0C and 12.7^0C and that during the winter was 17^0C and 2.8^0C, respectively.

Wet cultivation of rice is the chief agriculture practice of the Apatanis. However, on raised bunds along the margin of the rice plots, millet (Eleusine coracana) is grown. On well drained soils, are raised kitchen gardens with a variety of 8-12 crop species. The emphasis in the kitchen garden is on maize through other grain yielding crops such as Eleusine coracana, vegetable crops such as Cucurbita maxirma, Brassica oleracea and Colocasia antiquorum are also included. Apart from recycling the non-edible biomass before the next crop is raised, the village waste as well as dung from the animal husbandry system provide soil nutrients for sustainable yield. Bamboo gardens maintained by individual farmers provide material for house construction and meet part of the fuel wood needs. Apart from pisciculture included in wet cultivation of rice, the animal husbandry system consits of mithun (*Bos frontalis*) and cattle maintained in forest grazing lands, swine and poultry that are largely detritus based and maintained within the village.

METHODS

For the present study fifteen randomly selected households of village Hari were analysed. Inputs of energy due to tools/implements were negligible. Other basic requisites of the villagers such as clothing and medicine, have been excluded from the study due to difficulties in accounting the energy values for them. Solar energy which is primary source of energy, does not enter into the calculations for energetic efficiency as this is considered to be 'free' input and no special effort goes into obtaining it.

The amount of seed sown in the plot, as well as economic yield, were based on three replicate observations of each agroecosystem selected randomly

Table. 5.2 Energy Values (MJ kg^{-1}) for Different Items Considered in the Village Ecosystem.

Items	Energy value
Food items[1]	
Grains	16.31
Fruits	14.94
Leafy vegetables	13.77
Tuber and root crops	13.77
Fish	4.70
Local beverage (rice+millet)[2] (31 -/kg rice+ millet)	4.95
Cost of Production[3]	
N	79.99
P_2O_5	13.95
K_2O	9.97
Replacement Cost[4]	
Rice husk	1.0
Organic manure	1.4

---

[1] Gopalan et.al., 1978

[2] Kohli, 1983

[3] Pimentel et.al., 1973.

[4] Percentage of N, P_2O_5 and K_2O in rice husk and organic manure was 1.0, 0.2 and 1.8% and 1.4, 1.2 and 1.2, respectively.

from the fifteen households. The energy values for the economic yield of crops were based on standard values given in Table 5.2. Energy input through seed was calculated on the basis of the total energy expended to produce that fraction of crop yield. Energy input through organic manure and rice husk was calculated on the basis of the replacement cost values in terms of fossil fuel Pimentel *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 calculate the labour hour energy input into the sub-systems (Gopalan *et.al*., 1978).

Table 5.3. Protein Contents of Various Food Items Consumed by Apatani Tribes in North-East India (Gopalan *et.al*., 1978).

Category	Protein Content (%)
Crops - Grains	
Oryza sativa	8.5
Eleusine Coracana	7.3
Zea mays	11.1
Leaf & Fruit & vegetables	
Brassica oleracea	5.9
Capsicum frutescens	2.9
Cucurbita maxima	4.6
Cucumis sativa	0.4
Dolichos lablab	3.8
Lycopericum esculentum	1.9
Solanum melongena	1.4
Tuber and root crops	
Colocasia antiquorum	3.0
Manihot esculeutus	0.7
Solanum tuberosum	1.6
Zingiber officinale	2.3
Meat/egg	
Mithun	79.2
Cattle	79.2
Pork	12.0
Fish	19.7
Poultry	25.9
Egg (hen)	13.3
Local beverage[1] (rice & millet) (3 l /kg)	27.0

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[1] Kohli, 1983.

Total meat production (kg) from slaughtered animals of each category was multiplied by 17.2 MJ for mithun and cattle 4.56 MJ for poultry and 7.2 MJ for eggs (Gopalan et.al., 1978) to calculate their nutritive values. These values were multiplied by 1.149 (Mitchell, 1979) to calculate the heat of combustion of meat and egg. A value of 17.121 MJ was used to calculate the same for pig meat (Ranjhan, 1977).

Cost-benefit analysis of agriculture and animal husbandry sub-systems was calculated on the basis of the prevailing market rates. Thus, labour wages for agriculture were calculated at the rate of Rs.9 and 11 per day for female and male labour respectively. The annual cost of Mithun and cattle maintenance was Rs. 300 and 200 respectively. Economic efficiency was calculated as output/input ratio.

Estimation of actual amount of food/fuel consumed by humans was based on regular measurements made in the village and the energy equivalents of the food items (Gopalan et.al., 1978) and 19.7 MJ kg^{-1} for fuel wood (Mitchell, 1979). The protein equivalents of the food (crop and meat) harvested and that part of it consumed by the villagers was determined by multiplying the quantities of food and their respective protein contents (Table 5.3).

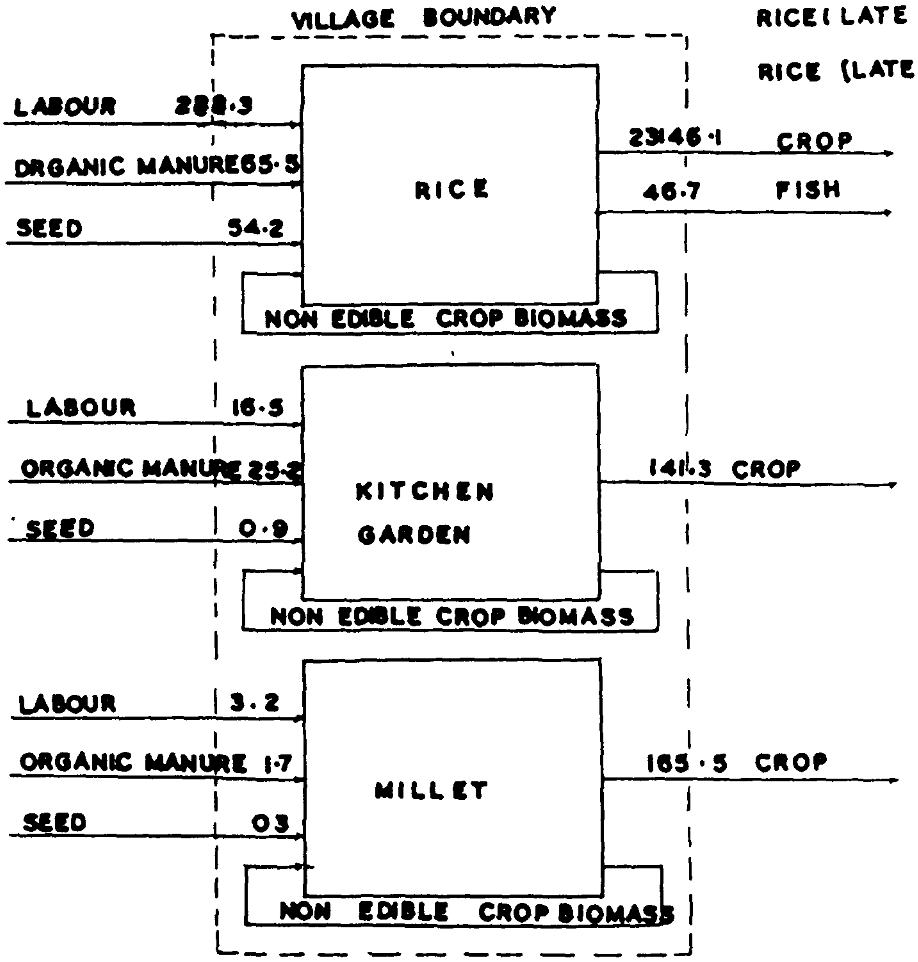
For calculation of grazing and scavenging animals it was assumed that the energy equivalent for this would be equal to the values obtained after substracting the energy values of the actual feed consumed (basedon regular observations) for their standard food energy requirement (Ranjhan, 1977).

For calculating the food energy/protein requirements of humans, the total consumption units (adult man values) for the whole village 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, 9-12 years 0.6, 0.7 and 0.8 units respectively. The total number of units for this village works out at 1788 (930 + 581.4 + 93.6 + 59.5 + 124). This was then multiplied by food energy equivalents of an adult (1 unit) of 10.142 MJ day^{-1} and protein equivalents of an adult (1 unit) of 55 g day^{-1} (Gopalan et.al., 1978).to calculate daily food energy/protein requirement of different categories of humans. To find energy equivalent of fuel wood needed per day for cooking purpose it was assumed that the potential energy required for one adult man (1 unit) would be 15.76 MJ (Mitchell, 1979). This was then multiplied by the total units obtained for the whole village.

Fig. 5.1 Energy flow (MJx10^3) through the agricultural sub-system of an Apatani village in north-east India.

Fig. 5.1

RICE (EARLY VAR) = 41 ha.
RICE (LATE VAR) = 110 ha.
RICE (LATE VAR) + FISH = 205 ha.



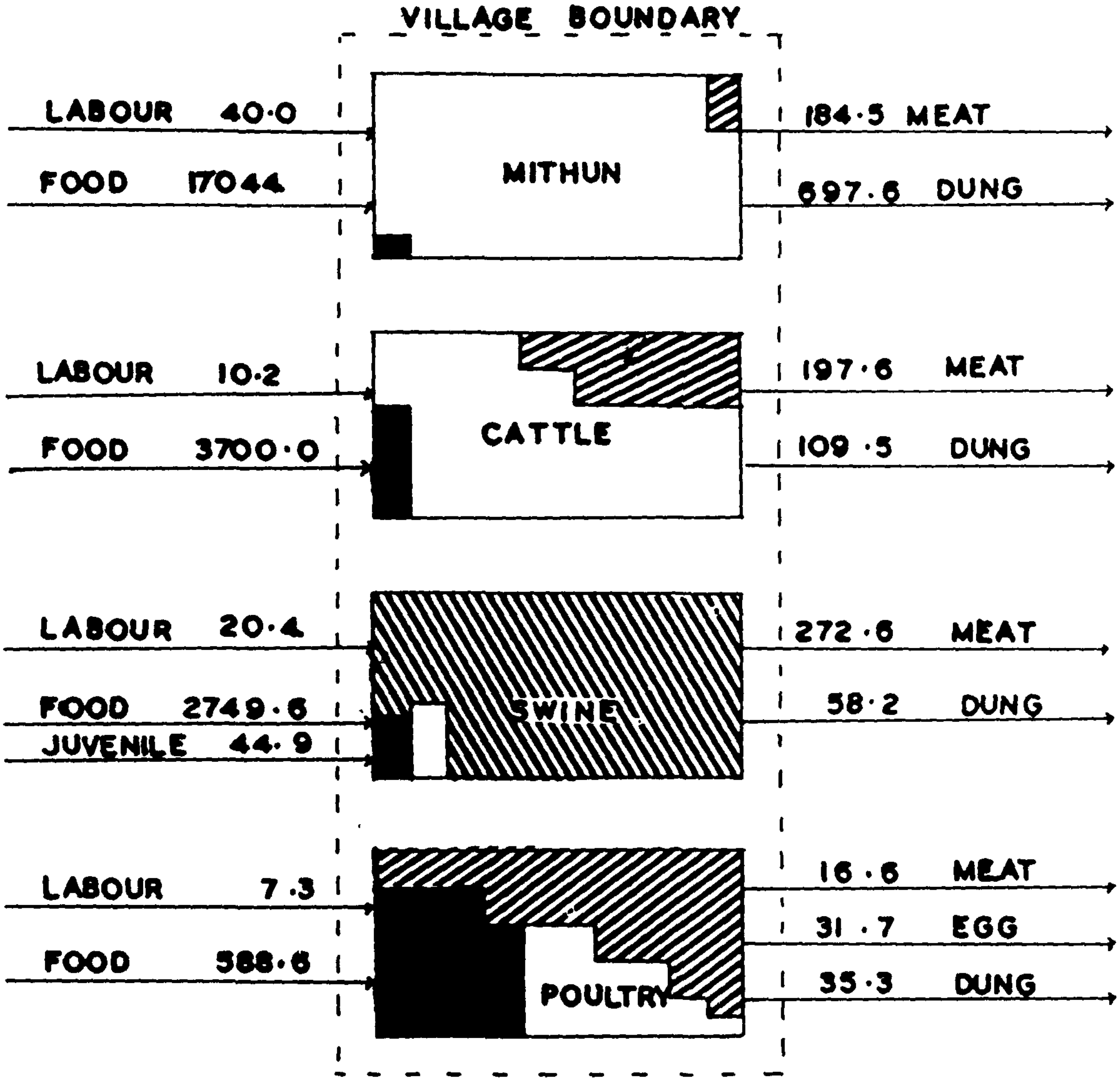
ENERGY EFFICIENCY OF AGROECOSYSTEM = 60·9

Fig. 5.2 Energy flow ($MJ\times10^3$) through the bamboo garden of an Apatani village in north-east India.

Fig 5.2

Fig. 5.3 Energy flow (MJx10^3) through the animal husbandry sub-system of an Apatani village in north-east India. Percentage of animals died (■), slaughtered(▧) and stocked (□) .

Fig. 5.3



ENERGY EFFICIENCY = 0·07

EDIBLE ENERGY OUTPUT/ LABOUR INPUT = 20·6

RESULTS

Labour energy is the major input into agriculture followed by organic manure and seed (Fig. 5.1) of the total labour energy input 40% was expended for weeding. Sowing and harvesting required about 43% ; 10% was expended for field preparation and 7% used for irrigation. Female members of the family contributed 78% of the total labour energy input. About 93% of the total energy harvested from agriculture came from wet rice cultivation and 1% through pisciculture. The overall energy efficiency (output/input ratio) of the agriculture was about 61.

Bamboo gardens are maintained by the Apatanis (within the village boundary (Fig. 5.2). Labour for maintenance and harvest is the only input. The output is used largely as fuelwood and some of it is also used for hut construction and exported out of the village.

Food and labour energy are the two inputs into the animal husbandry sub-system (Fig. 5.3). Mithun and cattle are totally dependent upon forest grazing while swine and poultry are largely maintained through domestic wastes and crop by-products. A small fraction of grains are fed to poultry.

Table 5.4. Monetary (Rs. x $10^3 yr^{-1}$) Input/Output Pattern for Agriculture, Bamboo Garden and Animal Husbandry Sub-systems of an, Apatani Village in north-east India.

Category	Agriculture	Bamboo garden	Animal husbandry
Input total	1134.4	69.3	345.4
Labour	234.9	69.3	240.4
Organic manure	139.9	-	-
Seed	59.6	-	-
Juveniles (pig litter)	-	-	-12.3
Food	-	-	92.7
Output total	3564.9	378.8	990.6
Crop	3564.9	-	-
Bamboo and fuel wood	-	378.8	-
Meat and egg	-	-	990.6
Net return	2231	309.5	645.2
Economic efficiency (output/input ratio)	3.14	5.47	2.87

Table 5.5. Annual food production (kg yr^{-1}) in an Apatani village in north-east India. Values in parentheses showed number of animals involved.

Category	Production	
Crop yield (dry weight)		
Grains and seed	1497010	
Vegetables and tuber crops	22096	
Meat/egg yield (fresh weight)		
Fish	9840	
Mithun and cattle	19335	(65)
Swine	15940	(420)
Poultry	3160	(4767)
Egg (hen)	3811	(548)

Much of the village labour went into maintaining mithuns followed by swines. Over 90% of the swines raised in the village were slaughtered every year and this contributed to about 40% of the total meat energy output from the village. Mithuns were most sparingly slaughtered (3%) but cattle slaughter was more (21%). These two animals contributed 57% of the total meat energy output. Overall energy efficiency for the animal husbandry sub-system of the village was very low (0.07). Edible energy output per unit labour energy input, however, was 9.

