Proc. Indian Acad. Sci. (Plant Sci.) Vol. 99, No. 3, June 1989, pp. 199–210.

Ecosystem function in a Khasi village of the desertified Cherrapunji area in northeast India

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MS received 25 March 1988; revised 2 March 1989

Abstract. Village ecosystem function of the Khasis in Meghalaya was studied. The land has been desertified around Cherrapunji as the traditional slash and burn agriculture (jhum) has been replaced by plantation systems. Apart from mixed plantations with areca nut, orange, jackfruit, bay leaf, black pepper and betel leaf, broom grass, thatch grass and bamboo are also raised in the village. All the systems generally are economically viable and have a high energy efficiency with labour as the major input. Poultry and swine husbandry are two animal husbandry systems in the village. Both are largely detritus based. About 9% of the produce from mixed areca nut plantation, 50% from the bamboo and entire produce of thatch grass is utilized within the village and the rest is exported. In the absence of agriculture much of the food for consumption is imported from outside the village boundary. The possibility of further useful changes needs evaluation with scientific inputs.

Keywords. Animal husbandry; desertification in humid tropics; plantation; slash and burn agriculture; village ecosystem.

1. Introduction

Traditionally, slash and burn agriculture (jhum) is the chief land use in the hill areas of northeast India. With rapid increase in population pressure in the recent past the overall length of the jhum cycle (the length of the fallow period between two successive croppings on the same site) has been brought down to about 4–5 years in the region. Where the cycle length has come down to less than 4 years, jhum is often replaced with a fallow system of agriculture (FAO/SIDA 1974) in which the burning operation of jhum is eliminated (Gangwar and Ramakrishnan 1987). This new system causes more rapid desertification of the landscape (Ramakrishnan 1985a) due to rapid depletion of soil fertility such that the fallow/sedentary agricultural systems often become uneconomic. Under fallow systems of agriculture the fallow growth is only herbaceous vegetation which in just ploughed back into the system. Plantation crops have been suggested as an alternative to slash and burn agriculture (Ruthenberg 1971; Andreae 1980; Watson 1983; Boonkird *et al* 1984; Akachuku 1985) in the humid tropics and recently in northeast India too (Ramakrishnan 1985b).

The present study is intended to evaluate the organization and function of a village ecosystem under a plantation economy, considering land use, animal husbandry and domestic sub-systems. Such an evaluation offers possibilities for designing strategies for development of the village considering plantation crops as an alternative to jhum in northeast India. With adverse modifications in the slash and burn agricultural system all over the world (Clarke 1976; Gross *et al* 1979; Arnason *et al* 1982; Nair 1984) this study could have implications for developing alternative land use cropping programmes elsewhere in the humid tropics too.

2. Study area

The village of Tynriang (table 1) (25°N, 92°E) is located 80 km southeast of Shillong at an elevation of 1150 m. The area is highly desertified (Khiewtam 1986; Ram 1986) except for small patches of sacred grove forests that are protected by the local people for religious reasons. The annual average rainfall is 1037 cm which may go up to 2456 cm in an exceptional year as in 1974. The climate is typically monsoonic with about 96% of the annual rainfall occurring between May–October. The mean monthly maximum and minimum temperatures during this period are 24 and 14°C respectively. November–February are winter months, February being a relatively dry period. The mean monthly maximum and minimum temperatures during the winter are 17 and 6°C respectively. The brief dry summer of March–April has mean monthly maximum and minimum temperatures of 20 and 12°C respectively.

3. Description of plantation systems

Nurseries of bay leaf (*Cinnamomum obtusifolium* Nees), betel nut (*Areca catechu* L.), orange (*Citrus sinensis* (L.) Osbeck) and jackfruit (*Artocarpus heterophyllus* Lam.) trees are raised separately by seed. Four-year old tree saplings are transplanted in May before the onset of monsoon on land prepared earlier. Betel leaf (*Piper betle* L.) and black pepper (*Piper nigrum* L.) vines are introduced directly around the tree saplings, two years after transplantation. During the first 6 years (before the tree plantations mature) banana (*Musa sapientum* L.), pineapple (*Ananas comosus* (L.) Merrill) and sweet potato (*Ipomoea batatas* (L.) Lam.) are cultivated. Weeding is done twice every year until the plantation is established. The trees are pruned during the winter. Harvest of bay leaf, betel nut and orange starts 6 years after transplantation whereas black pepper and betel leaf are harvested two years after planting. Since black pepper and betel leaf yield only for a period of about 7 and 15 years respectively, at such times old vines are removed and replaced by young vines. Harvesting of black pepper occurs in April, jackfruit in May–June, orange in

Table 1. Village ecosystem structure of a Khasi village at Tynriang (1986–87).

