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The science behind rotational bush fallow agriculture system (jhum)

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Abstract. Rotational bush fallow agriculture variously termed as shifting agriculture, slash and burn agriculture are commonly known in India as *jhum* is a traditional agricultural system of the humid tropics and is extensively practised by the tribes of the north-eastern hill region. There is a renewed interest in this agricultural system as it has so much to offer in terms of concepts and ideas to modern agricultural organization. The science behind jhum is based on intuitive experience of the farmer based on long tradition. This paper looks at the science behind jhum with particular emphasis on the ecological and economic significance of mixed cropping, recycling of resources within the system and between jhum and animal husbandry, the non-weed concept weed potential under different cycles of jhum, and nutrient cycling. The distortions brought about by the shortening of the jhum cycle to 4–5 yr is considered. Alternate strategies for development with jhum as the focal point, with suitable modifications but without the present-day distortions, have been considered.

Keywords. Rotational bush fallow agriculture; jhum; mixed cropping; recycling of resources; animal husbandry; non-weed concept.

1. Introduction

The forest farmer in the humid tropics has managed his traditional rotational bush fallow agricultural system for centuries, with optimum yield on a long term basis, rather than trying to maximize production on a short term basis (Watters 1960; Spencer 1966; Ruthenberg 1976; Soemarwoto 1975; Gleissman *et al* 1981). Forest farming variously termed as 'shifting agriculture', 'slash and burn agriculture', 'rotational bush fallow agriculture' or popularly known as 'jhum' in India is a major activity of the tribal population of the north-east. It is also practised by tribals of Orissa, Madhya Pradesh, Andhra Pradesh, Maharashtra and in peninsular India. That this form of land use has survived up to the present as a viable practice itself suggests that the system is essentially based on sound scientific principles. The ecological basis of these practices has been the subject of intensive study by our group (Toky and Ramakrishnan 1981a, b, 1982, 1983a, b; Ramakrishnan and Toky 1981; Mishra and Ramakrishnan 1981, 1982, 1983a, b, c, d, 1984; Saxena and Ramakrishnan 1984; Ramakrishnan *et al* 1979, 1981a, b). Such a thorough understanding of the ecological processes operating in the traditional agro-ecosystems of the humid tropics could form the basis for the development of a productive system with which the tribal people can identify themselves. Such a strategy could form the basis for providing a varied all-purpose diet with ecological stability in production with efficient use of family labour and recycling of natural resources. This paper looks at the science behind jhum, at the same time highlighting the present-day distortions brought about by the shortening of the jhum cycle (Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan 1981). It further looks at the possibilities of future development of cropping systems with high structural and species diversity, with jhum as the focal point.

2. Multiple cropping

One of the major objectives during cropping under jhum is to capitalize upon the transient resources of the soil and to obtain as high an economic return as possible. One of the ways in which this is achieved by the forest farmer is through multiple cropping. In fact, as many as 30 or more crops are sown together in the jhum plots. In a situation where market economy is either poorly developed or does not exist at all, multiple cropping provides not only an all-purpose diet to the farmer but also meets the need of fibre to some extent. Apart from these considerations, the multiple crop cover protects the soil from nutrient losses through hydrology and also contributes through efficient recycling of resources, aspects which would be considered at length, elsewhere.

2.1 *Cropping pattern at lower elevation jhum*

The jhum at lower elevations of Meghalaya as studied in detail by us (Toky and Ramakrishnan 1981) is typical of that practiced in many parts of the north-eastern region. Here the jhum cycle (the length of the fallow period between two successive croppings) would vary from a more frequent 4–5 yr to 10–30 yr in more remote regions. The average size of the jhum plots cropped by a family of 5 to 7 members may range from 1 to 2·5 ha.

During the winter months (December–January) the undergrowth is slashed and small trees and bamboos are felled. The boles of larger trees are not felled except for the branches. Short stumps of the trees are left in tact and underground organs of different species are not disturbed. These are left behind to have a quick regrowth of the vegetation cover after the plot is fallowed. In fact in parts of Nagaland, for *e.g.*, alder (*Alnus nepalensis*) is grown in jhum fallow plots and is allowed to coppice through stump sprouts. This species apart from being a fast growing one which provides fuel and fodder also is a non-leguminous fixer of nitrogen in the soil. Therefore it helps in quicker build-up of fertility in the soil. The slash and burn operation, being laborious is often done by the farmer on a cooperative basis with mutual help from 2–3 families joined together, with men alone taking active part in this operation. In fact, this co-operative organization of the society is not only evident in sharing of labour but the very manner in which the land is allotted by the village headman to the individual family. It may be worth noting here that private land is non-existent in the traditional rural tribal society and the land belongs to the village community as a whole.

Before the onset of the monsoon, towards the end of March or early April, the dried debris is burnt *in situ* after making a fire line around the field. After repetitive burning to destroy any unburnt material, if necessary, the seed mixtures are sown. The seed mixture used would vary depending upon the jhum cycle. In one study (Toky and Ramakrishnan 1981a), the crop mixture had 8 species under a short cycle of 5 yr and up to 13 species under a long cycle of 30 yr (table 1). All the species are sown together in the same plot. Cereals form the major component under longer cycles whereas perennials and tuber crops are emphasized under short jhum cycles. Such a shift in emphasis in crop mixtures is significant. Our results (unpublished) suggest that this is related to the nutrient status of the soil. Under short cycles where the soil is relatively infertile compared to longer cycles, the farmer shifts his crop species towards those which have a better nutrient uptake and use efficiency. Such a shift towards perennial crops also give better protective cover to the soil, checking erosive losses more effectively, once the

Table 1. Crops grown and yield in the jhum plots at lower elevations in Meghalaya (after Toky and Ramakrishnan 1981a).