Monetary input into agriculture was about 3 times more than that put into animal husbandry (Table 5.4). Monetary output from agriculture was also much higher for the village as a whole. However the monetary output/input ratio for bamboo garden was much higher than agriculture or animal husbandry of the village as a whole.

Out of total food production in the village about 97% was of plant origin and the rest was of animal origin (Table 5.5).

Rice is the staple diet of the Apatanis and much of it is consumed alongwith Eleusine coracana as an alchoholic beverage (Table 5.6). These two

Table 5.6 Annual food and protein consumption ($X10^3$) in an Apatani village. Values in parentheses indicate per capita consumption .

Food item	Quantity		Protein equivalent Kg.
	Kg	MJ	
Plant origin total[1]	542.2 (0.30)	6886.1 (3.9)	36.6 (0.02)
Polished rice	296.6 (0.17)	4835.1 (2.7)	25.2 (0.1)
Maize	57.1 (0.03)	931.1 (0.5)	6.3 (0.004)
Beverage (rice + millet)	167.7 (0.09)	830.2 (0.5)	4.5 (0.002)
Leafy and fruit vegetables	9.1 (0.004)	115.9 (0.06)	0.4 (-)
Tuber and root crops	12.6 (0.007)	173.9 (0.1)	0.2 (-)
Animal origin total[2]	48.6 (0.03)	794.5 (0.44)	21.7 (0.012)
Meat/egg			
Mithun	9.3 (0.005)	184.5 (0.10)	7.4 (0.004)
Cattle	13.2 (0.007)	260.5 (0.15)	10.4 (0.006)
Swine	17.5 (0.01)	299.0 (0.17)	2.1 (0.001)
Poultry	3.2 (0.002)	16.6 (0.009)	0.8 (-)
Egg (hen)	2.3 (0.001)	19.1 (0.01)	0.3 (-)
Fish	3.2 (0.002)	14.9 (0.008)	0.6 (-)
Total (Plant + animal origin)		7680.5 (4.3)	58.3 (.03)
Standard	-	7529.3 (4.2)	35.9 (0.02)

[1] Dry weight.

[2] Fresh weight.

Table 5.7. Daily fuelwood consumption in an Apatani village in north-east India. Values in parentheses represent per capita consumption.

Month	Dry weight (kg day^{-1})	Energy equivalent MJx10^{3}
November- February	12514 (7.0)	247.3 (0.14)
March - October	6019 (3.37)	118.9 (0.07)
Standard	-	0.016

Fig. 5.4 Energy flow ($MJ \times 10^3$) through the domestic sub-system of an Apatani village in north-east India.

Fig 5.4

ENERGY EFFICIENCY= 0·01

Table 5.8. Annual export/import (Rs.x10^3) pattern in on Apatani village in north-east India. Values in parentheses represent per unit export/import.

Items	Monetary value
Export total	1449.1 (0.81)
Rice	1247.9 (0.70
Fish	135.6 (0.08)
Egg	26.1 (0.01)
Bamboo	39.5 (0.02
Import total	352.0 (0.206)
Meat : Cattle	47.2 (0.03)
Swine	34.0 (0.02)
Juvenile (Swine)	12.3 (0.006)
Tea leaf	8.8 (0.005)
Chilli	3.6 (0.002)
Sugar	10.3 (0.006)
Salt	6.1 (0.003)
Kerosene oil	9.7 (0.005)
Clothing	138.6 (0.08)
Medicine	16.7 (0.009)
Others	64.7 (0.04)
Export/Import ratio	4.12
Stock total	1723.4 (0.96)
Rice	430.9 (0.24)
Animals	1292.5 (0.72)

together accounted for over 73% of the food energy and about 51% of the protein consumed. Tubers and root crop species form an important composition of the diet. Pork was an important component of the food of animal origin followed by cattle and mithun.

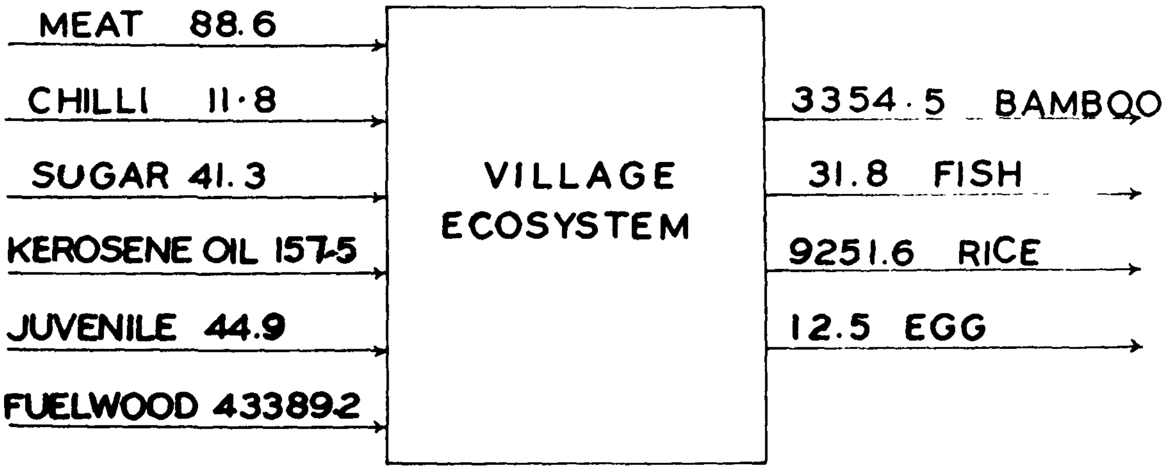
Per capita fuelwood consumption was more than twice during November-February compared to the rest of the year (Table 5.7). The actual fuel wood consumption was more than five times of the standard requirement worked out for India. Forest provided 74% of the fuel wood needs and the rest was provided by bamboo cultivated as part of the home garden.

Food and fuelwood are the energy inputs into the domestic sub-system which generated man power (629.1×10^{3}MJ) used for largely to support agriculture and animal husbandry (Fig 5.4).

Food related items such as tea, chilli, sugar and salt are the major import items along with medicine and clothing (Table 5.8). Some meat is also procured from outside. Rice is the chief export item. Apatanis tend to keep in reserve large quantities of rice. Besides, not all the animals are slaughtered. The export from the village for exceeded the import.

Fig. 5.5 Energy flow through an Apatani village in north-east India.

FIG 5·5



ENERGY EFFICIENCY= 0·29

Fuelwood to the extent of 74% of the total consumption comes from the forest outside the village boundary (free of cost) alongwith food items purchased from the market (Fig 5.5). With rice and bamboo as major outputs going outside the village voundary the output/input ratio worked out to be 0.3.

DISCUSSION

Wet rice cultivation is the main land use system of the Apatanis. Only about 8% of the total cultivable land is under mixed cropping under kitchen garden. Two different varieties of rice based on colour and crop maturation time are broadly categorised into early and late varieties. Intraspecific variation under rice cultivation and interspecific diversity under kitchen garden ensure harvest security of the agroecosystem (Chang, 1977; Colson, 1979; Clawson, 1985) of this relatively more advanced community (Furer-Haimendrof, 1962,1985). One of the chief advantages of valley cultivation is its self-sustainability as valleys are natural sinks for nutrient flow from the hill slopes (Toky & Ramakrishnan, 1981). Fish culture as part of the rice agroecosystem not only maximises productivity but also provides valuable animal protein.

Such a complimentary system of agriculture and animal husbandry are common in India (Iyenger, 1953, 1962; Alikunhi, 1960; Tripathi, 1963) and elsewhere in Java and Madagaskar (Hickling, 1961). Apatani recycle all the non-edible bimass of the previous crop into the following cropping system. Such a recycling of non- edible crop biomass (Jones, 1976; Evan, 1980) helps in maintaining a low input for maintenance agriculture system, on a long term basis. Further, these low input systems give comparatively higher yields making them highly yields making them highly energy efficient. With an overall energy efficiency of 1:61 which for wet rice cultivation alone may be as high as 1:78 (chapt.3) the energy output/input ratio is better than some of the shifting agricultural systems studied by us (Mishra & Ramakrishnan, 1981; Toky & Ramakrishnan, 1982), let alone the low energy efficiency of modern agriculture (Spedding, 1975; Spedding & Walsingham, 1976; Pimentel & Pimentel, 1975).

Mithun as an animal husbandry system is popular with the Apatanis as this is a pathway to gain status within the society, just as the Tsembaga farmer tries to raise larger pig herds which is considered to be a status symbol in their society (Rambo, 1983).

This cultural attitude of the Apatanis prevents them from slaughtering the animals at frequent intervals; some times the slaughtering frequency may be a very long 10-15 years or more. This makes this animal husbandry system very ineffícent from energy point of view with only 1% edible energy return, unlike swines and poultry husbandry which gave 14-17%. returns. Though animal husbandry system of the Apatanis has an overall energy efficiency only 0.07, the only energy expended that cost the farmer is labour, as these animals largely depend upon grazing and waste products from agriculture. If this is adjusted into the calculations the energy output of animal husbandry was 9 units per unit labour input.

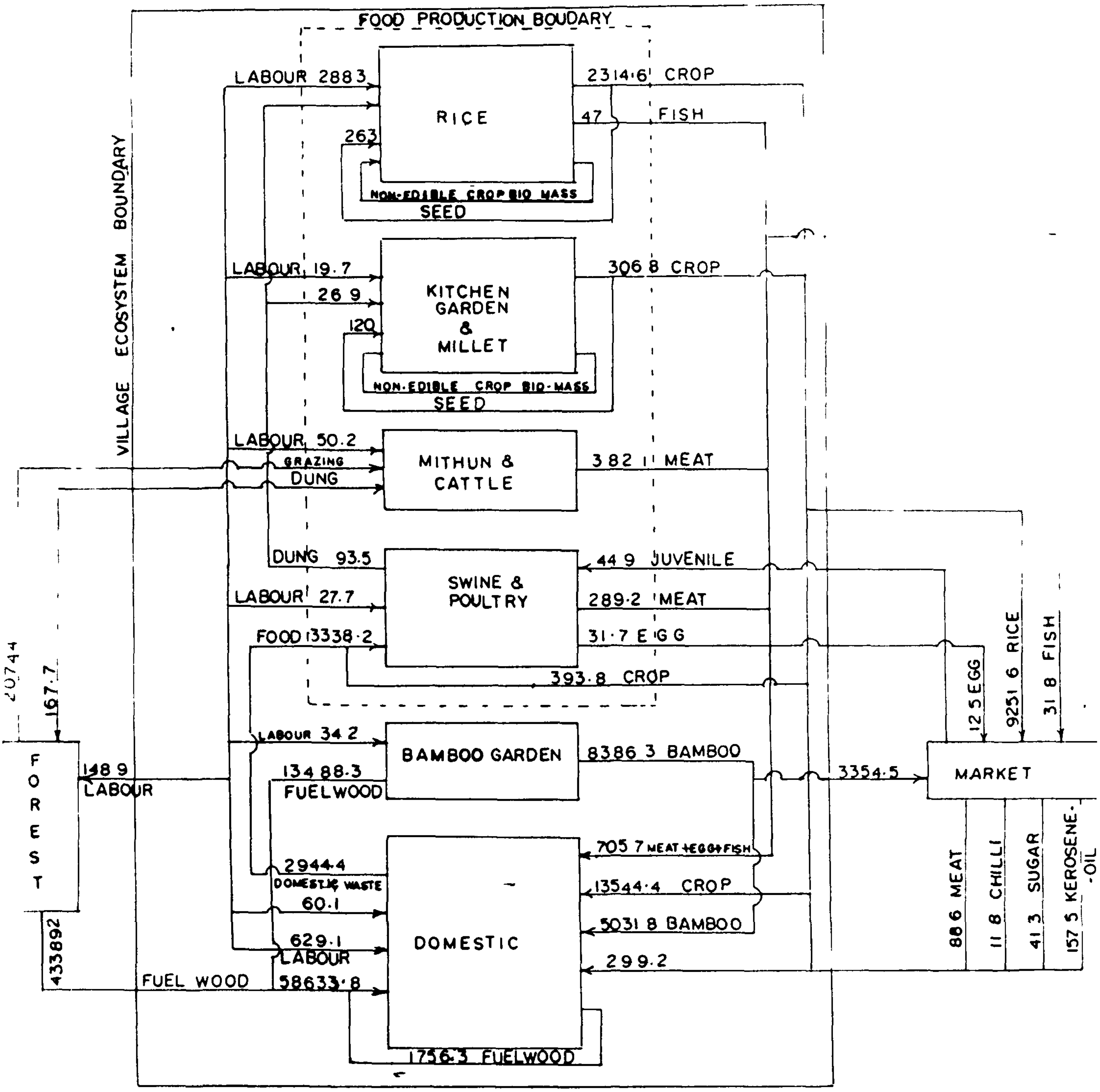
Though animal husbandry system was worked out to be economically and energetically more efficient when considered on an idividual animal basis (chap 4) but when this system was less efficient for the village as a whole. This is because of the fewer animals slaughtered out of the total maintained at a given time.

The diet of the Apatanis is rich both in terms of energy and protein compared to other tribes such as the khasis (Mishra & Ramakrishnan, 1982) who often have an energy consumption somewhat lower than the per capita standard requirement worked out for an Indian village (Gopalan et.al.,1978). Rice as the major dietary component has particularly high calorie content (Finck,1970). Further, the protein consumption is very high and is 63% above the standard requirement (Gopalan et.al., 1978). Particularly significant is the fact that 33% of the protein consumed is of animal origin which compares very well with the world consumption of 25% (Pimentel et.al. 1975)

Fuelwood consumption pattern was determined by the availability of this resource, the energy efficiency of the cooking stoves and the need for winter heating of the hut. Apatanis collect as much as 74% of the fuelwood from the forest which is rather close to the village at a distance of not more than 3-5 km. The remaining, about 25% is raised within the village in their bamboo gardens. The consumption of this resource within the village is about 5.7 times more than the standard per capita requirement for a typical Indian village (Mitchell, 1979). This is because of the high inefficiency of the cooking stoves (Leach, 1976) which dissipates

Fig. 5.6 Energy flow (MJx10^3) through the various sub-systems of an Apatani village in north-east India.

Fig 5.6



VILLAGE ECOSYSTEM BOUNDARY
FOOD PRODUCTION BOUDARY
LABOUR 2883
RICE
2314.6 CROP
47 FISH
263
NON-EDIBLE CROP BIO MASS
SEED
LABOUR 19.7
26 9
120
KITCHEN GARDEN & MILLET
306 8 CROP
NON-EDIBLE CROP BIO-MASS
SEED
LABOUR 50.2
GRAZING
DUNG
MITHUN & CATTLE
382 1 MEAT
DUNG 93.5
LABOUR 27.7
FOOD 13338·2
SWINE & POULTRY
44 9 JUVENILE
289·2 MEAT
31·7 EGG
393·8 CROP
20744
167.7
FOREST
148 9
LABOUR
LABOUR 34 2
BAMBOO GARDEN
8386 3 BAMBOO
134 88.3
FUELWOOD
3354.5
MARKET
12 5 EGG
9251 6 RICE
31 8 FISH
88 6 MEAT
11 8 CHILLI
41 3 SUGAR
157 5 KEROSENE-OIL
2944.4
DOMESTIC WASTE
60.1
629.1
LABOUR
433892
FUEL WOOD
58633·8
DOMESTIC
705 7 MEAT +EGG+FISH
13544·4 CROP
5031 8 BAMBOO
299.2
1756.3 FUELWOOD

outside, a large amount of energy which is convinient for home heating during the winter months. Much of the fuelwood consumption is related to distillation of the local alchoholic beverage. Any contemplated improvement in the cooking stoves should not only consider the energy efficiency of the stove but also the need for smoking the meat.