Number of households	34
Total human population	190
Adult male	74
Adult female	64
Children 9–12 years old	21
Children 7–9 years old	15
Children 5–7 years old	11
Area under cultivation (ha)	
Mixed tree plantation	54
Broom grass pure	17
Broom grass + bay leaf	17
Thatch grass	8·5
Bamboo	8·5
Animal population	
Pigs	105
Poultry	340

November–December and betel nut and bay leaf in December–February; betel leaves are harvested 3 times in May, September and December.

Broom grass (*Thysanoleana maxima* (Roxb.) Kuntze), used in broom making, an early successional grass (Saxena and Ramakrishnan 1983) is planted in fallow lands during May–June. Harvesting is done at yearly intervals for a period of about 7 years. Subsequently, the grass is burnt and replanted. Weeding is done once or twice a year.

Bamboo (*Dendrocalamus hamiltonii* Nees and Arn.), used for house construction, basket making and for export is planted using rhizomes in May and harvested selectively first after 6 years and subsequently at yearly intervals, for about 25 years.

Thatch grass (*Imperata cylindrica* Beauv.), used in hut construction, grows wild as a secondary successional weed. Transplantation is done only in free spaces to cover the ground.

4. Methods of study

Plots with mixed areca nut plantation, broom grass, broom grass mixed with bay leaf, thatch grass and bamboo were selected under similar topography and aspect conditions with 3 replicate plots of each category. Crop density in mixed areca nut plantation was measured using fifteen 10×10 m quadrats for trees and fifteen 1×1 m quadrats for ground level crops such as sweet potato, pineapple and banana. Economic yield per plant of each species was determined as an average of 15 randomly selected individuals from each replicate plot. Rupees equivalent of economic yield was calculated on the basis of the prevailing market prices.

The input of energy through seeds was calculated on the basis of the total energy expended to produce that fraction of crop yield. Total food energy consumed by the people was apportioned to each activity (Leach 1976) according to relative duration of sedentary, moderate or heavy work. Per hour average energy expenditure was assumed to be 0·418 MJ for sedentary work, 0·488 MJ for moderate work and 0·679 MJ for heavy work for an adult Indian male and 0·331 MJ for sedentary work, 0·383 MJ for moderate work and 0·523 MJ for heavy work for an adult Indian female (Gopalan *et al* 1985). Sedentary, moderate and heavy work was determined by personal observations depending upon the labour required. For calculating the output of energy, the total economic yield of various crops was converted into MJ of energy by multiplying with standard energy values of the crop products (table 2). A general value of 18·9 for organic materials (Odum 1975; Mitchell 1979) was used to compute the energy output of bamboo and broom grass.

The estimation of food/fodder consumed by the animals is partly based on the daily ration given to them. To this was added energy input values through scavenging calculated by assuming that the energy equivalent of this would be equal to the value obtained after subtracting the energy value of the actual feed consumed (based on our observations) from the standard food energy requirement of the animals: pig 20–30 kg (13·9 MJ) and 10–20 kg (14·7 MJ) per day and 11·1, 10·6 and 11·5 MJ per day for the poultry birds of 0–8 weeks, 8–20 weeks and the egg layers respectively since energy needs differ with age (Ranjhan 1977).

For an estimation of meat production, the weight gained by each category of animal at the time of slaughter was calculated and the values obtained were corrected using a dressing percentage of 75 and 70 for pig and poultry respectively

Table 2. Energy value of crop products and manures considered in the study (dry weight basis).

	Energy MJ kg^{-1}
Heat of combustion	
Areca catechu	15·16
Cinnamomum obtusifolium	16·80
Citrus sinensis	16·83
Artocarpus heterophyllus	15·42
Piper betle	12·33
Piper nigrum	14·21
Musa sapientum	22·14
Ananas comosus	16·08
Ipomoea batatas	16·26
Organic material	18·90
Fuelwood	19·77
Replacement cost	
Pig dung	1·32
Fowl dung	2·00
Production cost	
N	76·99
P_2O_5	13·95
k_2O	9·67

Percentage of N, P_2O_5 and K_2O was 1·5, 1·4, and 1·2 respectively in pig dung and 2·2, 0·8, and 1·97 respectively in fowl dung.