	Total economic yield ($kg\,ha^{-1}\,yr^{-1}$)		
	30 yr	10 yr	5 yr
Grain and seed			
Oryza sativa	1161	378	66
Sesamum indicum	446	541	25
Zea mays	770	397	30
Setaria italica	193	23	9
Phaseolus mungo	10	—	—
Ricinus communis	5	—	—
	(21046)	(6318)	(753)
Leaf and fruit vegetables			
Hibiscus sabdariffa	44	139	96
Hibiscus esculentus	—	50	—
Capsicum frutescence	—	1	—
Lagenaria lencantha	140	81	—
Cucurbita maxima	62	—	—
Cucumis sativa	16	—	—
Momordica charantia	—	5	—
Musa sapientum	—	105	—
	(657)	(5679)	(16182)
Tuber and rhizomes			
Manihat esculenta	338	1352	690
Colocacia antiquorum	260	294	180
Zingiber officianalis	10	—	—
	(1043)	(2712)	(1556)
Silk worm			
Cocoon (silk)	4	—	—
Pupae (without cocoon)	0·2	—	—

In parenthesis is given total plant biomass ($kg\,ha^{-1}\,yr^{-1}$)

cover is established. Besides, the shift towards tuber crops also provide higher crop yield and better economic returns to the farmer than when put under agro-ecosystem with emphasis on cereals. This is evident when one compares a 5 yr jhum cycle under lower elevation where cereals form an important component, to potato cultivation at higher elevations in Meghalaya. The shift towards potato cropping at higher elevations is thus in accordance with the shift towards tuber crops under low nutrient status in the soil. The high elevation soils, apart from being highly leached are also acidic and are developed under pine forest cover of a temperate climate which itself retards quick fallow regrowth and the consequent fertility recovery. More about these aspects are discussed below.

Seeds of pulses, cucurbits, vegetables and cereals like *Sataria italica* are mixed with dry soil from the sites to ensure their uniform distribution and broadcast. Maize seeds are dibbled at regular intervals amongst the crops. Rice is also dibbled at regular intervals. If one considers the hill slope, even the placement of the crop along the slope gradient is such that cereals are in the middle and lower parts of the slope while the perennials and tuber crops are emphasized on the top of the slope. Such a placement pattern on the slope, apparently, is related to the nutrient status of the soil. This again suggests that in the nutrient poorer top portion of the hill slope, for *e.g.* the emphasis is on tuber and perennial crops, whereas in the nutrient richer lower part of the slope, cereals like rice are emphasized. This aspect of the crop placement pattern on a plot which not only considers nutritional requirements such as uptake and use efficiencies but also leaf area index related to optimizing photosynthesis by the crop mixtures is currently receiving attention.

Apart from meeting the cereal and tuber crop needs of the farmer, the jhum system also meets to some extent the protein needs through legumes (figure 1). The leaves of *Ricinus communis* are used for rearing young silk worm caterpillars. Older caterpillars may be fed upon the leaves of other dicot trees left on the plot. Plots after slash and burn is used only for one year unless a garden of banana or pineapple is maintained after the first year of cropping.

2.2 *Cropping pattern at high elevation potato based modified jhum*

At higher elevations in Meghalaya, where we have done much of our studies on the modified jhum, the temperature is low, soil is highly acidic and the pine tree litter are difficult to decompose and release their nutrients faster into the soil and fallow regeneration is relatively slower. For these reasons, the farmer has modified his jhum to suit local conditions (Mishra and Ramakrishnan 1981). To start with the pine trees are sparsely scattered with much undergrowth. The undergrowth is completely slashed but only a few of the lower branches of the trees are lopped. These then are arranged in parallel rows, allowed to dry and then topped over with a thin soil layer before resorting to a more controlled burn. The cropping is done on these ridges while the furrows are compacted, running in parallel alternate rows down the slope (figure 2).

The main emphasis here is on potato along with other tuber crops such as *Ipomoea batatas* and *Colocasia antiquorum*. Some cereals like *Zea mays* and legume (*Phaseolus vulgaris*) and a few cucurbits (*Cucurbita maxima* and *Cucumis sativus*) are also sown. When a second crop is done, after the harvest of the first crop during the monsoon, the winter crop is potato alone. The emphasis on potato alone during a second cropping in the same year is perhaps related to reduced soil fertility. While under longer jhum cycles as many as 9 crop species are included, under a short 5 yr cycle only 2–3 crops of which potato is important along with *Zea mays* and *Brassica oleracea* are emphasized. Again, this reduction in the number of crop species under shorter jhum cycles is related to reduced soil fertility and increased weed problem, an aspect discussed in detail subsequently. The reduced soil fertility under shorter jhum cycles is partly compensated by the farmer with either pig dung or vegetable manure under a 10 yr cycle at the rate of 600 kg ha^{-1} yr^{-1} (oven dry wt) or with an additional supplement of NPK, 1:1:1 at the rate of 10 kg ha^{-1} yr^{-1} along with 1000 kg ha^{-1} yr^{-1} of organic manure or even more in the second year.

2.3 *Significance of multiple cropping*

As discussed earlier an important consideration in multiple cropping is related to optimal use of nutrient resources in the soil by appropriate changes in crop mixtures or

Figure 1. A close view of the mixed cropping under jhum at lower elevation of Meghalaya with tapioca, maize, colocacia, legume and cucurbit species.

Figure 2. Modified jhum at higher elevation of Meghalaya with emphasis on potato which is being harvested. Maize crop is standing. Note the ridges and furrows running down the slope.

by manipulation of their placement, with a shift to tuber and perennial crops either with shortening of the jhum cycle or in those portions of the plot where fertility is likely to be low due to the steep gradient (20–40° angle). A high leaf area index obtained helps in checking run-off losses of sediment and nutrients after the crop cover is established. The high leaf area index also helps in optimization of photosynthesis through increased active leaf surface area and thus maximize crop yield.

A high species diversity of many tropical ecosystems (Whittaker 1965, 1972) has been considered an important factor in the stability of these natural ecosystem types (Odum 1969; Woodwell and Smith 1969; Mellinger and McNaughton 1975). Such a stability in the agricultural production system of jhum is achieved by the tribal farmer through a high species diversity in his agro-ecosystem. Apart from the fact that under a transient environment of the steep slopes of the humid tropics, such a high species diversity with a multi-layered crop canopy above would help in efficient capture of light energy and a multi-layered root mass distribution below the soil would help in optimal use of nutrient from throughout the soil profile, there are other implications of this in terms of production efficiency. Crops being sown more or less at the same time but being harvested sequentially over a long time period (table 2), provide more space for the remaining species to grow when they are at their peak growth period.