The economy of the Apatani society is based upon intensive valley cultivation of rice. Though the village ecosystem efficiency (output/input ratio) is lower than that for shifting agriculture farmers in the region (Mishra & Ramakrishnan, 1982; Maikhuri, 1987) the net per capita monetary return to the farmer through sale of excess production is substantial with 40% rice production being sold to the economically weaker neighbouring tribes such as the Nishis and the hill Miris.

The schematic presentation of energy flow through an Apatani village ecosystem (Fig.5.6) emphasises the intricate relationships existing between agriculture, animal husbandry, domestic and forest sub-systems. The dependence on the forest is largely for fuelwood for the domestic sector and for grazing by cattle and mithun. In return, the dung produced by the grazing animals gets recycled back into the forest ecosystem providing about 8.59×10^3 kg, 2.66×10^3

and 8.96×10^3 kg of N, P and K, respectively. With swine and poultry raised in the village boundary the dung from these two animal husbandry systems provide 1.01×10^3, 0.6×10^3 and 0.93×10^3 kg of N, P and K, respectively and gets recycled into the agroecosystems.

The overall low energy efficiency (0.3) of the Apatani village, in spite of the exceptionally high energy efficiency of the agroecosystem may largely be related to : (i) the tendency to conserve mithuns as a status symbol with a long slaughtering frequency and the consequent low energy efficiency of the animal husbandry sub-system as a whole and (ii) the low energy efficiency of the domestic sub-system because of high fuelwood consumption at low energy efficiency levels. Apart from the possibilities for improving the energy efficiency of the animal husbandry and the domestic sub-systems, even the agroecosystem could be intensified through appropriate crop rotation during the winter season. In spite of these possibilities the Apatani village ecosystem is good example of economic self-sufficiency of an traditional agricultural society that practices sedentary agriculture with ecological considerations in the north-eastern hill region of India.

SUMMARY

This study deals with the energy flow through a typical Apatani village ecosystem predominant under wet cultivation of rice at an elevation of 1572 m in Arunachal Pradesh in north-east India. The energy efficiency of the agroecosystem is very high with an output/input ratio of 61. The high economic efficiency permits export of rice after meeting local needs. Animal husbandry system with swine husbandry and poultry is an important link in the detritus food chain by utilizing the by products and food wastes of agricultural sub-system. The forest apart from providing shelter and food for the mithuns and cattle, also meets part of the fuelwood requirements of the village. Extensive bamboo gardens maintained by this community meets the rest (25%) of the fuelwood needs and also provides material for hut construction. The overall economic efficiency of this relatively more advanced tribal society of north-east India is about 4 and the chief input for the operation of the village ecosystem is human labour.

CHAPTER 6

ENERGY FLOW THROUGH A HILL MIRI VILLAGE ECOSYSTEM OF ARUNACHAL PRADESH IN NORTH-EAST INDIA.

INTRODUCTION

Energetic studies of traditional agriculture would provide insight into how one may improve the quality of rural societies by utilizing local energy resources more efficiently. Energy flow data for rural ecosystems in developing countries are often fragmented. From the data compiled on a number of prototype villages in developing countries, Makhijani and Poole (1975) observed that the total amount of energy, including animal and human labour, going into farming is surprisingly high. It is often suggested that developing countries often use more energy per hectare than in industrialized nations (Stout, 1979). In any case, indigenous agricultural societies of Asia, Africa and South America have functioned as nearly independent agroecosystems (Calavan, 1977; Moerman, 1968; Norman, 1979).

Shifting agriculture is an important traditional agricultural practice still widely used over an estimated 36 million km^2 of land (about 30% of the world's exploitable soils), producing food for about 250 million people

(FAO, 1974). There are few studies on energy flow through village ecosystems under subsistence farming (Rappaport, 1971; Leach, 1976; Sundarraj and Mitchell, 1987). Mishra and Ramakrishnan (1982) in a study in north-east India showed that tight recycling of natural resources makes the village energetically efficient. The present study is an analysis of the village ecosystem function of the hill Miri tribe of Arunachal Pradesh in north-east India. Apart from examining the relationships between food and energy, the study aims: (i) to analyse the energy efficiency of agriculture and animal husbandry of the village, (ii) food production and consumption patterns, (iii) economic efficiency of the village ecosystem, (iv) fuel wood consumption pattern and forest dependency for fuel wood and hunting and, (v) interrelationships between food production systems of the village and the natural forest ecosystem.

VILLAGE STRUCTURE

'Dokhum' is a small hill Miri village situated at Raga (27° 44'N 93° 51'E) at an elevation of 1060 m with 33 families and a total population of 419 (Table 6.1). The average size

Table 6.1. Hill Miri village ecosystem structure at Dokhum (1984-85) in north-east India.

Number of households	33
Total population	419
Adult male	110
Adult female	146
Adolescents : 12-21 yr.	72
Children below 12yr.	92
Total area under cultivation. ha. (7-yr. shifting agriculture)	36
Total animal population	
Mithun	198
Cattle	110
Swine	183
Poultry	891

of family is about 12-13, living in bamboo house of about 19mx5.0m floor area.. The climate is monsoonic with over 75% of the total rainfall of 511 mm occurring during the monsoon period from May to September. The average maximum and minimum temperatures during the summer was 28.7°C and 16.1°C and that during the winter was 19.7°C and 5.4°C, respectively.

Shifting agriculture locally known as jhum is the only land use practice of hill Miris. During the winter months (December-January) the total ground vegetation is slashed and allowed to dry. Before the onset of monsoon, in the month of March-April the dried debris is burnt in situ. The jhum cycle of 7 years in the village was about 10-12 crop species in the mixture. Grains such as *Oryza sativa*, *Eleusine coracana*, *Setaria italica*, *Zea mays* constitute the major component of the crop mixture along with vegetables crops such as *Cucurbita maxima*, *Cucumis sativa*, *Colocasia antiquorum*. Sowing starts after burning of debris in the plots, with vegetables and tuber crops. Rice is the main crop sown after the onset on monsoon in the month of April-May. Weeding was done twice, once during May-June and again in July-August. Harvesting starts in the month of

August with Zea mays and continued upto December for tuber crops. Rice was harvested in the month of October-November.

Animal husbandry system of the hill Miris consists of mithun (Bos frontalis), cattle, swine and poultry. Mithun and cattle are maintained in the forest and they are totally dependent upon forest grazing. Swine and poultry which are largely detritus based are maintained within the village.

Agriculture and animal husbandry form the main occupation of the hill Miris. The food production system of the village is labour intensive, requiring large inputs of man-power; however, a part of the total man-power was exported also. Energy required for cooking food and heating the houses come from fuelwood, largely extracted from the forest.

METHODS

Six randomly selected households of the village 'Dokhum' were selected for this study. All the activities in the village were closely monitored and quantified over a one year period.

Table 6.2 Energy value (MJ kg^{-1}) of various food items consumed by hill Miris in north-east India. (Gopalan et.al., 1978).

Food items	Energy values (MJ kg^{-1})
Grains	16.31
Pulse	16.24
Sesamum	26.60
Fruits	14.94
Leafy vegetables	13.77
Tuber and root crops	13.77
Beverage[1] (Rice+Millet) (3 1 kg^{-1})	4.95

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[1] Kohli, 1983
[2] Ranjhan, 1977

The observations of agriculture were based on three replicate plots selected randomly from the six households. The energy values for economic yield of crops were based on standard values given in Table 6.2. Energy input through seed was calculated on the basis of the total energy expended to produce that fraction of crop yield.

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 calculate the labour energy input into the sub-systems (Gopalan _et_._al_., 1978).

Energy output per kg of meat of the slaughtered/hunted animals of each category was calculated on the basis of 17.2 MJ for mithun and cattle, 4.56 MJ for poultry, 7.2 MJ for eggs, 4.66 for deer, 5 MJ for rats, 3.94 MJ for frog, 5.88 MJ for wild birds (Gopalan _et_._al_., 1978). These values were multiplied by 1.149 (Mitchell, 1979) to calculate the heat of combustion of meat

Table 6.3. Protein contents of various food items consumed by hill Miris in north-east India. (Gopalan *et.al.*, 1978).

Food items	Protein content (%)
Plant origin:	
Oryza sativa	2.5
Eleusine coracana	7.3
Zea mays	11.1
Setaria italica	12.3
Sesamum indicum	18.3
Phoseolus mungo	24.0
Capsicum frutescence	2.9
Cucurbita maxima	4.6
Cucumis sativa	0.4
Musa sapientum	1.4
Colocasia antiquorum	3.0
Manihot esculentus	0.7
Beverage (Rice + millet)[1]	2.7
Animal origin:	
Mithun and Cattle	79.2
Swine[2]	12.0
Poultry	25.9
Egg (hen)	13.3
Deer	21.0
Frog	19.6
Rat	23.6
Wild birds	23.8

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[1] Kohli, 1983.
[2] Ranjhan, 1977.

and egg. However, the heat of comcution of pig meat was directly calculated as 17.121 MJ kg^{-1} of meat (Ranjhan, 1977).

Cost-benefit analysis of agriculture, and animal husbandry sub-systems was calculated on the basis of the prevailing market rates. Thus labour wages for agriculture were calculated at the rate of Rs. 12 and 15 per day for female and male labour, respectively. The annual cost of maintenance for per mithun, cattle, pig and poultry (per family) was Rs 175, 100, 60 and 40, respectively. Economic efficiency was calculated as output/input ratio.

Estimation of actual amount of food/fuel wood consumed by humans was based on regular measurements made in the village and the energy equivalents of the food items (Gopalan et.al.,1978) and 19.7 MJ kg^{-1} for fuel wood (Mitchell, 1979). The protein equivalents of all food produced and that part of it consumed by the villagers was determined by multiplying the quantity of food and their respective protein contents (Table 6.3).

For calculation of energy of grazing and scavenging by animals it was assumed that the energy equivalent for this would be equal to the values obtained after subtracting the energy values of the actual feed consumed (based on regular observations) from their standard food requirement (Ranjhan, 1977).

For calculating standard food energy/protein requirements of humans, the total consumption units (adult male values) for the whole village 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, 9-12 years 0.6, 0.7 and 0.8 units respectively. The total number of units for this village worked out at 373 (204.5+131.4 + 14.7 + 16.8 + 5.5). This was then multiplied by food energy equivalents of an adult (1unit) of 10.042 MJ day^{-1} and protein equivalents of an adult (1unit) of 55 g day^{-1} (Gopalan _et.al_., 1978) to calculate daily food energy/ protein requirement of different categories of humans. To find energy equivalent of fuelwood needed per day for cooking purposes it was assumed that the potential energy required for one adult (1unit) would be 15.76 MJ (Mitchell, 1979). This was then multiplied by the total units obtained for the whole village.

Table 6.4 Energy (MJ $ha^{-1}yr^{-1}$) and monetary (Rs. $ha^{-1}yr^{-1}$) (in parentheses) input/output pattern under a 7-year shifting agriculture of hill Miris in north-east India.

Production measure	Energy
Input total	681.1 (2262)
Labour total	650.1 (1886)
Slash and burn	48.8 (123)
Land preparation	16.4 (57)
Sowing	161.6 (440)
Weeding and Watching	248.0 (764)
Harvesting and transport	175.3 (502)
Seed	31 (376)
Output total	41886 (5706)
Slash	6304 (80)
Grains	30328 (4532)
Leafy and fruit vegetables	1375 (354)
Tuber and root crops	3879 (740)
Net return	41204.9 (3444)
Efficiency.	
Output/input ratio	61.5 (2.52)
Output/input ratio (- slash)	52.2 (2.49)

Table. 6.5. Per animal annual energy (MJ x 10^3) and monetary (Rs. x 10^3) (in parentheses) input/output pattern of animal husbandry of hill Miris in north-east India.

Production measure	Mithun[1]	Cattle[2]	Swine[3]	Poultry[4]	
				Meat	egg
Input total	28.73 (0.17)	21.22 (0.10)	8.13 (0.11)	1.76 (0.07)	0.62 (0.03)
Labour	0.03 (0.17)	0.02 (0.10)	0.08 (0.06)	0.03 (0.03)	0.01 (0.01)
Food	28.8 (0)	21.2 (0)	8.05 (0.05)	1.73 (0.04)	0.61 (0.02)
Output total	3.0 (1.05)	1.88 (0.74)	1.1 (0.83)	0.19 (0.40)	0.17 (0.16)
Meat	1.73 (1.05)	1.22 (0.74)	0.9 (0.83)	0.08 (0.40)	-
Egg	-	-	-	-	0.10 (0.16)
Dung	1.27 (0)	0.66 (o)	0.2 (0)	0.11 (0)	0.07 (0)
Output/input ratio	0.10 (6.18)	0.09 (7.40)	0.14 (7.55)	0.11 (5.71)	0.27 (5.33)
Output/input ratio (Dung and food)	52 (6.18)	61 (7.40)	11.3 (7.55)	2.7 (5.71)	10 (5.33)

[1] Slaughtering age of 6 years
[2] Slaughtering age of 5 years
[3] Slaughtering age of 1 year
[4] per family.

RESULTS

Labour is a major input into shifting agriculture, besides seed under a 7-year cycle operating in the village (Table 6.4). Only about 10% of the total labour energy input went for slash and burn operation and field preparation. About 40% energy was expended for weeding and watching the plots. Slash used as fuelwood was one of the outputs apart from the harvested crops. Grain crops were emphasized most, followed by tuber and root yielding species. The net return per hectare was Rs. 3444 and with a high energy efficiency.

Labour and food are the only two energy inputs into animal husbandry system (Table 6.5). Though Mithun and cattle raising required more total labour energy input because of the higher slaughting age for these two, the annual energy input was lower than for swines. Annual labour energy input was maximum for swines and minimum for egg-laying poultry birds. Per year energy output from mithun was more than from cattle. Energy efficiency of egg-laying poultry birds was maximum. However, edible energy output per unit labour input was maximum for

Fig. 6.1 Energy flow (MJx10^3) through the animal husbandry sub-system of a hill Miri village in north-east India. Values in parentheses represents the monetary flow (Rs.x10^3).