Table 3. Energy and protein equivalents of the food items consumed in a Khasi village ecosystem.

	Moisture content (%)	Energy (MJ kg^{-1})	Protein (g kg^{-1})
Rice	11·4	16·23	83·2
Pulses	11·1	17·10	240·0
Vegetables	80·2	2·55	45·9
Pork	77·5	17·11	187·2
Chicken	72·3	4·50	260·0
Egg	73·7	7·33	500·0
Fish	74·2	5·41	223·0

(Ranjhan 1977). Output of secondary production was calculated using energy values of different meat items (table 3).

To compute the energy content of juveniles of pigs and poultry their average body weight, based on 5 observations, was multiplied by the energy values of meat of that animal following Brody (1945). The quantity of dung production was based on observations over a 24 h period at different times of the year and is based on observations of 10 animals of each category.

Observations on energy flow through the village are based on 20 randomly selected families in the village. Production/consumption calculations for humans were done after calculating total consumption units (adult man value) for the whole village based on energy consumption scale suggested by Gopalan *et al* (1985): one adult male, .1 unit; one adult female, 0·9 unit; children aged 9–12 years, 7–9 years and 5–7 years, 0·8, 0·7 and 0·6 units respectively. Total consumption units in the village worked out to be 170. Nutritive values of the food items consumed were corrected to the heat of combustion by multiplying with the coefficient 1·129 (Mitchell 1979). Items such as clothes, medicine and utensils were excluded from the study due to difficulties in assigning energy values for them.

Labour charge for male and female workers were calculated based on prevailing daily wage rates of Rs 20 and 15 respectively. The monetary output/input for different items are based on prevailing market prices. Efficiency of the plantations and animal husbandry systems were calculated as the output per unit of money or energy invested into the system.

5. Results and discussion

Though slash and burn agriculture (jhum) is the traditional land use of the Khasis of Meghalaya (Mishra and Ramakrishnan 1981, 1982), and their staple diet is rice and fish, the people living in Tynriang close to Cherrapunji have largely abandoned this land use system because of large scale desertification that has occurred (Ramakrishnan *et al* 1981; Ramakrishnan 1985b; Ram 1986). The shift towards a plantation economy is a consequence of irreversible environmental damage to the fragile humid forest ecosystem represented only through sacred groves maintained and protected for religious reasons (Boojh and Ramakrishnan 1983; Khiewtam 1986).

A. catechu had the highest density (11·1/100 m^2) amongst trees followed by *C. obtusifolium* (6/100 m^2) and *C. sinensis* (2·3/100 m^2). Land preparation, raising of tree saplings in the nursery and their transplantation resulted in an initial expenditure of Rs 11481 per hectare. During the first 6 years, labour input for weeding particularly was heavy (table 4). In the first 6 years, banana, pineapple and sweet potato together gave a net return which was less than the yearly cost for maintenance.

From the seventh year onwards when the tree plantation was established the output per year increased sharply (table 5). Weeding cost declined in older

Table 4. Cost-benefit analysis of a mixed tree plantation of the Khasis during the early 6 years of establishment.

Production measure	Rs ha^{-1} yr^{-1}
Input total	7120 ± 550
Seed	270
Planting	340
Weeding	5250
Harvesting	480
Transportation	780
Output total	5178 ± 445
Ananas comosus	2050
Ipomoea batatas	1048
Musa sapientum	2080
Net return	− 1942
Output/input ratio	0·7

± SE of the mean.

plantations. From an output/input ratio of 0·7 (exclusive of initial cost) during the first 6 years, the efficiency value increased to 1·8. In older plantations *A. catechu* gave the highest monetary output.

Labour is the chief input into the plantation system. In mixed tree plantations, older than 6 years, males do more of labour-intensive activities such as girdling, harvesting and transportation (figure 1). Females play a major role in weeding.

Broom grass which is an early successional weed species (Saxena and Ramakrishnan 1983) is grown after burning the plot of land. Some sprouts of this grass may arise from underground rhizomes present on the site and a closed cover is established through transplantation from adjoining areas. The yield of broom grass increased with the age of the plantation up to 3 years and stabilized in the

Table 5. Cost-benefit analysis of an established mixed tree plantation of the Khasis.