A characteristic feature of the jhum agro-ecosystem is the high rate of biomass accumulation within the system in relation to economic output (table 1). This could be up to about 18000 kg ha^{-1} yr^{-1} of total biomass under 30 yr and 5 yr cycles, the high biomass under the latter being chiefly due to the shift in emphasis towards tuber and vegetable crops. The actual economic yield component in comparison to this is only about 3500 kg ha^{-1} yr^{-1} under a 30 yr cycle and about 1600 kg ha^{-1} yr^{-1} under a 5 yr cycle with a fractional economic yield of 1/5 to 1/11 of the total biomass. Such a high organic matter production which is in agreement with the range of 16 to 22 t ha^{-1} dry weight given by Whittaker (1975) is thought to play an important part in the long term stability of the system (Sanchez 1976). With higher crop diversity, it should be possible to combine the need for increased harvestable food portion with the need for maintaining high organic biomass content in the system as a whole (Trenbath 1974). Without this organic matter production it would become necessary to constantly import costly inorganic fertilizers which are hard to come by and whose effectiveness in the face of high temperature and heavy rainfall is questionable (Gleissman 1980; Gleissman *et al* 1981; Ramakrishnan *et al* 1981a, b), particularly when the soil is extremely porous contributing to heavy infiltration losses even when the land is terraced (Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a). The sequential harvest of crops would provide organic manure to the remaining crop species through efficient recycling of this important resource. The amount of nitrogen ploughed back as by-products into the system during cropping amounts to 0·6 to 0·8 kg depending upon the jhum cycle, at higher elevations of Meghalaya as shown (table 3) in one of our nitrogen budget studies (Mishra and Ramakrishnan 1984). Under a 15 yr cycle this amounts to 1/6th of the total of 4·1 kg ha^{-1} yr^{-1} non-edible biomass which goes into the system either directly or through the manure pit in the village (Mishra and Ramakrishnan 1982).

Mixed cropping as practised in this traditional agro-ecosystem is receiving considerable attention of modern agricultural scientists as a biological pest-suppressant (Litsinger and Moody 1976). The use of native varieties would probably ensure that a high degree of natural chemical defences are maintained (Janzen 1973).

Table 2. Sequential harvesting of crops on jhum plots under 30 year cycle at lower elevation of Meghalaya (after Ramakrishnan *et al* 1981a).

Species	Harvesting time
Setaria italica	Mid-July
Zea mays	Mid-July
Oryza sativa	Early September
Lagenaria spp.	"
Cucumis sativa	"
Zingiber officianalis	Early October
Sesamum indicum	"
Phaseolus mungo	"
Cucurbita spp.	Early November
Manihot esculenta	"
Colocasia antiquorum	"
Hibiscus sabdariffa	Early December
Ricinus communis	(Perennial crop)

All the seeds were sown in April.

Table 3. Nitrogen input:output budget (kg $ha^{-1} yr^{-1}$) for different jhum systems (after Mishra and Ramakrishnan 1984).

	Fallow cycle (yr)			
			5	
	15	10	I yr crop	II yr crop
Inputs				
Precipitation	3·6	3·6	3·6	3·6
Slash	43·6	18·6	29·3	—
Organic manure	—	8·4	14·0	25·9
Inorganic fertilizer	—	—	0·7	1·4
Weed ploughed back	0·8	2·6	3·5	3·4
By-products ploughed back	0·8	0·6	0·6	0·3
Total	48·8	53·8	51·7	34·6
Outputs				
Fire	510·2	462·1	262·8	—
Sediment	119·1	128·5	172·9	176·3
Run-off	13·0	8·2	8·9	10·0
Percolation	0·9	0·5	0·8	0·7
Weed removal	4·0	13·0	17·3	16·8
Total	690·5	643·6	482·4	213·5
Net difference	641·7	589·8	430·7	178·9

Dash represents absence of that input/output from the system.

Gleissman *et al* (1981) have considered the use of native varieties for management of modular production units based on the traditional agricultural systems of the Campesinos of the lowland tropical region of south-eastern Mexico. Under mixed cropping it is unlikely that any one of the pest populations of insects, fungi, bacteria or nematodes would reach epidemic levels due to high genetic diversity.

3. Yield pattern and socio-economics

A viewpoint commonly expressed, more often not based on data, is that jhum as an agricultural system is unviable on economic considerations compared to settled farming like terracing of the hill slopes. Even where data are available, these do not define the parameters under which these observations are made. In any study of this nature, one ought to specify the jhum cycle, the comparability of plots under consideration, the various inputs that go into the system particularly in the form of organic and inorganic manures that go into the terrace system and even the conversion factors used while expressing mixed crop yield as yield of rice or monetary returns. This confusion regarding crop yield also exists for agro-ecosystems in north-east India. In fact the rice yield under jhum was shown to be as low as 190 kg ha^{-1} (Borthakur *et al* 1978) to a high value of 1200 kg ha^{-1} (Misra 1976). Therefore the data on jhum yield at lower elevations (Toky and Ramakrishnan 1981a) and at higher elevations (Mishra and Ramakrishnan 1981) under the different jhum cycles and their comparison with sedentary valley cultivation and the terraces under comparable conditions gives an objective assessment of the yield returns. For the sake of comparisons only the monetary returns from the different systems are presented here though actual yield data are available (table 4).

One of the important conclusions of these studies is that the returns to the farmer is higher under a 10 yr jhum cycle or longer cycles compared to terrace cropping. While jhum is scientifically sound from the point of yield returns, the present-day problems are related to the distortion in the system due to shortening of jhum cycle to 4–5 yr. This apart, the quality of input into terrace is different. While the jhum system is exclusively labour-oriented which is in a way free to the farmer as it originates from

Table 4. Monetary input-output (Rs $ha^{-1} yr^{-1}$) into jhum, terrace and valley agro-ecosystems (after Toky and Ramakrishnan 1981a).

	Jhum (yr)				Valley
	30	10	5	Terrace	Crops I and II
Input	2616	1830	896	2542 (4544)	4843
Output	5586	3354	1690	3658	5565
Net gain/loss	2970	1524	794	1116 (−886)	722
Output/input	213	1·83	1·88	1·43 (0·80)	1·14

within the family unit itself, the input into terrace, atleast a major fraction of it, is in the form of inorganic fertilizers. If land is not a limiting factor a minimum cycle period of 10 yr is viable on economic considerations.