Fig. 6·1

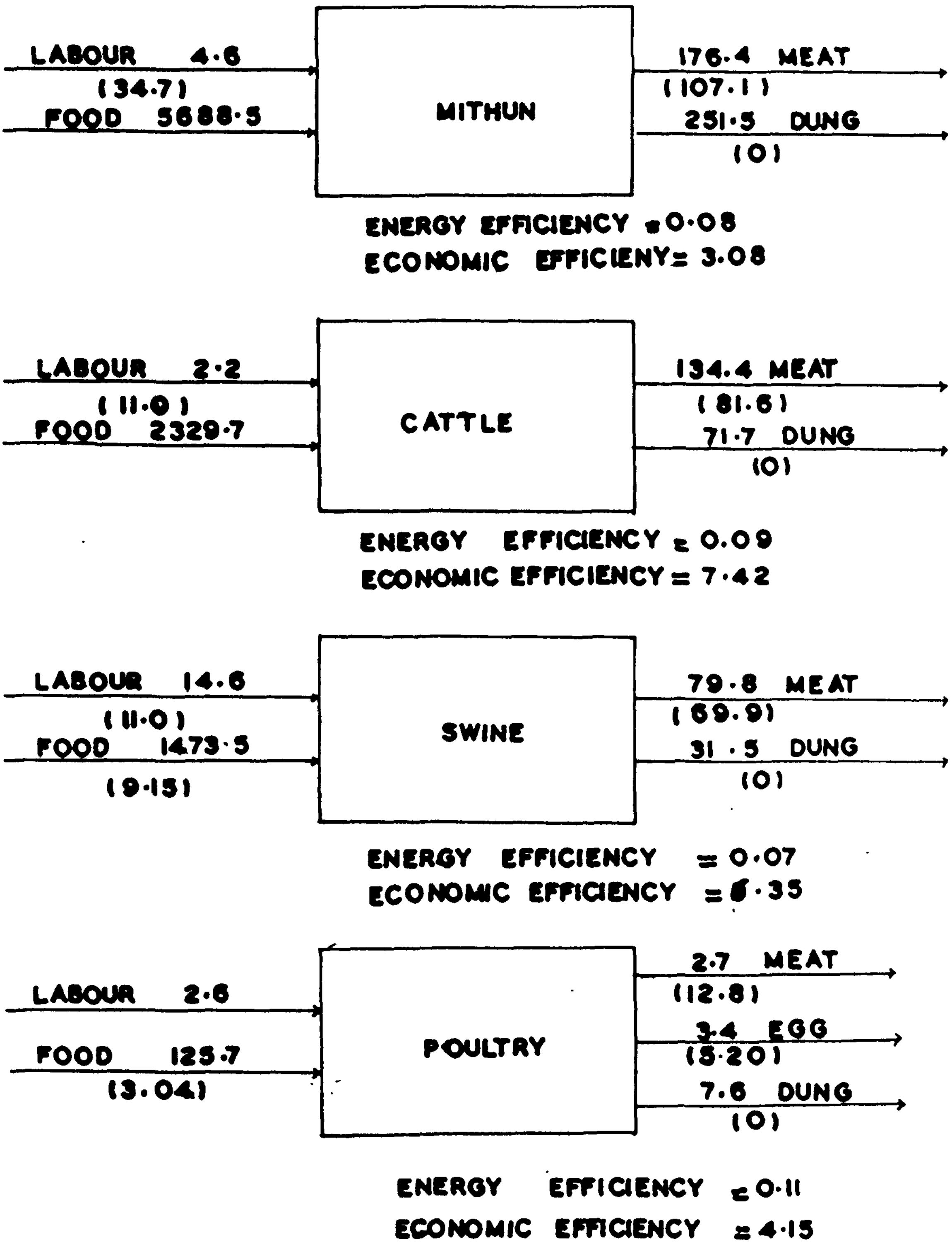

LABOUR 4·6
(34·7)
FOOD 5688·5
MITHUN
176·4 MEAT
(107·1)
251·5 DUNG
(0)
ENERGY EFFICIENCY = 0·08
ECONOMIC EFFICIENY = 3·08
LABOUR 2·2
(11·0)
FOOD 2329·7
CATTLE
134.4 MEAT
(81·6)
71·7 DUNG
(0)
ENERGY EFFICIENCY = 0.09
ECONOMIC EFFICIENCY = 7·42
LABOUR 14·6
(11·0)
FOOD 1473·5
(9·15)
SWINE
79·8 MEAT
(69·9)
31·5 DUNG
(0)
ENERGY EFFICIENCY = 0·07
ECONOMIC EFFICIENCY = 6·35
LABOUR 2·6
FOOD 125·7
(3·04)
POULTRY
2·7 MEAT
(12·8)
3·4 EGG
(5·20)
7·6 DUNG
(0)
ENERGY EFFICIENCY = 0·11
ECONOMIC EFFICIENCY = 4·15

Fig. 6.2 Food (plant origin) production and consumption pattern in a hill Miri village in north-east India.

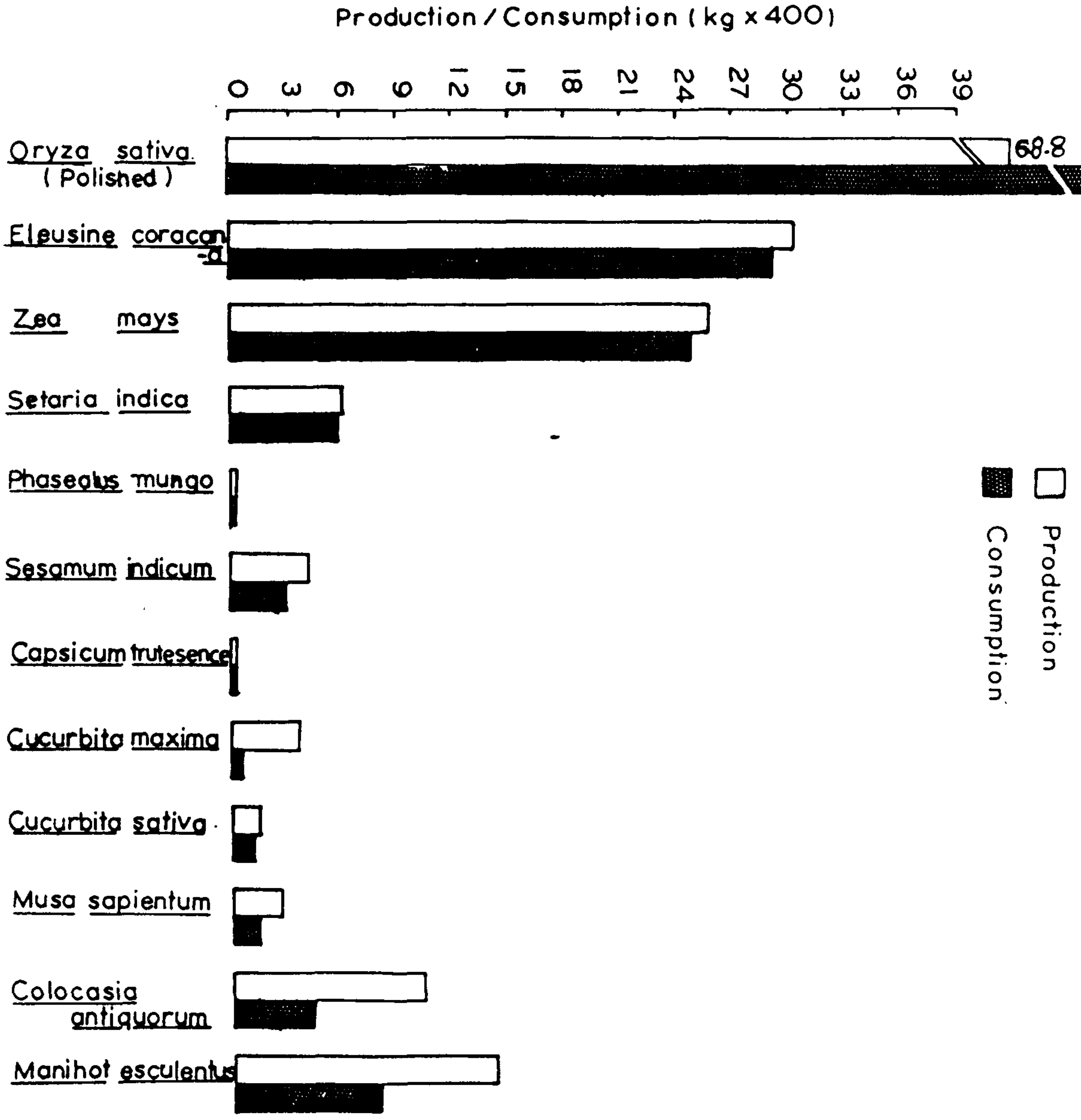

Production / Consumption (kg x 400)
0
3
6
9
12
15
18
21
24
27
30
33
36
39
Oryza sativa (Polished)
68.8
160.2
Eleusine coracana
Zea mays
Setaria indica
Phaseolus mungo
Sesamum indicum
Capsicum frutesence
Cucurbita maxima
Cucurbita sativa
Musa sapientum
Colocasia antiquorum
Manihot esculentus
Production
Consumption

Fig. 6.2

Fig. 6.3 Meat consumption pattern in a hill Miri village in north-east India.

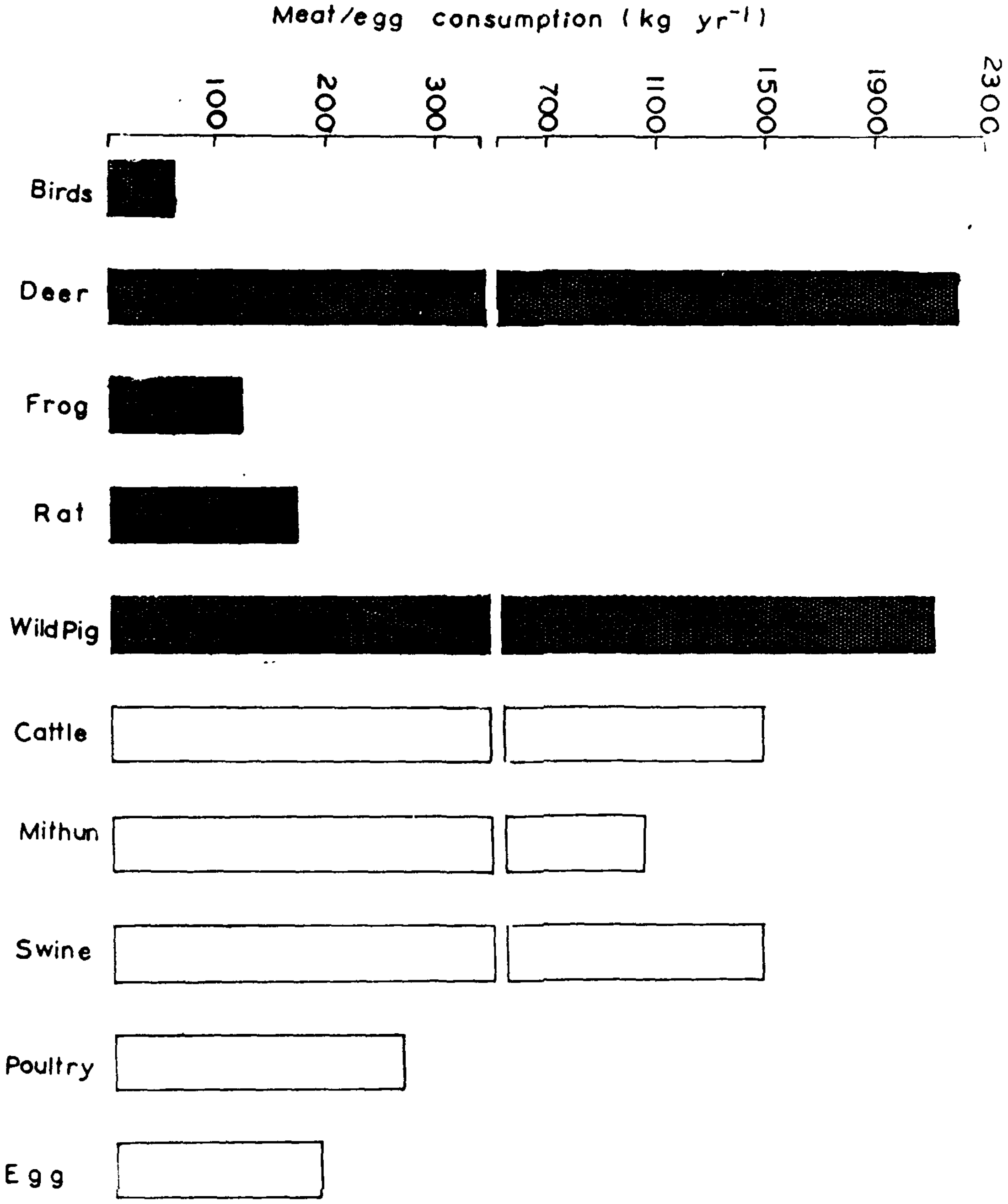

Meat/egg consumption (kg yr^{-1})
100
200
300
700
1100
1500
1900
2300
Birds
Deer
Frog
Rat
Wild Pig
Cattle
Mithun
Swine
Poultry
Egg

Fig. 6.3

Table 6.6. Annual food and protein consumption pattern in a hill Miri village in north-east India. Values in parentheses represent per unit consumption.

Food items	Energy (MJx10^3)	Protein (kgx10^3)
Plant origin total	1341.9 (3.59)	7.03 (0.02)
Grains	1098.8 (2.94)	6.07 (0.02)
Pulse	2.5 (0.006)	0.04 (-)
Sesamum	35.2 (0.09)	0.24 (-)
Leafy and fruit vegetables	36.7 (.10)	0.06 (-)
Tuber and root crops	66.8 (0.18)	0.07 (-)
Beverage (Rice+millet)	101.9 (0.27)	0.55 (0.001)
Animal origin total	126.6 (0.34)	3.05 (.008)
Wild animals	48.0 (0.13)	0.79 (0.002)
Domestic animals	77.0 (0.21)	2.23 (0.006)
Eggs (hen)	1.6 (0.004)	0.03 (-)
Total plant+animal origin	1468.5 (3.9)	10.08 (0.03)
Standard	1570.7 (4.2)	7.49 (0.02)

cattle closely followed by mithun; poultry birds were least efficient. Economic efficiency was maximum for swine husbandry and minimum for poultry.

In the village as a whole the energy efficiency of animal husbandry systems was low with maximum for poultry. The economic efficiency of swine was better than that of poultry (Fig.6.1). Economic efficiency of cattle husbandry was the highest where as it was minimum for mithun.

Most of the food requirements of the domestic sub-system was met from the produce under shifting agriculture except rice that is imported (Fig. 6.2). Only a small fraction of the produce was sold in the market

52% of the total meat consumption by the hill Miris was obtained from wild animals (Fig. 6.3) Only a small fraction of this was gathered from the wild in the form of frogs and rats and a large fraction was hunted deer and wild pig. The contribution of poultry to the meat/egg consumed from animal husbandry system was only a small fraction

Out of the total food energy consumed within the village, over 90% was of plant origin and the rest was of animal origin (Table 6.6) About 30% of

Table 6.7. Daily fuel wood consumption in a hill Miri village in north-east India. Values in parentheses represent daily per unit consumption.

Month	Average kg day^{-1}	Energy equivalent MJ x 10^3
November- February	2442 (6.55)	48.10 (0.13)
March - October	1650 (4.42)	32.50 (0.09)
Standard		0.016

Fig. 6.4 Energy flow (MJx10^3) through domestic sub-system of a hill Miri village in north-east India.

Fig. 6.4

Energy efficiency = 0·02

Table 6.8. Annual monetary and energy export/import pattern of essential items in a hill Miri village in north-east India. Values in parentheses represent per unit export/import.

Items	Quantity (kgx10^3)	Monetary value (Rs. x 10^3)		Energy equivalent (MJ x 10^3)	
Total export		339.2	(0.909)	380.8	(1.02)
Crops					
Sesamum indicum	0.4	3.8		9.3	
Cucurbita maxima	0.7	3.2		11.0	
Tuber crops	2.8	6.2		39.6	
Meat and egg					
Mithun	7.9	94.5		155.6	
Cattle	5.3	63.6		104.8	
Swine	3.2	47.7		54.7	
Poultry	0.2	6.2		1.0	
egg (hen)	0.1	1.5		1.0	
Labour	-	112.5		4.0	
Total import		158.5	(0.425)	851.9	(2.28)
Rice	52.2	114.9		851.9	
Clothing	-	18.6		-	
Medicine	-	8.2		-	
Miscellaneous	-	16.8		-	
Export/import ratio	-	2.14		0.45	

the protein consumed was of animal origin and the rest came from plants. Though the energy consumed was lesser than the standard requirement for an average Indian adult, the protein consumption was much higher.