Production measure	Rs ha^{-1} yr^{-1}
Input total	13093 ± 972
Pruning/girdling	380
Weeding	3500
Harvesting	6443
Transportation	2150
Storage	620
Output total	23155 ± 1463
Areca catechu	12750
Artocarpus heterophyllus	1238
Citrus sinensis	1617
Piper nigrum	1350
Cinnamomum obtusifolium	4680
Piper betle	1520
Net return	10062
Output/input ratio	1·8

± SE of the mean.

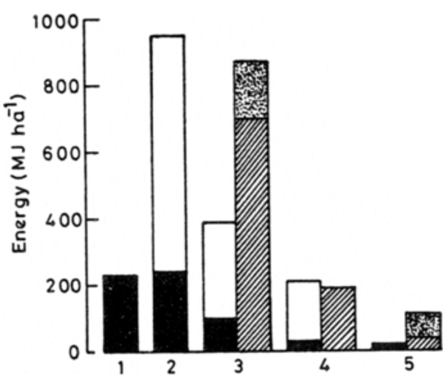

Figure 1. Distribution of male and female labour from within the family and imported from outside for various activities under an established mixed tree plantation of the Khasis in northeast India. (1) Pruning and girdling; (2) weeding; (3) harvesting; (4) transportation; (5) storage. (■), Male from within; (□), female from within; (▩), male imported; (▨), female imported.

subsequent 3–7 years (table 6). Though the yield of the grass in plantations of *C. obtusifolium* was slightly lower, the leaf of *C. obtusifolium* was an additional item harvested and, therefore, the total economic returns per hectare was higher. The input for various operations under pure and mixed cultivation of broom grass decreased with the age of grass plantation and monetary output increased. Monetary output was generally higher under mixed plantation compared to the pure one, and therefore mixed system is more advantageous. Broom grass mixed with bay leaf plantation is more energy efficient than broom grass cultivated alone. The lower efficiency of the broom grass system is because here only the upper portion of the shoot with the mature inflorescence is harvested and not the entire biomass.

Bamboo and thatch grass are additional early successional species (Toky and Ramakrishnan 1983) cultivated in the village. Monetary returns from bamboo plantation is higher compared to thatch grass harvest per hectare (table 7). However, the monetary efficiency of bamboo is lower than that of thatch grass, because of higher labour input for the former.

With labour as the only input into all the land use systems, the energy efficiencies are high (figure 2). With a fast growth rate for bamboo (Rao and Ramakrishnan 1988) and a large biomass the energy efficiency of this plantation is the highest. Thatch grass has a higher energy efficiency than broom grass.

Poultry and swine husbandry are two animal husbandry systems of the Khasis in this village (table 8). Both these systems are largely detritus based (Rappaport 1971; Mishra and Ramakrishnan 1982; Gangwar and Ramakrishnan 1987). Swine husbandry is economically more efficient than poultry. If labour, which is contributed by the family itself is excluded, the efficiency of these two systems would be much higher.

Whereas swine husbandry is based on human labour, waste food arising from domestic sector and scavenging by the animals themselves, the poultry is partly fed on grains purchased from the market (figure 3). The energy efficiency of swine husbandry is somewhat higher than that of poultry if all inputs and outputs are considered. When free inputs of feed are excluded, the energy efficiency of swine husbandry increased to 4 times more than that of poultry.

As the village is based upon a plantation economy, agricultural produce is imported (table 9). Only a small fraction of plantation produce is consumed within the village. All of the bay leaf and broom grass produce is exported. However, the entire output from the animal husbandry is consumed within the village. Inspite of substantial import of food items along with other commodities, the net gain to the village was substantial.

Fish and rice form the staple diet of the village community (table 10). The energy consumption compared favourably with the standard requirement whereas protein intake is almost double the standard needs worked out for India (Gopalan *et al* 1985).

The fuelwood requirements are met from the plantation systems; 63% from mixed plantation, 26% from bamboo and 11% from others. The total consumption in the village was 61×10^4 kg (1210×10^3 MJ) which was higher than 978×10^3 MJ which is the standard requirement (Mitchell 1979). The low fuelwood use efficiency for the Khasis is due to the use of stoves that are less energy efficient. In this highly desertified environment it is important, therefore, to consider introduction of energy

Table 6. Monetary output/input ratio (Rs ha^{-1} yr^{-1} mean ± SE) of a broom grass pure and broom grass mixed with bay leaf plantation of different age groups of the Khasis.