Apart from these, the shift in cropping pattern with shortening of the jhum cycle itself is partly based on economic considerations. Thus, if under a 5 or 10 yr cycles, the crop mixture was not altered towards perennial and tuber crops, the output from the system would have been lower. This may explain why potato cultivation under the high elevation jhum became popular when it was introduced into this region by the British in the early part of this century. Thus, a comparison of data for different jhum cycles under low and high elevations shows the returns to the farmer through emphasis on tuber (potato in this case) is 3–4 times more (table 5). However, I do realize that the comparison is not strictly valid though the broad conclusions are obvious.

Apart from the economics of it, multiple cropping provides an 'insurance policy' to the cultivators because some crops are likely to give a good return even if there is partial or complete failure of other crops. This apart, the farmer manages to get all his diverse requirements in cereals, vegetables and other tuber crops from the same site.

4. Energy efficiency

The increasing agricultural yields of the last half century were possible through industrialization of agriculture, involving large energy subsidies, sophisticated chemical control and high yielding crop varieties. Such agricultural systems are efficient in terms of human time and labour but are highly inefficient from energy viewpoint as 5–10 units of fossil fuel energy are required to produce one unit of food energy (Steinhart and Steinhart 1974). The limitations of such systems as models for development in an energy-limited world have led to renewed scientific interest in traditional systems of agriculture, such as jhum, as offering a greater ecological efficiency. Under jhum, for every unit of energy input which itself is chiefly in the form of human labour 50 or even more units of energy are harvested (Rappaport 1971; Steinhart and Steinhart 1974; Mishra and Ramakrishnan 1981; Toky and Ramakrishnan 1982).

Our studies on the three jhum cycles at lower elevations of Meghalaya (Toky and Ramakrishnan 1982) and at higher elevations of Meghalaya (Mishra and Ramakrishnan 1981) show very high efficiency values compared to sedentary terrace farming. If the cycle is long enough and land is not a limiting factor the input of solar energy to a larger area of the jhum system could offset imported fossil fuel energy which

Table 5. Monetary input-output analysis of jhum under a 10 yr cycle at lower and higher elevations of Meghalaya (after Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan 1981).

	Low elevation jhum	High elevation jhum
Input	1830	3842
Output	3354	14171
Net gain	1524	10329
Output/input	1·83	3·9

would ensure harmony of the system with the environment. Even if one uses a correction factor of 1/30, 1/10 or 1/5 to calculate the effective energy output from the values given in table 6, still a 10 yr jhum cycle would be efficient in terms of energy ratio and land use (Toky and Ramakrishnan 1982). Terrace farming also involves high input of fossil fuel energy, the use efficiency of which is very low in view of heavy infiltration losses from the system (Mishra and Ramakrishnan 1983a).

Keeping the energy efficiency high, the possibilities of increased crop production has been suggested (Greenland 1975; Revelle 1976; Mutsaers *et al* 1981; Gleissman *et al* 1981) without departing too much from the traditional jhum system which has been considered as a highly evolved system for the forested areas of the tropics by many workers (Conklin 1957; Carneiro 1960; Nye and Greenland 1960; Watters 1971). Our own studies tend to confirm this, provided the jhum cycle is kept longer than 10 yr. In a wider context of the Indian agriculture, it should be possible to replace the use of imported chemical fertilizers by local resources based on bio-fertilizers using available manpower more effectively through small scale irrigation projects and so on, to have a stable production system. With a large rural population engaged in agriculture and most of them being small and marginal farmers, more emphasis on agricultural technology based on efficient recycling of natural resources, rather than a major shift to that chiefly based on chemical fertilizers, seems to be more appropriate at this juncture (Toky and Ramakrishnan 1982).

5. The non-weed concept

Weeds are wild plants that grow in highly disturbed sites (Baker 1965) and are considered to be undesirable and adversely interfering with crop yield. Therefore, in modern agriculture, considerable effort has gone into developing technology for controlling them through mechanical, chemical or biological methods. Recently, weeds have been viewed as a useful component in agro-ecosystems and therefore, in future, may play an important role in ecosystem management. Recent studies by Chacon and Gleissman (1982), Saxena and Ramakrishnan (1984) and Mishra and Ramakrishnan (1984) suggest that this 'non-weed' concept is an essential ingredient of traditional rotational bush fallow agro-ecosystems in different parts of the world.

While in many traditional systems, the incomplete removal of weeds from crop-lands may not be a deliberate husbandry practice and it may merely be due to lack of labour and poor returns from the jhum plots, all the same the weeds may be considered as

Table 6. Energy ratios in agricultural systems—jhum, terrace and valley cultivation (after Toky and Ramakrishnan 1982).

Agricultural system	Energy ($MJ\,ha^{-1}\,yr^{-1}$) Input	Output	Output/input ratio
Jhum—30 yr cycle	1665	56766	34·1
Jhum—10 yr cycle	1181	56601	47·9
Jhum—5 yr cycle	510	23858	46·7
Terrace	6509	43602	6·7
	(8003)		(5·4)
Valley—I and II crops	2843	50596	17·8

useful elements in the agro-ecosystem and may often be a consequence of intuitive expertise of the farmer based on long tradition.

In north-eastern India, in the jhum plots, weeding is never total; a considerable proportion of the individuals is left in tact. Our experience with the jhum farmer suggests that he knows how intense should the weeding be so that the weed population does not interfere with the crops and yet the beneficial effects are manifest.

Obviously, one of the important roles of the weeds in the crop-lands is related to reduction in soil erosion, protection of the soil surface from solar radiation and improved soil micro-climate (Chacon and Gleissman 1982). An aspect studied in detail pertains to the role of weeds along with the crop cover in checking soil erosion. This becomes obvious when one looks at the run-off or infiltration loss patterns during the monsoon season which is the cropping period. There is a sharp peaking in the total loss of all nutrients before the plant cover is established. This is illustrated with respect to monthly losses of K, Ca and Mg in figure 3. Along with the crops, the residual weeds play an important role in checking the losses through water after the plant cover is established. The role of weeds in checking run-off and infiltration losses becomes even more dramatic in the reduction in losses of nitrogen, phosphorus and potassium through hydrology in a 5-yr old weed-dominated fallow when compared with the agro-ecosystem types of different jhum cycles (table 7). Obviously, even the exotic weeds like *Eupatorium odoratum* and *Mikania macrantha* along with others have a useful role to play in the jhum systems of the north-east.