Per capita fuelwood consumption in the village was over 10 times higher than the standard requirement for an average Indian (Table 6.7). Consumption was higher during the winter months than at other times. Slash from shifting agriculture of the village contributed about 7% of the total fuel energy needs and the rest came from the forest.

Food consumed and fuelwood for cooking and for heating houses are two inputs into the domestic system, with 87.1×10^3 MJ of the labour energy output used mainly for agriculture, animal husbandry and hunting (Fig.6.4). The energy efficiency of the domestic system of the village worked out at a low 0.02.

Meat is the major export out of the village (Table 6.8). A large quantity of rice is imported. The energy import is about 2.2 times more than the export whilst in economic terms the village export is about 2.1 times more than the total import. The hill Miris contributed substantial labour outside the village.

DISCUSSION

Hill Miris, like most of the other tribes of north-east India depend upon shifting agriculture with mixed cropping of grain, tuber and vegetable yielding plants, with emphasis on grain yielding species. Both human preferences and ecology may govern the selection and combination of cultivars. Grains may be preferred over tuber crops because these are less bulky and easier to store with less risk of loss (Mitchell, 1984). Crop preferences may also be related to soil fertility status (Ramakrishnan, 1984a). The hill Miri tribes operating their shifting agriculture under a short 7-year cycle are not able to meet their yearly requirements and have to depend upon import from outside. This is to a certain extent compensated through income from labour export working largely for Governmental agencies or private enterpreneurs involved in developmental activities and through export of meat. The chief advantage of shifting agriculture (Jhum) lies in that, labour is the only input which comes from within the family itself and therefore it does not cost anything to the farmer. Even if the cost of labour is included in the calculations as we have done in our study the energy and economic efficiencies are high. Very high energy efficiencies for these traditional agriculture systems has been shown by other workers (Lewis, 1951; Norman, 1978; Uhl & Murphy, 1981) with a reasonably high economic efficiency (Toky & Ramakrishnan, 1981a; Mishra & Ramakrishnan, 1981).

Animal husbandry with emphasis on swine husbandry and poultry are important activities linked with shifting agriculture in north-east India (Mishra & Ramakrishnan, 1982; Maikhuri, 1987) and elsewhere in the world (Rappaport, 1971). The energy and economic efficiencies of these two systems are generally high. This is largely because these two animal husbandry systems particularly swine husbandry are detritus based and therefore it is no input activity.

Apart from these, cattle and mithun maintained by them depend largely on forest land for grazing the animals. Mithun is a traditional animal maintained by the tribes of Arunachal Pradesh, but this is on the decline with large-scale deforestation in the area and the consequent decline in land for grazing. This decline is in spite of the social and cultural values attached with Mithuns. It may be noted here that, apart from determining the social status of the family these animals traditionally are also used for gift and barter.

Cattle farming is a recent introduction into the region by Governmental agencies and therefore has yet to find large scale acceptance. However, these animals are used exclusively for meat and not for milk. This is because milk consumption is traditionally not done by the tribal societies in the region.

Between swine husbandry, mithun and cattle, the economic and energy efficiencies of swines are higher. This is partly related to the slaughtering frequency of the animals. With yearly slaughtering of swines and 5-to 6-year intervals for cattle and mithun, the efficiency of the former one is better than the later two. In the case of swine husbandry slaughtering of pigs at more frequent intervals gave about 11% edible energy return per pig which is more than the Tsembaga system (Rappaport, 1971) where the slaughtering interval for swine is 10 years.

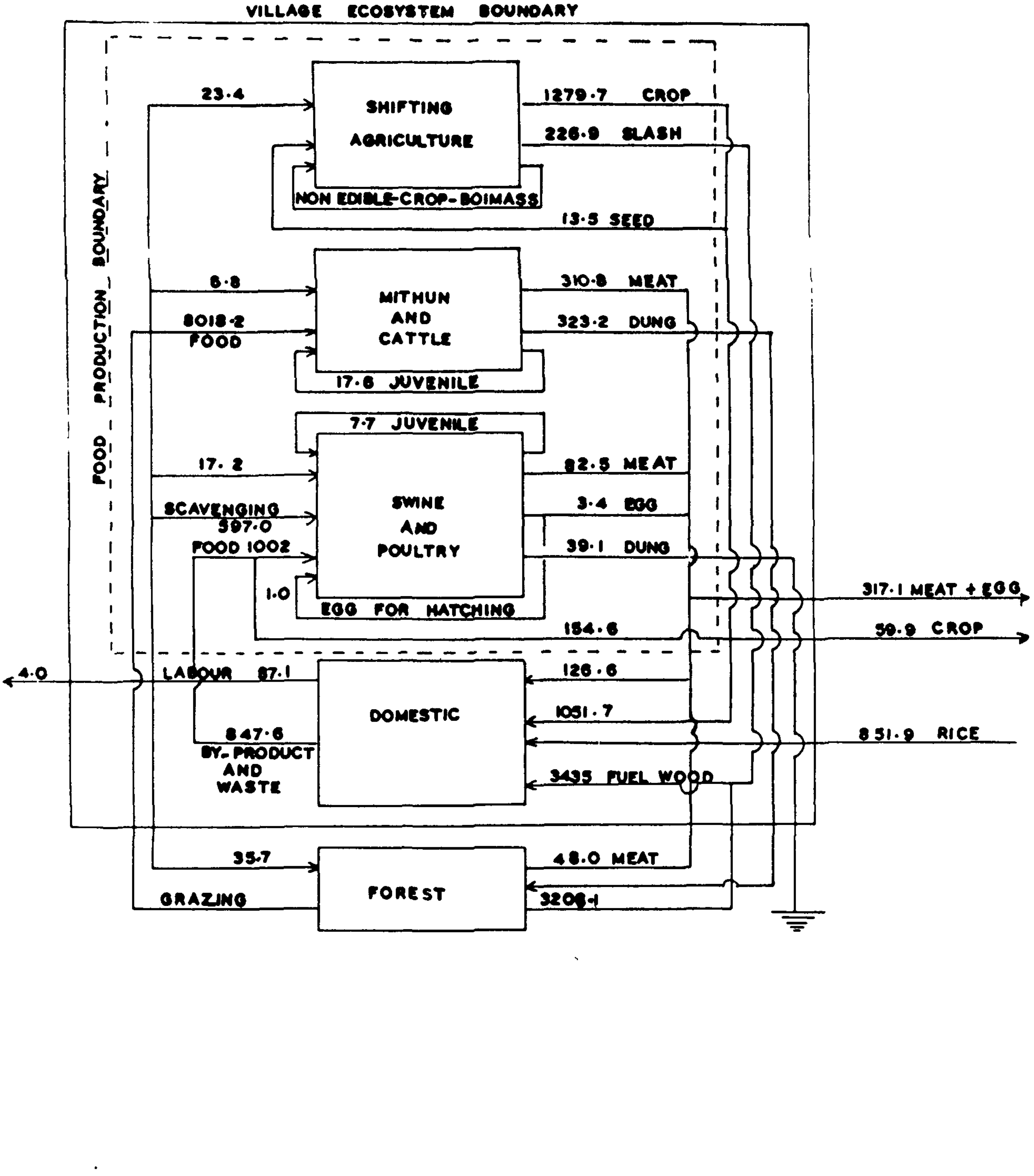
The general reduction in the energy and economic efficiencies of the animals of the village, as a whole, is because of the lesser number of slaughtered animals out of the total maintained at a given time.

Hunting and gathering is a common practice of tribals in north-east India (Gangwar, 1987). A variety of animals (bush meat) is available to hunters in the less populated areas, which may include monkeys, birds, deers, etc. (Ajayi, 1971; Heyman and Maurice, 1973). In some areas today it is estimated that 50% to 65% of the protein available to rural population is still derived from forest wild life and fisheries (UNESCO, 1978). Hill Miris obtain 7 to 8% of the total protein needs from the wild.

The food energy consumption of the hill Miris is below the standard requirement. With about 90% of the food energy being met through shifting agriculture, the shortened shifting agriculture cycle of 7 years is unable to provide sufficient food to the farmer as was also shown for the Khasis in Meghalaya (Mishra and Ramakrishnan, 1982). However with 30% of the protein needs coming from animal husbandry the hill Miris obtain more than their standard requirement.

Fig. 6.5 Energy flow (MJx10^3) through the various sub-systems of a hill Miri village in north-east India.

Fig. 6.5


VILLAGE ECOSYSTEM BOUNDARY
FOOD PRODUCTION BOUNDARY
23·4
SHIFTING AGRICULTURE
1279·7 CROP
226·9 SLASH
NON EDIBLE-CROP-BOIMASS
13·5 SEED
6·8
MITHUN AND CATTLE
310·8 MEAT
8018·2 FOOD
323·2 DUNG
17·6 JUVENILE
7·7 JUVENILE
17·2
SWINE AND POULTRY
82·5 MEAT
SCAVENGING 597·0
3·4 EGG
FOOD 1002
39·1 DUNG
1·0
EGG FOR HATCHING
317·1 MEAT + EGG
154·6
59·9 CROP
4·0
LABOUR 87·1
126·6
DOMESTIC
1051·7
847·6 BY-PRODUCT AND WASTE
851·9 RICE
3435 FUEL WOOD
35·7
48·0 MEAT
FOREST
GRAZING
3206·1

The heavy fuelwood consumption is due to low efficiency of the cooking stoves. In general, the per capita consumption of fuelwood in developing countries worked out to be about two-and-a-half times more than in the west (Leach, 1976). Most of the fuelwood by the hill Miris, is used for heating the huts and for distilling the local beer. Excessive fuelwood extraction from the forest is an important cause for fast depletion of forest resources (Singh, 1979; Bowonder, 1982, 1983; Guppy, 1984).

Per capita income of hill Miris is about $\frac{2}{3}$ of the Apatanis (Chapter 5) and about $\frac{1}{7}$ of the Khasis (Mishra and Ramakrishnan, 1982) of north-east India. Apatanis have a highly evolved wet cultivation of rice that meets all their requirements where as the Khasis with their agricultural activity geared to potato cultivation obtain better price for the produce in the market.

The schematic presentation of energy flow through a hill Miri village ecosystem (Fig 6.5) emphasises the linkages between agriculture, animal husbandry, domestic and forest sub-systems. The whole village ecosystem is based upon recycling of resources within and between the different sub-systems considered. However, the village ecosystem of the hill Miris suffer following deficiencies: (i) a short shifting agriculture cycle of 7 years that is unable to meet all their energy needs so that import of rice becomes necessary, (ii) wastage of dung that is not recycled into the agriculture system, (iii) poor efficiency of fuelwood use. Apart from agro-forestry inputs for stabilizing a short shifting cycle of a 7 years (Ramakrishnan, 1987b) : better resource recycling and input of technology for animal husbandry and efficient use of energy are aspects that need to be considered.

SUMMARY

This study deals with energy flow through a typical hill Miri village ecosystem under 7-year shifting agriculture cycle at an elevation of 1060 m in Arunachal Pradesh in north-east India. Even though village is not self-sufficient in their food production, the energy and economic efficiency (output/input ratio) of the agroecosystem is very high (61.5 and 2.5 respectively). Animal husbandry system with swine husbandry and poultry is an important link in the detritus food chain that utilises the by-products and food wastes of the agriculture system. The forest apart from providing shelter and food for mithun and cattle, which are a important components of animal husbandry system also meet over 90% of the fuel wood requirement. Hunting and gathering contribute about 52% of the total meat consumed in the village. The intricate relationships between production and consumption compartments of the village alongwith forest dependency have been discussed here.

GENERAL DISCUSSION

In the north-eastern hill region of India shortening of the shifting agriculture cycle from a long 20-30 years to 4-5 years, has adversely affected the economic return to the farmer, apart from large-scale environmental degradation. An approach towards plantation/cash crop system and terrace cultivation has been suggested from time to time. In this context, the economic and energy efficiencies of tea, coffee, pineapple with other crops and terrace cultivation of ginger was evaluated. Coffee introduced into the region has not been successful, perhaps related to management practices. This aspect needs further investigation. Ginger cultivation which is economically profitable though is widely practised by tribals in the region needs heavy input of labour and fertilizer and therefore not very efficient from energy view point. There is perhaps, possibility for efficient recycling of resources to reduce the input of inorganic fertilizers. Tea and pineapple alongwith other crops, both have higher energy efficiency, at the same time providing better returns to the farmer. However, tea cultivation does lesser damage to the soil because of reduced disturbances. In any case, plantation/cash crops have the intrinsic advantage of reduced losses occurring through hydrology, compared to annual cropping under terraces or under shifting agriculture. Traditionally grown pineapple with other crops was found to be advantageous in that efficient recycling of crop residue along with weed biomass contributed substantially in conserving nutrients within the system. However, the long term sustainability of this cropping pattern is doubtful unless combined with strong agroforestry inputs.

Unlike most of the tribal communities of north-east India, theApatanis of Arunachal Pradesh have evolved sedentry agriculture chiefly in the form of wet cultivation of rice in their extensive valley lands. Pisciculture along with rice cultivation not only improves the bioproductivity of the agroecosystem, but is also found to be highly efficient both from energy and economic points of view. A unique feature of the Apatani wet rice cultivation, is combining it with Eleusine coracana on the bund areas separating rice plots which traditionally in India are otherwise used as foot path for walking from one plot to another. In this way the Apatanis maximize production per unit land. The rice agroecosystem is mainly labour intensive and depend upon tight recycling of organic wastes from within the village ecosystem. Bamboo gardens maintained around rice plots besides providing fuelwood and timber for village consumption, also provides cash income through export.

A comparative analysis of the village ecosystem study of the Apatanis and the hill Miris indicates that the former are far better organized than the lesser developed hill Miris who depend upon shifting agriculture. The Apatanis are not only self-sufficient in food production and consumption, but also produce surplus rice for export, unlike the hill Miris who are not self-sufficient and have to import rice.

Mithun (Bos frontalis), cattle, swine and poultry form the animal husbandry practices of these tribes. With lesser economic efficiency for shifting agriculture, the hill Miris emphasize upon animal husbandry and this sub-system of the village is more efficiently organized by them compared to the Apatanis. Therefore hill Miris are able to export meat to the neighbouring more affluent Apatanis and purchase excess rice produced by the latter.

Heavy fuelwood consumption in both the tribes because of energy inefficient cooking stoves results in heavy dependence upon forest resources that are fast dwindling.

Even though Apatani rice cultivation is very sophisticated with high energy effieiency (1:78), provide high economic returns, further intensification through modern inputs in terms of cultivars and through winter cropping which is not done now, perhaps through mixed legumes/tuber crops is a possibility. Similarly the shifting agriculture of the hill Miris under a 7-year cycle could be further improved upon through more agroforestry inputs (Ramakrishnan, 1985c, 1987a). Better management practice for cattle and mithun, so that the waste resources from these two could be effectively utilized for agriculture, would ensure better land use management also. Better organisation of slaughtering regime for animals would ensure better returns to the farmer since some of the animals maintained are often not slaughtered for many years. These efforts combined with better organization of the domestic sub-system with appropriate rural technology inputs (Ramakrishnan, 1984a;b, 1985a) would ensure development based on ecological considerations.