	Pure			Mixed[a]		
	1 yr	2 yr	3–7 yr	1 yr	2 yr	3–7 yr
Total input	4670 ± 275	3930 ± 220	3870 ± 245	4995 ± 325	3886 ± 255	3303 ± 292
Clearing and burning	340	—	—	340	—	—
Transplantation[b]	1350	—	—	1040	—	—
Weeding and maintenance	1740	1740	870	1652	1652	826
Harvesting and transportation	1240	2190	3000	1963	2234	2477
Total output	3348 ± 275	5913 ± 524	8100 ± 745	6474 ± 481	7935 ± 621	9250 ± 756
	(620 ± 51)	(1095 ± 97)	(1500 ± 138)	(390 ± 22)	(660 ± 48)	(904 ± 73)
Net return	− 1322	1983	4230	1479	4049	5947
Output/input ratio	0·72	1·50	2·09	1·30	2·04	2·80

Values in parentheses represent dry weight economic yield (kg ha^{-1} yr^{-1} mean ± SE) of broom grass.
[a]Bay leaf yield worth Rs 4368 (1820 ± 151 kg) was obtained.
[b]The cost of bay leaf plantation has not been included.

Table 7. Monetary output/input ratio (Rs ha^{-1} yr^{-1} mean ± SE) of a thatch grass and bamboo plantations of the Khasis.

	Thatch grass	Bamboo
Input (total)	1716 ± 125	3695 ± 242
Maintenance	180	270
Harvesting	720	2055
Transportation	816	1370
Output (total)	3827 ± 260	6850 ± 408
	(4133 ± 280)	(14385 ± 850)
Net return	2121	3155
Output/input ratio	2·23	1·85

Values in parentheses are the economic yield (dry wt. kg ha^{-1} yr^{-1}).

efficient stoves for cooking in order to conserve fuelwood. For plantations, there are many traditional multiple cropping systems available in the humid tropics (Harwood and Price 1976; Watson 1983; Mitchell 1984) on which it could be based. All the systems emphasize trees, that produce fruits, nuts and timber, and vines such as *Piper* spp. and even a middle storey of shrubs. The advantage of these homesteads is that they are based on the concept of vertical organization of crops that optimize production. The plantation system discussed here is much simpler than the more complex home gardens described by Mitchell (1984) from south India and similar systems from northeast India itself (Maikhuri 1987). Obviously there is scope for diversification of the crop mixture in a system of this kind.

In the absence of agriculture, the pigs scavenge on domestic waste alone including human faeces. Therefore, productivity of the animal husbandry system is low. The village being easily accessible by road, plantation economy is sustainable, as the produce could be exported easily. The closeness of the village to the Bangladesh border facilitates exchange of the produce from the plantation crops for fish on a barter basis. Unlike, other tribal villages located in areas rich in forest

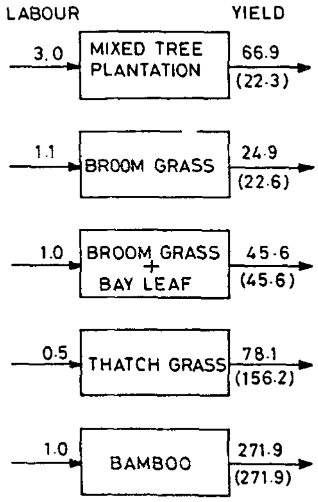

Figure 2. Energy (MJ × 10^3 ha^{-1} yr^{-1}) output/input pattern of various plantation systems of the Khasis in northeast India.

Table 8. Annual monetary output/input pattern (Rs × 10^3 yr^{-1} mean ± SE) into the animal husbandry of a Khasi village.

Input/output	Swine husbandry	Poultry
Input (total)	40·0 ± 3	34·8 ± 2
Feed	—	11·2
Labour	46·5	23·3
Juveniles	2·5	0·3
Output (total)	30·6 ± 2	6·9 ± 0·4
Meat	28·1	4·9
Eggs	—	1·7
Juveniles	2·5	0·3
Output/input ratio	0·6	0·2
	(12·2)	(0·6)

Values in parentheses are when labour which is met from within the family is excluded.