Another important positive role of the weed lies in the recycling of the nutrients through organic manure. When the jhum farmer in the north-east does 3 to 4 partial weedings during the cropping season, at lower elevations in Meghalaya, all the weeds

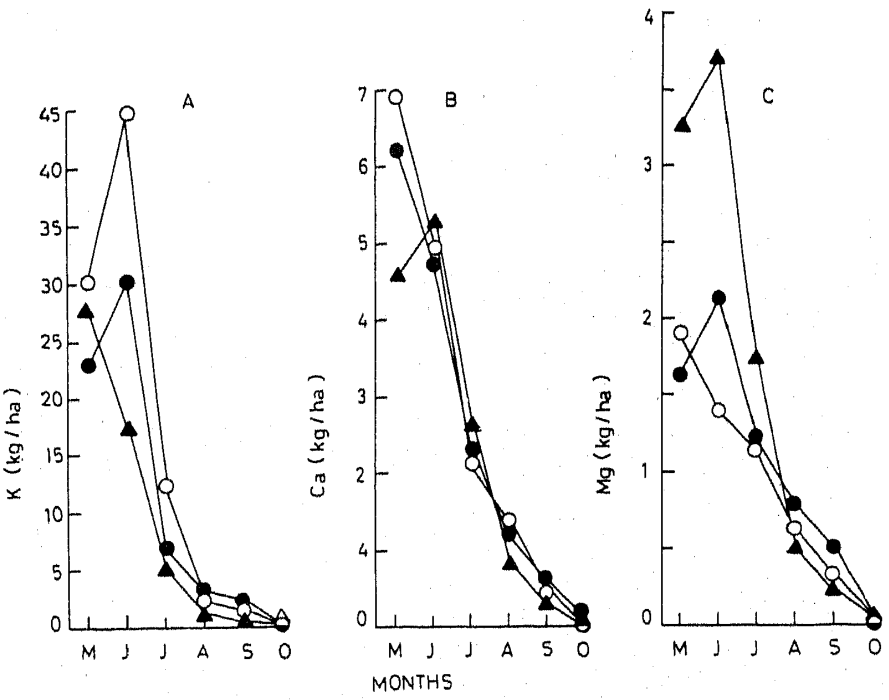

Figure 3. Monthly loss of **A.** potassium, **B.** calcium and **C.** magnesium in run-off water during the monsoon at time of cropping after the burn on sites under 30 (•), 10 (o) and 5 (▲) year jhum cycles (after Toky and Ramakrishnan 1981b).

Table 7. Nutrient losses (kg ha^{-1} yr^{-1}) through run-off and percolation water under 10 yr jhum cycle agroecosystem and a 5 yr fallow (after Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a).

	10 year cycle jhum plot		5 year fallow	
	Run-off	Percolation	Run-off	Percolation
Low elevation jhum:				
Nitrate nitrogen	4·2	10·7	0·8	1·1
Available phosphate	1·3	0·1	0·1	0·02
Potassium	91·2	21·2	0·9	0·5
High elevation jhum:				
Nitrate nitrogen	1·7	0·5	1·0	0·9
Available phosphate	0·9	0·1	ND	ND
Potassium	80·1	25·8	19·6	ND

ND—Not detectable.

removed from the plot are ploughed back into the soil. Table 8 gives the weeds retained in the jhum plots (Swamy and Ramakrishnan, unpublished) along with the crops, at lower elevations in Meghalaya by the Garos. This is in contrast to what a Nepali farmer does. He is not a traditional jhum farmer. At higher elevations in Meghalaya, on the other hand, part of the harvested weed is ploughed back into the plot itself and the rest goes into the compost pit of the village ecosystem (Mishra and Ramakrishnan 1982). The compost from the pit eventually gets back into the jhum plot as organic manure. In fact, the compost pit is an essential component of the Khasi village ecosystem as it also forms an important link with animal husbandry in the form of swine husbandry by providing food for the pigs in the form of crop residues (Mishra and Ramakrishnan 1982).

In a study on the nitrogen budget of three jhum cycles of 15, 10 and 5 yr at higher elevations of Meghalaya, (Mishra and Ramakrishnan 1984) the nitrogen recycled through weeds was estimated to range from 4·8 to 20·8 kg ha^{-1} of which about 1/6th is ploughed back into the soil and the rest is routed eventually *via* the manure pit. This works out to be a good fraction of the total input into the system. It is interesting to note that the actual quantity and contribution of nitrogen through weed as a fraction of the total increased drastically with the shortening of the jhum cycle due to increased weed potential with shortening of the cycle. Not only the input of nitrogen but all other nutrients through the weed component of the jhum agro-ecosystem is significant.

Weeds are also used as a food source. In the Mokokchung District of Nagaland, for *e.g.*, the Naga tribe uses *Gnetum montanum* and *G. gnemon* as an important food resource. Bamboo shoots and wild banana are also consumed. These species are vigorous weeds in the jhum plots. Amongst the other uses, *Imperata cylindrica* is used for thatching of huts while another grass species *Thysalonaema maxima* is used for brooms. A number of plants like *Hedychium* species are also used for medicinal purposes. In fact, in the north-east the weeds associated with jhum plots used for various purposes are many depending upon the location and the tribe involved. Though this aspect of the use of the weed is not *in situ* in the jhum plots, its value in the 'non-weed' concept is significant indeed, though not in the same sense in which it is recognized as part of the agro-ecosystem itself.

Table 8. Use pattern of biomass by the Garos at lower elevations in Meghalaya (after Swamy and Ramakrishnan unpublished).

Jhum cycle (years)	Weeding	Total weed biomass produced (kg-ha)	Weed biomass ploughed back (kg-ha)	Weed biomass retained (kg-ha)
20	1	9357	7110 (76·0)	2247 (24·0)
	2	10180	8257 (81·1)	1923 (18·9)
10	1	8085	6189 (76·5)	1896 (23·5)
	2	8608	6930 (80·5)	1678 (19·5)
5	1	4378	3160 (72·2)	1218 (27·8)
	2	5780	4815 (83·3)	965 (16·7)
	3	4242	3592 (84·7)	650 (15·3)

Percentage values given in parentheses.