REFERENCES

REFERENCES

Adeyoju, S.K. 1980. The future of tropical agroforestry systems. Commonwealth Forestry Review, 59, 155-161.

Ahlgren, I.F. & Ahlgren, C.E. 1965. Effects of prescribed burning on the soil micro-organisms in a Minnesota Jack Pine Forest, Ecology, 46, 304-310.

Ajayi, S.S. 1971. Wild life as a source of protein in Nigeria: some priorities for development. The Nigerian Field, 36, 115-127.

Alikunhi, K.H. 1960. Rice field fish culture outside Indonesia. In; Lectures presented at the Third International Inland Fisheries Training Centre, Boger, October-December, 1955.

Allen.S.E., Grimshaw, H.M., Parkinson, J.A. and Quarmby, C., 1974. Chemical Analysis of Ecological Meterials. Blackwell Scientific Publications, Oxford, 565 pp.

Alvani, P.K. and Chancellor, W.J. 1975. Energy requirements for wheat production and use in California. Amer. Soc. of Agric. Eng. Paper No. 75-1557.

Anderson, E. 1952. Plants, man and life. Little Brown and Company, Boston.

Andreae, B. 1980. The economics of Tropical agriculture. Commonwealth agricultureal Bureaux. England, 178 pp.

Angladette, A. 1966. Le riz.. Maisonneuve and Larosse, Paris.

Ardiwinata, R.O. 1957. Fish culture in rice fields in Indonesia- Proc. Indo-Pacific Fisheries Council, 7, 119-162.

Ashton, D.H. 1976. Phosphorus in forest ecosystems at Beenak, Victoria. J. Ecol 64. 171-186.

Aurora, G.S., Billorey, R.K., Patton, A. and Myrchiang, P. 1977. Socio-economic impact of shifting cultivation control scheme in North-Eastern region, Dept. of social & Anthroplo., North-Eastern Hill Univ., Shillong (Mimeographed).

Baidy, K.N. 1984. Fuel wood shortage, International Journal of Environmental Studies, 22, 255-272.

Bernhard, P. 1970. Etude de la Litt'ere et de la contribution an cycle des 'elements mineraux, en forest omrbrophile ou cote d'Ivoire. Oecologia; Plantarun 5, 247-266.

Berntalanffy, L. von. 1973. General systems theory (4th edn). Brazillier, New York.

Blaxter, K.L. 1975. The energetics of British agriculture. The Biologist, 22, 14-18.

Bolton, W. 1970. The role of Poultary. Proceeding of the Nutritional society, 35, 253-262.

Bornemisza, E. 1982. Nitrogen cycling in coffee plantations. Plant soil, 67, 241-246.

Bormann, F.H. , Likens, G.E., Fisher, D.W. and Pierce, R.S. 1968. Nutrient loss accelerated by clear cutting of a forested ecosystem. Science, 159, 882-884.

Borthakur, D.N., Singh, A., Awasthi, R.P., & Rai, R.N. 1978. Shifting cultivation in the north-eastern region. In. Resources, Development and pp. 330-342. Dept. Sci. & Tech., Govt of India.

Bowers, R.D. 1982. Agricultural tree crops as a no-tillage system. In: Agro-forestry in the African humid tropics. 13-16 (ed. L.H. MacDonald) Ibadan. Nigeria : United Nations University.

Bowonder, B. 1982. Deforestation in India. International journel of Environmental studies, 18, 223-236.

Bowonder, B. 1983. Forest depletion. Resource Policy, 9, 206-224.

Braude, R. 1916. New sources of protièn for pigs. Proceedings of Nutritional society, 35, 93-103.

Bray, P. & Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus is soils. Soil Sci., 59, 39-45.

Briscoe, J. 1979. Energy use and social structure in a Bangladesh village. Population and Development Review, 5, 615-641.

Buckman, H.O. and Brady, N.C. 1960. The Nature and Properties of soil. Macmillan, New York, NY, USA : XV+567 pp., illustr.

Buol, S.W. & Sanchez, P.A. 1978. Rainy tropical climates : physical potential, present and improved farming systems. In : Proc. 11th International Congress of soil Sciences, 292-311. Univ. of Alberta, Edmonton, Canada.

Calavan, M.M. 1977. Decisions against nature : An anthropological study of agriculture in northern Illinois Univ., special report no. 5.

Carneiro, R.L. 1960. Slash and burn agriculture : A closer look at its implications for settlement patterns. In men and cultures (ed) A.F.C. wallace (Philadelphia), pp 229-234.

Carvajal, J.F. 1959. Mineral nutrition and crop requirements of the coffee crop. Ministerio de Agriculture Y. Ganaderia (MAG) - Servico Tecnico Interamericanode Cooperacin Agricola (Stica), Tech. Bull. No. 9. San Jose, Costa Rica, 16 pp (In Spanish).

Chacko, P.I. & Ganapati, S.V., 1952. Fish culture in paddy fields. Ind. Com. J., 7, 173-175.

Chacon, J.C. and Gliessman, S.R. 1982. Use of the non weed concept in traditional tropical agriculture. Agro-Ecosystems, 8, 1-11.

Chang, K. 1970. The beginning of agriculture in the foreast. Antiquity, 44, 175-185.

Chang, T.H. 1977. Tropical agriculture: crop diversity and crop yields. Econ, Geogr., 53, 241-254.

Charter, C.F. 1941. A reconnaissance survey of the soils of British Honduras. Belize.

Chavunduka, D.M. 1976. The role of cattle in the traditional African Society. Beef cattle production in developing countries: 398. Centre for Veterinary tropical medicine. Univ. of Edinburgh.

Clarke, W.C. 1966. From extensive to intensive cultivation: a succession from New Guinea. Ethnology. 5, 352-355.

Coche, A.G. 1967. Fish culture in rice fields, a world wide synthesis. Hydrobiologia, 30, 1-44.

Cole, D.W., Gessel, S.P. & Rice, S.F. (1967). Distributions and cycling of nitrogen, phosphorus, potassium and calcium in a second-growth Douglas Fir ecosystem. In: Symposium on Primary Productivity and nutrient cycling in natural ecosystems. pp 197-232. Univ. of Maine Press, Orono, Maine.

Colson, E. 1979. In good years and in bad: food strategies of self reliant societies. J. Antropol. Res. 35, 18-29.

Conklin, H.C. 1957. Hanunoo agriculture, F.A.O. forestry Development Paper No. 12, F.A.O. Rome, 109 pp.

Clawson, D.L. 1935. Harvest security and intraspecific diversity in tropical agriculture. Econ. Bot., 39, 56-67.

Cooil, B.J. & Fukunaga, E.T., 1959. Mineral nutrition of coffee. II. Intensive fertilizer application and its effects. In progress in Coffee Production Techniques, pp. 91-95. Interamerican Institute of Agricultural Sciences, Turrialba, Costa Rice (In Spanish).

Cook, C.F.1921. Milpa agriculture, a primitive tropical system. Annual report of SmithSonion Institution, 1919, Washington, D.C., 307-326.

Cowgill, V.M. 1961. Soil fertility and the ancient Maya. TRANSACATIONS of the Connecticut Academy of Arts and Science, 42, 1-56.

Cunningham, J.M.M., Eadie, J., Maxwell, T.J. & Sibbald, A.R. 1978. Inter-relations between agriculture and forestry : An agricultural view. Scottish Forestry, 32, 182-193.

Curtis, J.T. 1959. The vegetation of Wisconsin : an Ordination of Plant Communities. Univ. of Wisconsin Press. Wisconsin.

Cutting, C.V., Wood, P.A., Brown, P. and Ambrose, H.B. 1959. Assessment of fertility status and the maintenance of productivity of soils in Nyasaland. Paper No. 69. Third Inter-Afr. Soils. Conf. Dalaba.

Das, A.K. & Ramakrishnan, P.S. 1985. Litter dynamics in Khasi Pine (Pinus Kesiya Royle ex. Gordon). of north-eastern India. For. Ecol. & Manag., 10, 135-153).

Dart, P.J. and Day, J.M., 1975. Nonsymbiotic nitrogen fixation in the field. In: Soil microbiology (ed. N. Walker), Butterworth Scientific Publications, London.

David, L.C. 1983. Harvest Security and Interaspecific diversity in traditional tropical agriculture. Economic Botany 39 : 56-57.

Davision, G.M.H. 1982. How much forest is there ? Malayan Naturalist: Supplement to the Malayan Nature Journal, 35, 11-12.

Dazhong, W. and Pimentel, D. 1984. Energy inputs in agricultural systems of China. Agric. Agric. Ecosystems Environ., 11, 29-35.

Dean, G.W., Carter. H.O., Wagstaff, H.R., Olayide S.O., Ronning, M. and Bath, D.L. 1972. Production functions and linear programming models for dairy cattle feeding, Giannini Found. Monogr. No. 31, Calif Exp. Stn., Berkeley, Univ. Calif, 52 pp.

De Vos, A. 1977. Game as food. Unasylva, 29, 2-12.

Dent, J.B. and Anderson, J.R. (eds) 1971. Systems analysis in agricultural management. Wiley, sydney. New York, London Toronto.

Dickinson, J.C. 1972. Alternative to monoculture in the humid tropics of Latin America. The Professional Geogropher, 24, 217-222.

Donaldson, G. 1978. Forestry. Sector Policy Paper. World Bank. Washington D.C., U.S.A.

Douglas Sholto, J. & Hart, R.A. de J. 1976. Forest Farming. London : Watkins Publishing.

Doyen, A. 1980. Integration of multiple-use research in an environmental study of a rice development project in the Guinean zone-Lower Casamance-Senegal. Paper presented at the IUFRO/MAB Conference : Research on multiple-use Forest Resources.

Dukham, A and Masefield, G.B. 1970. Farming systems of the world. London, U.K. ; Chatto & Windus, 542 pp.

Earl, D. 1975. A renewable source of fuel. Unasylva, 27, 21-26.

Eaton, J.S., Likens, G.E. and Bormann, F.H. 1973. Throughfall and stemflow chemistry in a Northern Hardwood forest. J. Ecol., 61, 495-508.

Eckholm, E.P. 1975. The other energy crisis : Worldwatch Paper 1. Worldwatch Institute, Washington, D.C, U.S.A.

Eden, M.J. 1980. A traditional agro-system in the Amazon region of Colombia. Tropical ecology & develop, 509-514.

Egunjobi, J.K. 1974. Litterfall and mineralization in a teak *Tectona grandis* stand. Oikos, 25, 222-226.

Emergy, F.E. and First, E.L. 1971. Socio-technical systems. In systems thinking (ed. F.E. Emery). Penguin Books, Harmondsworth, Middlesex.

Epstein, H. 1955. Domestication features in animals as functions of human societies. Agric. Hist., 29, 137-146.

Evans, L.T. 1980. The natural history of crop yield. American Scientist, 68, 308-397.

F.A.O. 1957. Shifting cultivation. Trop Agric., 34, 159-164.

F.A.O. 1974. Shifting cultivation and soil conservation in Africa. Rome, Soil Bulletin No. 24.

F.A.O. 1977. The state of food and agriculture. Rome.

Finck, A. 1970. Moglichkeiten de Nahrungsproduktion in Landbau. Ernahrungs-Umschau, 2, 47-52.

Foster, N.W. and Gessel, S.P. 1972. The natural addition of nitrogen, potassium and calcium to a *Pinus banksina* Lamb, forest to soil. Can. J. Bot., 61, 1300-1306.

Freeman, J.D. 1955. Iban Agriculture. A report on the shifting cultivation of hill rice by the Iban of Sarawak. H.M.S.O., London.

Freedman, B. 1981. Intensive forest harvest: a review of nutrient budget considerations. Res. Centre. Frederiction, N.B. M-X -121, April, 1981.

Furer - Haimendrof, C.Von. 1962. The Apa Tanis and Their Neighbours. London.

Furer - Haimendrof, C.Von, 1985. Tribals of India: The struggle for survival. Oxford Univ. Press, Delhi; Bombay; Calcutta; Madras, 342 pp.

Gangwar, A.K. 1987. Cropping and yield patterns under slash and burn agriculture at higher elevations in north-east India and related ethnobiological studies. Ph.D. Thesis, North-Eastern Hill Univ., Shillong, India. 248 pp.

Georgescu-Roegen, N. 1979. Energy analysis and economic valuation. Southern Economic Journal, 44, 1023-1058.

Gomez-PomPa, A., C. Vazuez- Yanes and S. Guevara. 1972. The tropical rain forest: A non-renewable resource. Science, 172, 762-765.

Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C. 1978. Nutritive Value of Indian Foods. Nat. Inst. Nutrition, Hyderabad, India, 204 pp.

Gosz, J.R., Likens, G.E., Eaton, J.S. & Bormann, F.H. 1975. Leaching of nutrients from leaves of selected tree species of New Hamp'shire. In: Mineral cycling in Southeastern Ecosystems. (eds. Hawell, F.G., Natt. Tech. Info. Ctr. Springfield, Virginia.

Grau, C.R. and Klein, N.W. 1957. Sewage grown algae as a foodstuff for chicks. Poultry Science, 365, 1046-1051.

Greenland, D.J. 1975. Bringing the green revolution to the shifting cultivor. Science, 190, 841-844.

Grigg, D.B. 1969. The agricultural regions of the world : review and reflections. Econ. Geogr., 45, 95-132.

Grigg, D.B. 1974. The agricultural systems of the world. An evolutionary approach. London, U.K., New York, U.S.A. ; Melbourne, Australia ; Cambridge University Press. 358 pp.

Grist, D.H. 1953. Rice. Longmans, Green and Co. London.

Guppy, N. 1984. Tropical deforestation. Foreign Affairs, 62, 926-965.

Harlan, J.R. 1971. Agricultural orgins : Centers and noncenters. Science, 174, 468-474.

Harrory, J.P. 1949. Afrique, Terre qui Meurt. Brussels.

Harris, M. 1966. The cultural ecology of India's sacred cattle. Current Anthropology, 7,51-59.

Harwood, R.R.& Price, E.C. 1976. Multiple cropping in tropical Asia. In: Multiple cropping, 11-40. As A special publication Number 27, Madison : American Society of Agronamy.

Harword, L.E. & Jackson, W.D. 1975. Atmospheric losses of four plant nutrients during forest fire. Aust. For., 38, 92-99.

Helback, H. 1959. Domestication of food plants in the old world. Science, 130, 365-372.

Heymans, J.C. and Maurice, J.S. 1973. Introduction a l' exploitation de la faune come resource au lmentaire en Republique du Zaire. Forum Univ, 2, 6-12.

Hickling, C.F. 1961. Tropical inland fisheries. Longmans. London.

Hora, S.L. 1951. Fish culture in rice fields. Curr. Sci., 20, 171-173.

Iyenger, H.D.R. 1953. Paddy-cum-fish culture. Pilot studies conducted at Hesserghatta and Visweswaraya Canal farms in Mysore state. Ind. J. Vet. Sci. and Animal Husbandry, 23 (4), 289-297.

Iyenger, H.D.R. 1962. Further studies on paddy-cum-fish culture at Hesserghatta fish farm in Mysore state: J. Bombay nat Hist. Sci. 59 (1), 301-305.

Jhingran, V.G. 1982. Fish and Fisheries of India. 2nd ed., Hindustan Publishing Crop. (India), Delhi. 666 pp.

Jones, M J., 1976. The significance of crop residues to the maintenance of fertility under containuous cropping at Samaru, Nigeria, J. agric Sci, Camb., 86, 117-125.

Klinge, H.& Rodrigues. W. 1968. Litter production in an area of Amazonian terra firma forest, Amazonian, 1, 267-310.