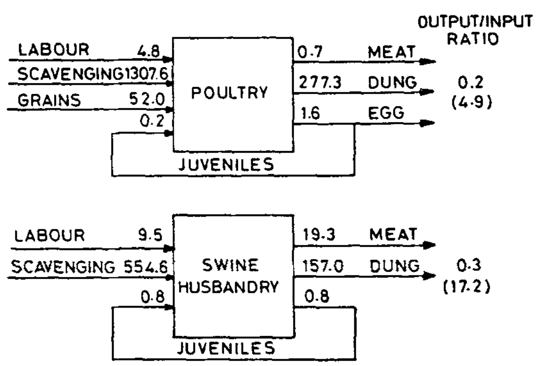

Figure 3. Energy (MJ × 10^3 yr^{-1}) output/input pattern into animal husbandry systems in a Khasi village in northeast India. Values in parentheses are when free inputs of feed are excluded.

Table 9. Production, export and import (Rs yr^{-1}) in a Khasi village.

Export/import	Rs yr^{-1}
Production (total)	726812
Mixed areca nut plantation	543348
Bay leaf + broom grass	52972
Broom grass	85646
Thatch grass	18028
Bamboo	26818
Animal husbandry	34421
Export (total)	577441
Mixed areca nut plantation	425414
Bay leaf + broom grass	52972
Broom grass	85646
Thatch grass	—
Bamboo	13409
Animal husbandry	—
Import (total)	518692
Rice	92299
Pulses	6868
Vegetables	94640
Fish	166980
Spices	36720
Other foods	40528
Masticatories	2040
Kerosene oil	4284
Clothes	34000
Medicine	4250
Transport	19584
Others	17000
Net gain (export-import)	58749

Table 10. Annual food consumption in a Khasi village.

Category	Quantity (kg)	Energy (MJ) equivalent	Protein (kg) equivalent
Rice	26371 ± 572	428001	2194·1
Pulses	1241 ± 18	21221	297·8
Vegetables	18165 ± 468	47468	854·4
Pork	1117 ± 32	19112	209·1
Chicken	124 ± 5	558	32·2
Egg	186 ± 7	1363	93·0
Fish	11107 ± 441	60089	2532·4
Others	—	50385	—
Total		625197 (623106)	6213·0 (3412·8)

Values in parentheses are standard requirements.
± SE of the mean.

resources (Gangwar and Ramakrishnan 1987; Maikhuri 1987) where agriculture, animal husbandry and domestic sectors are closely interlinked and provide self-sufficiency, this village of the Khasis studied here though economically stable is to a very large extent dependent upon imports from outside the village boundary

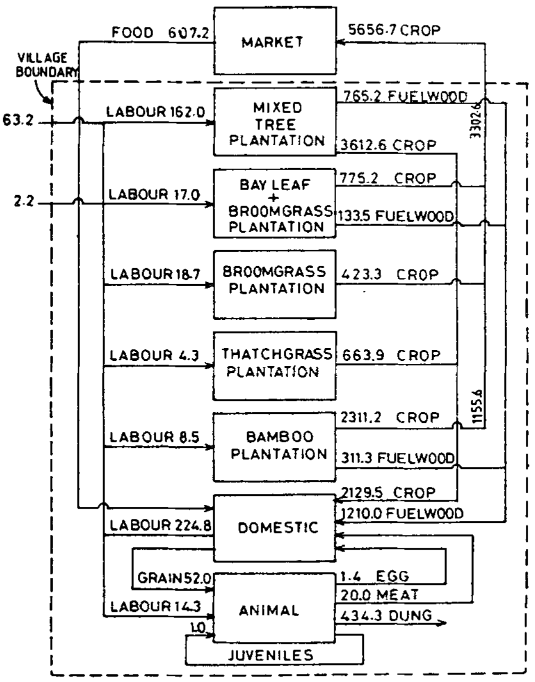

Figure 4. Annual energy flow through various sub-systems of the village ecosystem and market in a Khasi village in northeast India. Unit MJ × 10^3.

(figure 4). From a developmental point of view, this study suggests possibilities for replacing the traditional jhum system with a plantation economy that would provide a permanent plant cover. With a mixed tree culture of areca nut, orange, bay leaf and jackfruit, the efficiency of mixed plantation system increased through the use of vines such as betel leaf and black pepper in the understorey. The efficiency of this system is further enhanced through the use of species such as banana, pineapple and sweet potato that are cultivated for a short period during the first few years, before the tree plantation itself starts giving economic returns to the farmer. However, such a plantation economy can be sustained only through import of food grains from adjoining areas or from outside the region.

Acknowledgements

This study was supported by the Department of Environment and Forests, New Delhi through a research grant and was completed at the Centre for Eco-Development, North-Eastern Hill University, Shillong.

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