Apart from these beneficial effects, weeds around crop areas (Van Emden 1965; Price 1976) or within the plantings (Attleri *et al* 1977; Root 1973) can significantly alter the insect population and the resultant damage on the crop. Gárcia (1980) has considered the role of weeds in the control of soil pathogens while Gleissman and Garcia (1979) have considered the possibility of controlling one weed by another.

The role of weeds in nutrient conservation, nutrient recycling and fertility recovery of the tropical traditional agricultural systems such as jhum in the north-east along with many-fold positive roles of weeds in tropical agriculture opens up a new area of agro-ecological studies. This in turn would make it possible to have a greater degree of integrated management capability (Chácon and Gleissman 1982), a capability already well-developed by the jhum farmer in the north-east India and their counterparts elsewhere. This is not to underestimate the negative role of weeds in crop production, particularly with shortening of the jhum cycle due to increased weed potential (figure 4). Though larger biomass of weeds removed from plots under shorter jhum cycles are recycled as organic manure, the weeds do pose a problem resulting in reduced yield under shorter cycles. The ingenuity of the jhum farmer lies in his ability to distinguish the 'weed' and the 'non-weed' status of the same species or set of species in his jhum plot, depending upon the intensity of the weed population in relation to the crops.

6. Why swine husbandry part of the jhum system?

Swine husbandry is an integral part of the jhum system (Mishra and Ramakrishnan 1982) and is also part of the rotational bush fallow agriculture in many parts of the world. Thus the Tsembaga farmer raises pigs to be eaten but such consumption involves religious beliefs and practices (Rappaport 1971). In fact the tribal farmer of the north-east India consumes pigs not only as part of his normal diet but makes a feast of it during celebrations related to the jhum procedures. Again the main reason why swine husbandry is part of the jhum system is because of its inexpensive maintenance costs. It is one animal husbandry practice, in the traditional sense, which is so much inter-linked with the jhum agricultural sub-system and yet makes so little demand on it.

This animal husbandry practice is based on (i) efficient recycling of resources with a

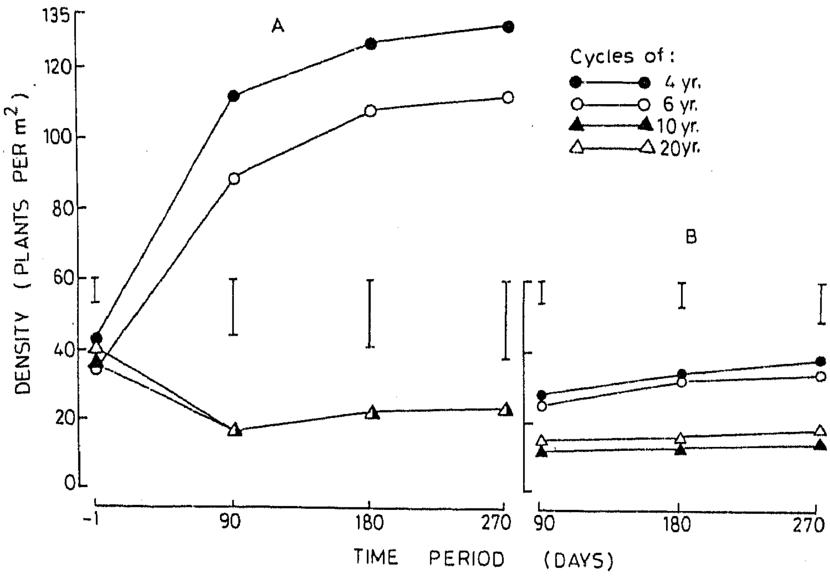

Figure 4. Density of herbaceous weeds under different jhum cycles **A.** uncropped sites; **B.** cropped sites; −1, a day before slashing the vegetation, 90, 180, 270 are the days of fallow development following the burn. Vertical lines represents LSD ($P = 0{\cdot}01$) (after Saxena and Ramakrishnan 1984).

reasonable level of energy efficiency, two basic principles on which the operation of the jhum system itself is anchored. In a study of the animal husbandry sub-system of a Khasi village ecosystem of 20 members (Mishra and Ramakrishnan 1982), a major fraction of the total energy input is the feed, crops accounting for about 4·9 % while the crop residues plus grazing accounting for the rest of the input. Meat and dung are important outputs from the system. The output: input ratio is low if by-products and grazing are included but higher if they are excluded (figure 5).

About 70 % of the protein consumption by this Khasi village community is of plant origin, the rest being contributed by pork. While rice (*Oryza sativa*) coming out of the jhum sub-system and valley sub-system along with *Zea mays* accounted for about 70 % of the total food energy consumed, pork provided about 13 % of the total food energy consumed (table 9).

With an energy expenditure of $18{\cdot}8 \times 10^6$ MJ over a 10 yr period for raising a single pig under Tsembaga system in the New Guinea Highlands (Rappaport 1971) and with only 1·5 % of return on the food energy feed to pig meat energy according to the calculations of Pimental and Pimental (1979), this system is not very efficient though a practical way of storing excess food energy. However the efficiency of the system in the north-east India is better as the demands are lighter on the farmer. Here the animals are dependent upon crop residues, cheap feeds such as poor quality tubers which are unfit for human consumption and on browsing. Further slaughter of pigs every year rather than once in 10 yr as in Tsembaga markedly bring down the rearing costs. In short, this is one animal husbandry practice which is in harmony with the jhum system.

7. Why not terracing?

The significance of jhum as a land use in the humid tropics cannot be appreciated without a brief mention on the alternatives tried out for the tribal farmer. We have seen

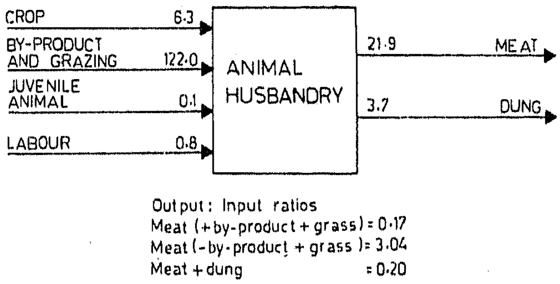

Figure 5. Energy input: output pattern and efficiency ratios for animal husbandry sub-system of a Khasi village ecosystem (after Mishra and Ramakrishnan 1982).