Kohli, Y. 1983. Our scientific heritage. In: Arunachal News. Directorate of information and public relations, Itanagar.

Kupper, A. 1976. Monthly nitrogen use by coffee and the form and timing for fertilizer nitrogen use. In : Summary 5th Brasilian Congress in coffee Res., pp. 215-217, Caxambu, M.G., Brasil (in Purtuguese).

Laudelot, H. and Meyer, J. 1954. Mineral element and organic material cycles in the equatorial forest of the Congo. Oecologia Plantarum, 7, 1-21.

Leach, G. 1976. Energy and Food Production. Guildford, I P C Science and Technology Press, 137 pp.

Leach, G. and Slesser, M. 1973. Energy Equivalent of Network Inputs to Food Processing Processes. Glasgow; Strathclyde Univ.

Le Clere, J.A., Breazeale, J.F. 1908. Plant food removed from growing plants by rain or dew. In ; U.S. Department of Agricultural yearbook. (ed. Arnold, J.R.). 389-402.

Lee, R.B. 1966. Kung Bushman subsistence: An input output analysis. In. Ecological of Canade, Bill No. 230.

Leith, H. 1976. Biological productivity of tropical lands. Unasylva, 28, 28-114.

Lewis, O. 1951. Life in a Mexican village: Tepoztlau restudied. Univ. of Illinois Press, Urbana, 512 pp.

Lewis, W.M. Jr. 1974. Effects of fire on nutrients movement in a south carolina pine forest. Ecology, 55, 1120-1127.

Likens, G.E. Bormann, F.H. Pierce, R.S., Fisher, D.W. 1971. Nutrient hydrologic cycle interaction a small forested watershed ecosystems. In: Productivity of Forest Ecosystems. (ed. P.S. Duvigneaud). Proc. Busselo Synop. UNESCO, Paris, 553-563.

Likens, G.E. Bormann, F.H. Pierce, R.W., Eaton, J.S. and Johnson, N.M. 1977. Biogeochemistry of a Forested Ecosystem. 146 pp. Springer. Verlag, New York.

Likens, G.E. , Bormann, F.H. Pierce, R.S. and Reiners, W.A. 1978. Recovery of deforested ecosystem. Science, 199: pp 492-495.

Lioyd, P.S. 1971. Effects of fire on the chemical status of herbaceous communities of the Derbyshire Daks. J. Ecol., 59, 261-273.

Loomis, R.S. 1984. Traditional agriculture in America. Ann. Rev. Ecol. Syst.,15, 449-478.

Loosli, J.K. 1974. New sources of protien for human and animal feeding Bioscience, 24, 26-31.

Loucks, O.L. & D' Alessio, 1975. Energy flow and human adaptation. As summary of ecosystem studies. The institute of ecology, Madison, Wisconsin.

MacNeish, R.S. 1964. Ancient mesoamerican civilization. Science, 143, 531-545.

Madgwick, H.A.H. and Ovington, J.D. 1959. The chemical composition of precipitation in adjacent forest and open plots. Forestry, 32, 14-22.

Maikhuri, R.K. 1987. Studies on tribal village ecosystem function in north-eastern hill region of India. Ph.D. thesis. North-Eastern Hill University, Shillong. 239 pp.

Makhijani, A and Poocle, A. 1975. Energy and agriculture in the third world. Cambridge, Mass., Ballinger. 168 pp.

Manshard, W. 1974. Tropical Agriculture. London, U.K. ; New York, U.S.A. ; Longman, 226 pp.

Maydell, H.J. Von 1979. Agro-forestry to combat desertification. Agroforestry : Proc. 50th Tropische Landbouwdag' (Symposium on Agriculture) 1978. Bull. 303m Dept. Aric. Research, Korinklijk Institute voor de Tropen, Amsterdam.

McArthur, M. 1974. Pigs for the ancestors : a review article, Oceania, 45, 87-123.

McConnell, D.J. & Dharmapala, K.A.E. 1978. The forest garden farms of Kandy. A paper based on farm management report no. 7, Economic Structure of Kandyan Forest-Garden Farms. F A O Agicultural Diversification Project, Peradeniya, Sri Lanka, 1973.

Mes, M.G. 1954. Excretion of Phosphorus and other mineral elements by leaves under the influence of rain. S. Afric. Journ., 1, 167-172.

Meerman, J. and Cochrane, S.H. 1982. Population growth and food supply in sub-Saharan Africa. Finance and Development, 19, 12-17.

Mishra, B. 1976. A positive approach to the problem of shifting cultivation in eastern India and a few suggestions to the policy makers. In: Shifting cultivation in North-East India. (ed.B. Pakem, J.B. Bhattacharjee, B.B. Dutta & B. Dutta Ray), pp. 80-91. North-East India Counc. Social Sci. Res., Shillong, Meghalaya.

Mishra, B.K. and Ramakrishnan, P.S. 1981. The economic yield and energy efficiency of hill agroecosystem at higher elevations of Meghalaya in north-east India. Acta Oecol./ Oecol Applic, 2: 369-389.

Mishra, B.K. and Ramakrishnan, P.S. 1982. Energy flow through a village ecosystem with slash and burn agriculture in north-eastern India. Agric- Systems. 9: 57-72.

Mishra, B.K. and Ramakrishnan, P.S. 1983a. Slash and burn agriculture at higher elevations in north-eastern India I. Sediment, water and nutrient losses. Agric. Ecosyst. Environ., 9: 69-82.

Mishra, B.K. & Ramakrishnan, P.S. 1983b. Slash and burn agriculture at higher elevations in north-eastern India II. Soil fertility changes. Agric. Ecosys. Environ., 9, 83-96.

Mishra, B.K. and Ramakrishnan, P.S. 1984. Nitrogen budget under rotational bush fallow agriculture (Jhum) at higher elevations of Meghalaya in north-eastern India. Plant and soil, 80: 237-246.

Mitchell, R. 1979. The analysis of Indian agroecosystems. Interprint, New Delhi, 180 pp.

Mitchell, R. 1984. The ecological basis for comparative primary production. In Agriculture ecosystems. ed. B. Lawrence B.R. Simner. C.J. House New York. John Wiley.

Moerman, M. 1968. Agricultural change and peasant choice in a Thai village. Berkeley. C.A. Univ. of California Press.

Monokaran, N. 1979. Stemflow, throughfall and rainfall interception in a lowland tropical rainforest in Peninsular Malaysia. Malay. Forester, 42, 174-201.

Montelambert, M.R. De and Clement J. 1983. Fuel wood supply in the developing countries. FAO Forestry paper, FAO, Rome, Italy, ix+125 pp.

Moody, K., 1975. Weeds and shifting cultivation. PANS, 21, 188-194.

Morse, R. 1982. Complementary aspects of rural energy and farming systems. Paper prepared for the farming systems research symposium, Kansas state Univ., Manhatter, Kansas.

Mutsaers, H.J.W., Mbouemboue, P & Boyomom, 1981. Traditional food crop growing in the yaounde area (Cameron) Part I. Synopsis of the system; Agro-Ecosystems, 6, 273-287.

Nair, P.K.R. 1982. Agro-forestry: A sustainable land use system for the fragile ecosystems in the tropics. The malayan Nature Journal, 35, 109-123.

National Productivity Council. 1973. Solar energy application in India: Status and potential. Total energy and energy substitution. Seminar proceedings. New Delhi. 282 pp.

Newbould, P.J. 1967. Methods of estimating the primary production of forests. International Biological Programme, Handbook No.2. Blackwell Scientific Publications, Oxford.

Nguu, N.V. Palis. R.K. 1977. Energy input and output of a modern and traditional cultivation system in lowland rice culture. Philippines Journal of Biology, 6, 1-8.

Norman, M.J.T. 1978. Energy inputs and outputs of subsistence cropping systems in the tropics. AgroEcosystems, 4, 355-366.

Norman, D.W. 1979. An economic study of three villages in Zaria. II. Input-output study. Vol. I, Samaro; Nigeria : Institute for Agricultureal Research.

Nye, P.H. and Greenland, D.J. 1960. The soil under shifting cultivation : Tech. Comm. 51, Comm. Bur. Soils, Harpenden, 156 pp.

Nye, P.H. 1961. Organic matter and nutrient cycles under moist tropical forest Plant Soil, 8, 333-346.

Odum, H.T. 1971. Enviornment, power and Society (New York, Wiley-Interscience, 1971), 105-109.

Okigbo, B.N. and Greenland, D.J. 1976. Intercropping cropping systems in tropical Africa. In Multiple Cropping. 63-101 As A Special Publication No. 27. Madison : American Society of Agronomy.

Ovington, J.D. 1962. Quantitative ecology and woodland ecosystem concept. Advances in Ecological Research, 1, 103-192.

Parodi, L. 1938. Procesos biologicos de la demonsticacion vegeral. Rev. Argent. Agron. 5, 1-24.

Pasca, T.M. 1981. Concerning wood energy. Unasylva, 33, 2-3.

Patrick, W.H. and Mahapatra, J.C. 1968. Transformations and availability to rice of nitrogen and phosphorus in waterlogged soils. Adv. Agron., 20, 323-359.

Pierre, G. 1980. How we use the principal of multiple-use forestry in Belgium. Proc. IUFRO/MAB Conference: Research on multiple-use forest resources. Flagstaff, Arizona, 97-101.

Pimentel, D., Hurd, L.E. , Bellotti, A.C., Forster, M.J. , Oka, I.N., Sholes, O.D. and Whitman, R.J. 1973. Food production and the energy crisis. Science, 182, 443-449.

Pimentel, D., Lynn, W.R., Macreynolds, W.F.,. Hewes, M.T. and Rusk, S. 1974. Workshop on research methodology for studies of energy, food, man and environment. Phase I. Ithaca, N.Y., Centre for Environment Quality Management, Cornell University, pp. 52.

Pimentel, D., Dritschilo, W., Krummel, J. and Kutzman, J. 1975. Energy and land constraints in food-protein production, Science, 190, 754-761.

Pimentel, D. and Pimentel, M. 1979. Food, energy and society, London : Edward Avnold, 165 pp .

Pongsuwana, U. 1962. Progress of ricefield fish culture in Thailand- Proc. Indo-Pacific Fisheries Council, 10, 157-163.

Queiroz, J.S. de, Aleman, N.G. and de Leon F.A.O. 1986. The ecology and management of small ruminant production system in the sertao of Ceara, in the Northern Brazil, Agricultural Systems, 22, 259-287.

Rahman, A.H.M M. 1969. A study of the movement of elements from leaf crowns by natural litterfall, a stemflow and leafwash, M.F. Thesis in File University Wash. Saatle.

Ram, S.C. 1986. Ecosystem function of seral communities at Cherrapunji and adjoining areas. Ph.D. Thesis. North Eastern Hill University, 192 pp.

Rambo, A.T. 1983. Conceptual Approach to Human Ecology. Research Report No. 14. East-West Environment and Policy Institute, 37 pp.

Rao, T.S. 1977. The handling of nitrogenous wastes in rural India. Ambio. 62, 134-136.

Ramakrishnan, P.S., Toky, O.P., Mishra, B.K. and Saxena, K.G. 1981a Slash and burn agriculture in north-eastern India. In: H. Mooney, T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, W.A. Reiners (eds). Fire Regimes and Ecosystem Properties. USDA. For. Serv. Gen. Tech. Rept. W.O. 26, Washington, D.C., 570-586.

Ramakrishnan, P.S., Toky, O.P. and Mishra, B.K. 1981b Jhum- an ecological assestment : In Souvenir Volume (eds) A Singh and P. Wali. Int. Sco. Trop. Ecol., pp 41-49.

Ramakrishnan, P.S. 1983. Socio economic and cultural aspects of Jhum in the north-east and options for eco-development of tribal areas. In N.P. Chaubey (ed) Tribal Techniques, Social Organisation and Development: Disruption and Alternates. Indian Acad. Social Sci. 12-30.

Ramakrishnan, P.S. 1984a. The science behind rotational bush fallow agriculture systems (Jhum). Proc. Indian Acad. Sci. (Plant Sci.), 93: 379-400.

Ramakrishnan, P.S. 1984b. Let the tribals decide what they want. Science Age, 2, 8-11.

Ramakrishnan, P.S. 1985a. Tribal man in the humid tropics of the north-east. Man in India. 65 : 1-32.

Ramakrishnan, P.S. 1985b. Research on humid tropical forests. In: Proc. of Regional meeting of the national MAB committees of central and south Asian countries, New Delhi, India, 39 pp.

Ramakrishnan, P.S. 1985c. Jhum cultivation-Prospects for developing countries, Science, Technology and Development (ICSU - COSTED), 9: 1-3.

Ramakrishnan, P.S. 1987a. Role of tree architecture in agroforestry. In: Agroforestry for rural needs (eds. Khosla, P.K., and Khurana, D.K.), Indian Soc. Tree Scientists. Solan, India. Vol-I, 112-131.

Ramakrishnan, P.S. 1987b. Energy flows and shifting cultivation. In: Rural Energy Planning for the Indian Himalaya. Eds. Kumar, T.M.V. and Ahuja, D.R. Wiley- Eastern, New Delhi, pp. 247-276.

Ramakrishnan, P.S. and Toky, O.P. 1981. Soil nutrient status of hill agro-ecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India. Plant Soil, 60, 41-64.

Ranjhan, S.K. 1977 (2nd edition) Animal Nutrition and Feeding Practices in India. Vikas Publishing House New Delhi, pp 350.

Rappaport, R.A. 1968. Pigs for the Ancestors : Ritual in the Ecology of a New Guinea People. New Haven: Yale University Press.

Rappaport, R.A. 1971. The flow of energy in an agricultural society. Sci. Am., 225, 116-122, 127-132.

Raven, P. 1976. The destruction of the tropics. Frontiers, 40, 22-23.

Raven, P.H. 1981. Tropical rain forests : a global responsibility. Natural History, 90, 28-32.

Rea'tegui, R.R. 1979. Development of integrated agricultural,livestock and forestry production systems in tropical peru. In: Proc. Workshop Agro-forestry Systems in Latin America, 91-100 (ed. G. De las Salas) Turrialba, Costa Rice : CATIE.

Reid, J.T. 1973. Potentials for improving production efficiency of dairy and beef cattle. Proc. 21st A. Mtg. Agric. Res. Inst. Natn. Acad. Sci, pp. 87-100.

Revelle, R. 1976. Energy use in rural India. Science 192, 969-975.

Ruthenberg, H., 1967. Organisationsformen der Bodennutzung and Viehhaltung in den Tropen and Subtropen, dargestellt an ausgewahlten Beispielen. In: Blançkenberg, P.Von and Cremer, H.D. (eds) Handbuch der Lanwirtschaft in den Entwicklungslandern, Vol. I. Stuttgart, German Federal Republic; Eugen Ulmer. 122-208.

Ruthenberg, H. 1976. Farming systems in the tropics, 2nd edn., Oxford, U.K. : Clarendon Press 366 pp.

Rosswall, T. and Paustian, K. 1984. Cycling of nitrogen in modern agricultural systems. Plant and soil 76, 3-21.

Sahu, S.D. 1978. Energy requirement for some selected cultural practices in a hilly region of Meghalaya. M. Tech. Thesis, Dept of Agric. Energy, I.I.T., Kharagpur.

Sanger, C 1977. Trees for People. Ottawa: International Development Research Centre. Publications I.D.R.C. - 094 e.

Sauer, C.O. 1965. Cultural factors in plant domestication in the New World Euphytica, 14, 301-306.