Table 9. Annual food and protein consumption in a Khasi village ecosystem in Meghalaya (after Mishra and Ramakrishnan 1982).

Category	Food		Protein
	Quantity (kg)	Energy equivalent (MJ)	equivalent (kg)
Solanum tuberosum	88·96	1288	4·16
Colocasia antiquorum	43·30	629	4·23
Ipomoea batatus	360·00	5965	15·59
Zea mays	342·80	5685	44·02
Oryza sativa	2567·00	42538	213·57
Phaseolus vulgaris	10·78	169	2·55
Cucurbita maxima	28·00	430	6·00
Pork	112·50	8560	93·49
Total		65264 (67383)	383·61 (321·20)

Values in parentheses are the standard requirements.

from the preceding discussions that terracing is not a viable alternative to jhum. Apart from the fact that infiltration losses are heavy (Mishra and Ramakrishnan 1983a) particularly with respect to nitrogen and phosphorus (for cations it is not so much as the slash and burn system has a heavier load of cations arising out of the ash and this is not true for terraces where burning is not done), the fertility depletions are very rapid as was observed during the second year of terrace cropping of the same site (Mishra and Ramakrishnan 1983b). In fact, the physical and chemical qualities of the soil gets so much adversely altered that the farmer very often has to leave the terrace plots after 6–8 yr of continuous cropping, as the land becomes totally desertified. In fact, our extensive observations in this region suggest that the terraces are also gradually eaten away from the periphery and that maintenance costs for these are heavy, apart from the input need for heavy dose of inorganic fertilizers which are expensive and are in short supply. Besides, the weed potential under terrace cultivation gets intensified when compared to a 10 yr jhum cycle in the same area, adversely affecting crop returns (Mishra and Ramakrishnan 1981). While valley cultivation of rice is tenable on both economic and ecologic considerations as water and nutrients are high, as the valleys form a sink for what comes through hill slopes (Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan 1981), the terraces maintained closer to the valleys are viable for longer durations; it is not unlikely as we have observed in this region for such terraces closer to the valleys eventually to grade into the valley lands. On the other hand, three-tier model of ICAR, (Singh 1981) where the top portion of the hill slope is suggested for forest cover, the mid-portion for plantation/horticultural crops and the lower part for terraces, seems scientifically sound. However, we feel that apart from problems related to maintenance costs for terraces as viable units, the model is completely divorced from the social organization of the tribal society and may not be acceptable to the farmer in the foreseeable future.

8. Is jhum unavoidable?

A major concern of the jhum farmer has been to obtain his diverse food needs in terms of cereals, legumes, vegetables and tubers from the same plot. This becomes important for the tribal farmer because of the inaccessible terrain, cost of transportation and uncertainty of a regular and assured supply and absence of a well-developed market economy. Ideally, one would perhaps wish to avoid all forms of cereal cultivation or annual crops on the hill slopes and confine it and intensify it only in the valley lands; cultivation along the hill slopes is restricted to horticultural and plantation crops of various species for which this area is ideally suited. Such a strategy of diverting the economy would permit a permanent plant cover along the hill slopes with forestry and forestry based produces as another major supplement to the economy. If this is done, then the cereals like rice and other crops may have to be heavily supplemented by import from outside the region. Needless to emphasize here that valley system could be intensified in terms of crop varieties and number of croppings and in many other ways by improved agricultural technology.

If cereal cultivation along the hill slopes cannot be completely done away with, considering the social organization of the community and considering that jhum is a highly evolved system of land use for the humid tropics, one could consider as to how the jhum cycle can be extended to a reasonably longer time period. One could argue that the longer the cycle the better it is from the point of view of ecology and even economics. Our own extensive studies discussed in the earlier pages suggest that a 10 yr cycle is the minimum that should be attempted on both ecologic and economic considerations. We have considered economic considerations earlier. Here, perhaps a brief discussion on the ecological aspect of it in terms of environment may not be out of place.

One of the important events that occur after slash and burn is that there is a rapid depletion particularly nitrogen due to volatalization (Ramakrishnan and Toky 1981; Mishra and Ramakrishnan 1983b; Mishra and Ramakrishnan 1984) which within a few months recovers due to rapid nitrification related to higher pH and temperature on the soil surface (Ahlgren and Ahlgren 1965) and removal of allelopathic inhibitors (Smith *et al* 1968). Perhaps, under certain conditions, there could be a heavy loss of phosphorus too after the burn (Lloyd 1971; Mishra and Ramakrishnan 1983b) though there is no obvious mechanism for volatalization of this important element. However recovery occurs over a short time period during cropping. All the cations like potassium, calcium and magnesium are released in one flush after the burn. During cropping, losses occur through run-off and infiltration of water. Losses also occur due to crop removal. The total budget for one of the important elements, nitrogen, is given elsewhere (cf table 3).

After cropping, further losses of nutrients from the soil pool occur through rapid uptake and removal by the developing vegetation. The recovery process for nutrients in the soil occurs only beyond 5 to 10 yr old fallow stage (figure 6) as shown here for the high elevation jhum (Mishra and Ramakrishnan 1983b) and also observed for the low elevation system (Ramakrishnan and Toky 1981). On this consideration too continuous imposition of jhum of shorter duration than 10 yr would adversely affect the soil fertility recovery.