Saxena, K.G. and Ramakrishnan, P.S. 1984. Herbaceous vegetation development and weed potential in slash and burn agriculture (Jhum) in north-eastern India. Weed Res. 24, 135-142.

Schlippe, P. de 1956. Shifting cultivation in Africa. Routledge and Kegan Paul, London. 304 pp.

Schultz, T.W. 1964. Transforming traditional agriculture New Haven, Conn, Yale University Press, 212 pp.

Schwanitz, F. 1966. The origin of cultivated plants. Harvard University Press, Cambridge, Massachusetts.

Singh, M.K.R. 1979. Forest destruction in Asia and South Pacific. Ambio, 8, 192-201.

Singh, J.& Ramakrishnan, P.S. 1982a. Structure and function of a sub-tropical humid forest of Meghalaya. II. Litter dynomics and nutrient cycling. Proc. Indian Acad. Sci. (Plant Sciences), 91, 255-268.

Singh, J. and Ramakrishnan, P.S. 1982b. Structure and function of a sub-tropical humid forest of Meghalaya III. Nutrient flow through water. Proc. Indian Acad. Sci. (Plant Sci.) 3, 269-280.

Smith, R.L. 1974. Ecology and field biology. 2nd. Harper and Row, New York, 850 pp.

Spedding, C.R.W. 1975. The study of agricultural ecosystems pp 3-19. In: G.E. Dalton (ed.) Study of Agricultural systems. Applied Sci. Publ. London, England, XIV + 441 pp.

Spedding, C.R.W. 1982. The comparative economics of agricultural systems. In: Energy and Effort (ed. Harrison G.A. & Francis, T.) London Symposium for study of Human Biology, Vol. 22, pp 305-317.

Spedding, C.R.W. and Walshingam, J.M. 1976. The production and use of energy in agriculture. Journ. Agric. Econ. 27, 19-30.

▲→

Suarez de Castro, F. & Rodriguez, A. 1955a. Organic matter equilibria, in coffee plantations. Natl. Coffee growers Assoc. Tec. Bull. Colombia, 2, 5-28 (In Spanish).

Surez de Castro, F.& Rodriguez, A. 1955b. Nutrient losses by erosion as affected by different plant covers and soil conservation practices. Natl. Coffee Growers Assoc. Teah. Bull. Colombia. 2, 1-24 (In Spanish).

Sundarraj, T.S.P. and Mitchell, R. 1987. Analysis of ecosystem structure and energy flow in a south Indian village. In: A multi-disciplinary approach to renewable energy in developing countries (eds. Hitzhusen, Horizons, Inc. Columbus, Ohio. 141-165.

*Swank, W.T. & Henderson, G.S. 1976. Atmospheric input of some cations and anions to forest systems in North Carolina and Tennessee. Water Resour. Res., 541-556.

▲ See in next page

Swamy, P.S. 1986. Eco-physiological and demographic studies of weeds of successional environments after slash and burn agriculture in north-eastern India. Ph.D. thesis, North-Eastern Hill University, Shillong. 270 pp.

Swamy, P.S. & Ramakrishnan, P.S. 1987a. Nutrient budget under slash and burn agriculture (Jhum) with different weeding regimes in north-eastern India. II. Nitrogen and phosphorus. in press. Acta Oecologica/ Oecologia applicata.

Swamy, P.S. & Ramakrishnan, P.S. 1987b. Nutrient budget under slash and burn agriculture (Jhum) with different weeding regimes in north-eastern India. II. Potassium, calcium and magnesium. Acta Oecologica/Oecologia applicata. in press.

* →

Stark, N. 1971. Nutrient cycling I. Nutrient distribution in some Amazonian soils. Trop. Ecol., 12: 25-50

Steggerda, M. 1941. Maya Indians of Yucatan. Washington, D.C. Carnegie Institution of Washington. Publication No. 531.

Stewart, G.C. 1987. Inter-relations between agriculture and forestry in the uplands of scotland: A forestry view. Scottish Forestry, 32, 153-181.

Steinhart, J.S. and Steinhart, C.E. 1974. Energy use in the U.S. food system, science, 184, 307-316.

Stout, B.A., Myers, C.A., Hurand, A and Faidley, L.W. 1979. Energy for World Agriculture. F A O Agriculture Series No. 7. 286 pp

Stromgaard, P. 1984. The immediate effect of burning and ash fertilization. Plant Soil, 80, 307-320.

Toky, O.P. and Ramakrishnan, P.S. 1981a. Cropping and yields in agricultural systems of the north-eastern hill region of India. Agro-Ecosystems, 7: 11-25.

Toky, O.P. and Ramakrishnan, P.S. 1981b. Run-off and infiltration losses related to shifting agriculture in north-eastern India. Environ. Conserv. 8: 313-321.

* see on back page

Toky, O.P. & Ramakrishnan, P.S. 1982. A comparative study of the energy budget of hill agro-ecosystems with emphasis on the slash and burn system (Jhum) at lower elevations of north-eastern India. Agricultural System, 9, 143-154.

Toky, O.P. & Ramakrishnan, P.S. 1983a. Forest wealth of the north-eastern India and its conservation. In: The vegetational wealth of the Himalayas (ed. Paliwal, G.S.), Delhi, 422-432.

Toky, O.P. and Ramakrishnan, P.S. 1983b. Secondary succession following slash and burn agriculture in north-eastern India. II. Nutrient cycling: J. Ecol., 747-757.

Tripathi, R.S. 1977. Weed problem-an ecological perspective. Tropical Ecol., 18: 138-148.

Tripathi, S.D. 1963. Fish as a byproduct of paddy cultivation. India Livestk., 1, 53-54.

Tukey, J.B. Jr., Tukey, H.B. and Wittwer, S.H. 1958. Loss of nutrients by foliage leaching as determined by radioisotopes. Proc. Am. Soc. Hortic. Sci., 71, 496-506.

Tukey, H.B. Jr. & Amling, H.J. 1958. Leaching of foliage by rain and dew as an explanation of differences in the nutrients composition of greenhouse and field grown plants. Mic. Quart. Bull., 40, 876-881.

Ucko, P.J. & Dimbleby (eds.) 1969. The domestication and exploitation of plants and animals. Duckworth, London.

Uhl, C. & Murphy, P. 1981. A comparision of productivities and energy values between slash and burn agriculture and secondary succession in the Upper Rio Negro region of the Amazon Basin, Agro-Ecosystems. 7, 63-83.

UNESCO, 1978. Tropical forest-ecosystems. A state of knowledge report prepared by UNESCO/FAO/UNEP. Natural Resources Research, XIV, UNESCO, Paris, 683 pp.

Vandemaele, F.P. 1977. The role of animal production in world agriculture. Wld. Anim. Rev. 21, 2-5.

Voigt, G.K. 1960. Distribution of rainfall under forest stands. For. Sci., 6, 210.

Walter, H. 1971. Ecology of tropical and subtropical vegetation. Van Nostrand Reinhold Company, New York, 539 pp.

Walters, R.F. 1971. Shifting cultivation Latin America. FAO Forestry Development Paper No. 17, FAO. Rome, 305 pp.

Watson, G.A. 1983. Development of mixed tree and food crop systems in the humid tropics : A response to population pressure and de-forestation. Expl. Agric., 19, 311-332 pp.

Weaver, P. 1980. Agri- silviculture in Tropical America. Unasylva, 21, 2-12.

Wedin, W.F.,Hodgson, M.J. & Jacobson, N.L. 1975. Utilising plant and animal resources in producing human food. J. Anim. Sci., 41, 667-685.

Wells, C.G. 1971. Effects of prescribed burning on soil chemical properties and nutrient availability. pp. 86-97. In: Prescribed Burning Symposium, USDA For. Ser. south-eastern for. Expt. Stn, Asheville, NC, USA: 160 pp - illustr.

Wiersum K.F. 1980. Possibilities of use and development of indigenous agro-forestry systems of sustained land use in Java. Tropical Ecology & Development, 515-521.

Will, G.M. 1955. Removal of mineral nutrients from tree canopies by rain. Nature, 176, 1180.

Will, G.M. 1959. Nutrient return in litter and rainfall under some exotic conifer stands in New Zealand. New Zealand Journal of agriculture research, 2, 719-734.

Wilson, P.N. & Brigstocke, T.D.A. 1980 Energy usage in British agriculture. A review of future propects. Agriculture Systems, 5, 51-70.

Zeuner, D.E. 1963. A history of domesticated animals. Harper and Row. New York.

Zinke, P.J. , Sabhasri, S. and Kunstadter, P. 1978. Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation. In: Farmers in the Forest (ed. P. Kunstadter, E.C., Chapman and S. Sabhasri). East-West Centre, Hanululu, Hawaii.

PLATES

Cash crop plantation introduced by the Governmental agencies in Meghalaya in north-east India.

Plate 1 a. A general view of coffee plantation
b. Coffee bears ready for plucking.

II a. A general view of the tea plantation.
b. Plucking of tea leaves by the female labourers.

III


Ia


Ib

IIa


IIb

Cash crop plantation traditionally grown by the khasis in Meghalaya in north-east India.

Plate III a. Mixed cropping of pine apple with *Colocasia antiquorum*, *Curcuma longa* and *Manihot esculentus*.

b. A mature pineapple plant with frunit ready for harvest.

IV a. Ginger cultivation on terraces.

b. Ginger ready for sale in the local market.

IV


III a


III b


IV a


IV b

Plate V. Wet cultivation of rice done by the Apatanis in the valleys of Arunachal Pradesh, in north-east India.

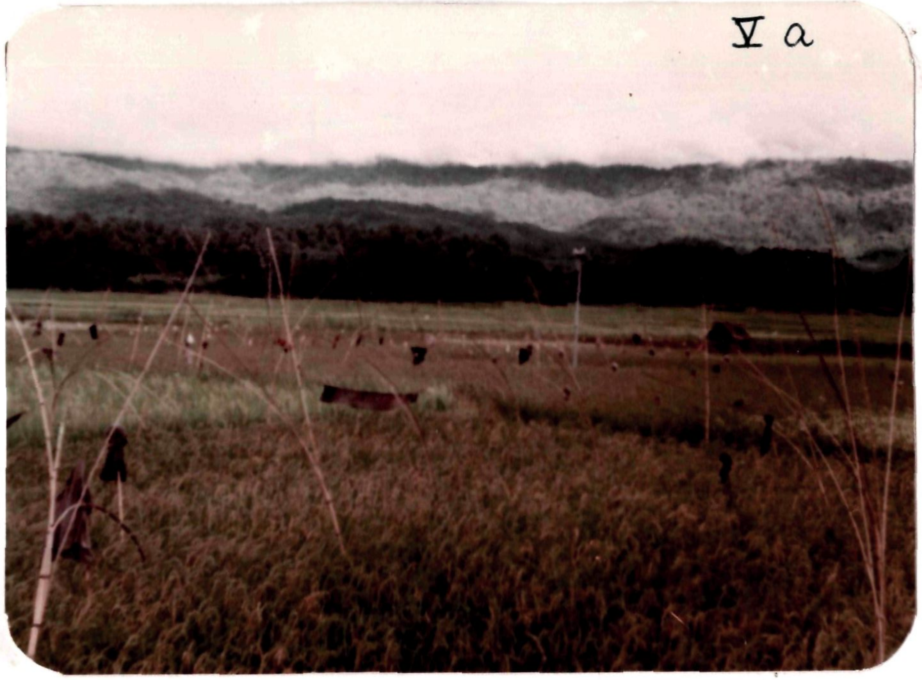
a. An early var (in the foreground) and a late var. (at the back) of rice are cultivated by due Apatanis.

b. <u>Eleusine</u> <u>coracana</u> cultivated on bunds reparating two rice plots.

c. Harvesting of rice by the Apatanis.

d. Fish collected from rice plots in the integrated farming system of the Apatanis.

V


V a


V b


V c


V d

Plate VI. Animal husbandry of the Apatanis of Arunachal Pradesh, in north-east India.

a. Mithun (*Bos frontalis*): a prized animal of many tribes in the region.

b. Swine husbandry: an integral component in traditional societies.

VI

VI a

VI b

Plate VII. Different aspects of the Apatani village ecosystem functions of the Arunachal Pradesh, in north-east India.

a. Bamboo gardens maintained by the Apatanis around rice plots.

b. A view of the Apatani village.

c. Bamboo being prepared for house construction.

d. Bamboo baskets being prepared by an Apatani couple.

VII


VII a


VII b


VII c


VII d

Plate VIII. Dependency upon forest resource by the hill Miris of Arunachal Pradesh, in north-east India.

a. Shifting agriculture (Jhum) with mixed cropping with *Zea mays*, *Oryza sativa*, *Eleusine coracana* & *Musa sapientum*.

b. Fuelwood extraction in an important activity of this tribe.

c. Skulls of the animals hunted by this community being exhibited in the hut.

d. Forest degradation around the village as a result of varied human activities.

VIII

VIII a

VIII b

VIII c

VIII d

[redacted] [redacted] [redacted] [redacted]

Plate IX. Aspects of the village ecosystem functions of the hill Miris of Arunachal Pradesh, in north-east India.

a. A typical hut of the hill Miri Note-the hollowed out tree trunk used to keep pig feed, outside the hut. Bamboo baskets used for bringing hunted animals from the forests are exhibited outside the hut to indicate the hunting ability of the family.

b. The hill Miris use open stoves for drinking the local bear.

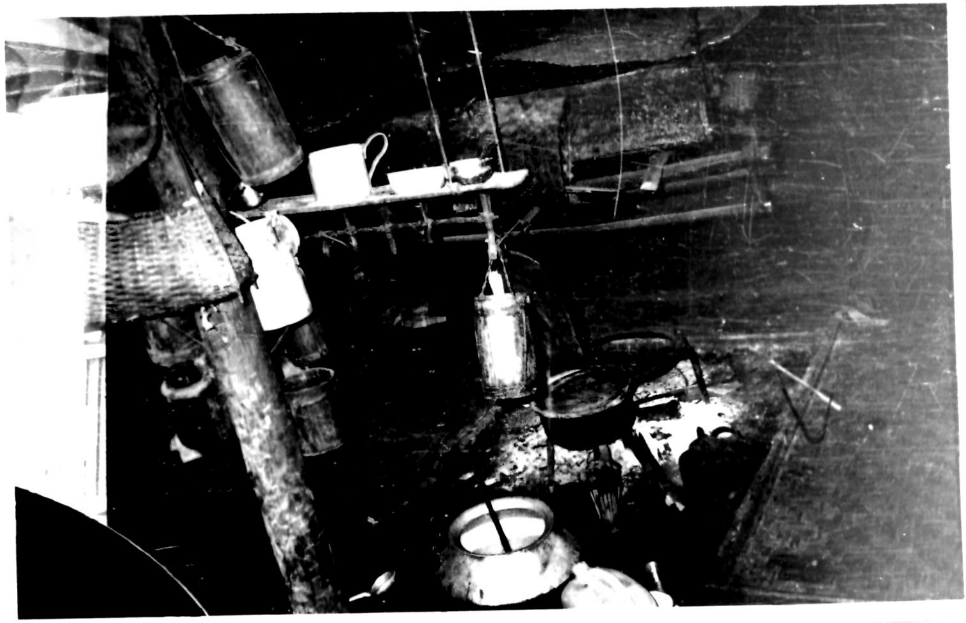
c. A hill Miri lady bringing fuelwood from the forest and a young boy with bow and arrow used for hunting.

d. A young hill Miri couple standing out in the village.

IX.

IX a

IX b



IX c

IX d