Another ecologic consideration for a minimum of 10 yr cycle is related to secondary successional processes and the related vegetation development. During the first 5–6 yr of fallow regrowth, the community is dominated by herbaceous weeds and subsequently by larger shrubs, bamboos and trees (Toky and Ramakrishnan 1983a, b; Mishra and Ramakrishnan 1983c, d). Our demographic analysis of weed populations (Ramakrishnan and Mishra 1981; Kushwaha *et al* 1981, 1983) suggest that these weedy species get biologically eliminated during succession after 5 to 6 yr due to change in micro-environmental conditions particularly due to reduced light available for these

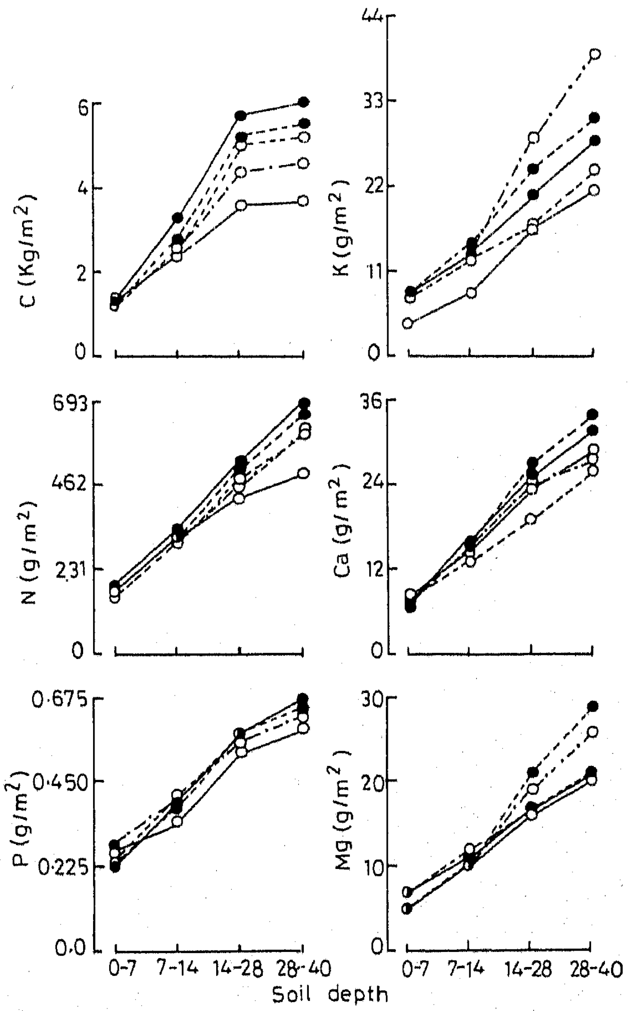

Figure 6. Changes in cumulative quantity of various nutrients (within a soil profile of 40 cm depth) during the various stages of fallow development (o—·—·—o, 0 year; o——o, 1 year; o---o, 5 year; •——•, 10 year; •---•, 15 year jhum fallow (after Mishra and Ramakrishnan 1983b)).

light demanders (Kushwaha and Ramakrishnan 1982). If the succession is not allowed to proceed beyond the 5–6 yr stage due to a shortened jhum cycle and if successive shorter cycles are imposed the succession would be arrested at the weed stage resulting in takeover of large tracts of the hill areas by weeds with consequent problems of conservation of a variety of wild germplasm of this region, which is already happening in many areas (Ramakrishnan 1984a). Therefore a jhum cycle longer than 10 yr with sufficient land area under a forest cover would ensure ecological viability.

9. Developmental strategies

With greater emphasis on valley cultivation by introducing more modern agricultural practices by way of improved varieties of crops of shorter duration of growth, one could have 2 to 3 harvests from the same site, with suitable rotation. If the pressure on the land for jhum is diverted towards a horticultural or plantation economy with village as the unit for development, then a co-operative system could be developed. One to 2 ha plot for each family for this purpose, with a number of families and contiguous village being involved on a co-operative basis—the basis which is already available in the tribal society could form viable economic plantation unit of a 100 ha or more. Fast-growing native species in small plots in the village could meet the fuelwood needs of the village community which is getting scarcer (Mishra and Ramakrishnan 1982; Ramakrishnan 1984b). Apart from a wide variety of tropical temperate fruit trees, the area is also suited for coffee, tea and rubber plantations. The possibilities are unlimited.

With such a diversion of the economy, the jhum cycle would automatically get to 10 yr or longer. Having thus increased the length of the jhum cycle, one could now think of introducing innovations into the jhum system itself at the same time retaining all the positive points associated with this traditional agricultural technology. Thus in jhum fallow plots, *e.g.* species such as *Alnus nepalensis* or legumes could be introduced which would improve soil fertility, help in quick fallow regrowth and supplement fuelwood needs, which the traditional jhum provides to the farmer to some extent. Modern agricultural technology, on the other hand, would only perhaps lead to an ever-increasing dependance on imported food products, poorer nutrition and environmental degradation, yet without achieving the production levels originally proposed, as has happened in the lowland tropical region of south-eastern Mexico (Gleissman *et al* 1981).

By having a shelter belt of forest and fruit tree species along the boundary it should be possible to check some of the losses from the jhum system through wind blow of ash during the burning season (Toky and Ramakrishnan 1981b) and also check losses through hydrology, at the same time meeting the needs of the farmer for food and fuel wood. In any land-use modification, two important social considerations that should be reconciled are: (i) that the tribal is an independent person by nature and (ii) that in spite of his being independent he works on a cooperative basis within the village sharing labour and land through the village headman, but as equal partners of the village system.

Animal husbandry in the form of swine husbandry provides much scope for development on more modern lines with better breeds. Poultry is another traditional activity of the tribal which could be better organized. These could meet the animal protein needs of the local population and could even be exported outside the village boundary.

All these activities of a primary nature would necessitate generation of village-based low-level technology for semi-processing, atleast of the primary produce before transportation to city centres for further refinement. The low level technology could also be directed to conservation of resources within the village through better energy use for cooking or through bio-gas technology, improving upon the manure pit which is an important component in many village systems (Mishra and Ramakrishnan 1982).

The jhum farmer has always closely linked his food production system with the forests. Conservation of natural forests could be through well-planned agro-forestry and social forestry programmes designed for the village unit using native species. Further, mixed forestry systems could be developed for reclaiming damaged sites, using native tree species. Our extensive work on tree growth strategies and architecture (Ramakrishnan *et al* 1982; Boojh and Ramakrishnan 1982a, b, c, 1983; Ramakrishnan and Shukla 1982; Shukla and Ramakrishnan 1984a, b, c) is directed towards a basis for such a strategy for forest development in north-eastern India.

The major deficiency in the developmental strategy design for the tribals of the humid tropics of the north-east has been that scientists, planners and administrators have tried to impose from outside what they have considered to be good for the people of the area without trying to understand the processes that operate in the traditional ecological systems. Any developmental strategy for the future should have to be based on an understanding of the ecological processes operating in the traditional village ecosystem and with which the local people can identify. This should incorporate the empirical knowledge associated with traditional systems such as jhum.

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