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Evaluating second year cropping on jhum fallows in Mizoram, north-eastern India: Energy and economic efficiencies

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Abstract. Energy and economic efficiencies were evaluated on young (6 year) and old (20 year) jhum fields in Mizoram, north-eastern India during second year of cropping, and were compared with those in the first year. The effect of auxiliary measures such as tilling the soil or application of fertilizers (chemical or farm-yard manure or both in combination) was also examined on energy and economic efficiencies. The results indicated that traditional jhum cultivation is labour intensive and energy efficient, producing almost 15-20 times of energy invested. Energy and economic efficiencies decline with shortening of jhum cycle. These efficiencies decline further from first to second year of cropping. Tilling is not useful to improve either energy or economic efficiency. Fertilizer application, which is though profitable from the point of view of economic efficiency, is highly energy inefficient. Application of fertilizers during second year cropping can be encouraged. Organic manuring may be a better option than others to alleviate energy efficiency. However, a combination of organic and inorgamic manuring could be the best option to enhance economic efficiency.

Keywords. Jhum; energy efficiency; economic efficiency; fertilizer application; farm-yard manure; rice cultivation,

1. Introduction

In an earlier paper of this series of investigations (Tawnenga *et al* 1996), we have monitored phytomass dynamics and primary productivity as an indicator of the ecological efficiency on young (6 year) and old (20 year) jhum fields to ascertain whether second year cropping is recommendable. It was concluded that the second year cropping causes a decline in ecosystem productivity in old jhum field, but not in young jhum field. Further, economic yield from second year cropping in its traditional form is not much lower than that in first year, and can be improved by manuring the soil. Tilling of soil did neither improve ecosystem productivity nor economic yield. Different fertilization treatments responded differently; while inorganic manuring had greater impact on ecosystem productivity, a combination of inorganic and organic manuring was more suitable to improve economic yield.

The assessment of feasibility of second year cropping on jhum lands from the ecosystem perspective alone may not be admissible to the farmer. For the farmer, jhum is an economic activity as he aims at the material benefits. He cannot risk the grain yield (which may not even subsist his family all along the year) by deviating from his

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traditional cultivation procedure unless he is insured of equal or better returns. Therefore, the viability of second year cropping is being viewed in terms of economic and energy efficiencies in this paper. We shall quantify monetary and energy budgets for young and old jhum fields during first and second year of cropping and compare them. We shall also test whether tilling and fertilizer application would have an impact on monetary and energy budgets positively.

2. Methodology

A detailed description of the study site, its physical environment and vegetation is given in Tawnenga *et al* (1996). The experimental protocol included the selection of an area of 5000 m^2 as study plot in both young (6 year) and old (20 year) jhum fallows. The thriving vegetation on these fallows was slashed and burnt prior to the start of agricultural activities. For first year cropping, the whole plot was used and referred to as 6:I:C (6 years age, first year cropping, control plot) for young and as 20:I :C (20 years age, first year cropping, control plot) for old fallow. For second year cropping, the herbaceous vegetation which grew during intervening fallow period between the first year's crop harvest and the initiation of second year's agricultural activity was slashed and burnt again. Each plot was then divided into five sub-plots of approximately 1000 m^2 area along the slope. One of these five sub-plots was cultivated without any treatment which thus served as control (6:II:C for young and 20:II:C for old fallow). Tilling of soil was introduced in the second sub-plot (6:II:T for young and 20:II:T for old fallow). In the third sub-plot chemical fertilizers were applied (6:II:CF for young and 20:II:CF for old fallow). Farm-yard manure (FYM) was supplied to the fourth sub-plot (6:II:FYM for young and 20:II:FYM for old fallow). The fifth sub-plot was treated with a combination of chemical fertilizer and farm-yard manure (6:II:CF + FYM for young and 20:II:CF + FYM for old fallow).

The input and output were measured in terms of energy (megajoules, M J) and money (Indian rupees, Rs) for each experimental plot. The input in control jhum plots is through following agricultural operations: slashing, burning, seed sowing, weeding, harvesting and threshing. Traditionally, threshing of rice is not a step involved in jhuming. However, it has been taken into account in this study because threshing was done in the field following crop harvest, and the determination of energy output through grain (rice) production is possible only after threshing.

Tilling of soil and application of fertilizers are additional agricultural operations that require input in experimental plots during second year cropping. The chemical fertilizers applied in the field were urea (50kg ha^{-1}), diammonium phosphate (60kg ha^{-1}) and muriate of potash (65kg ha^{-1}). Urea contains 46 % N, diammonium phosphate contains 18% N and 46% P_2 O_5, and muriate of potash contains 60% K_2O. The cost for different input and output components in terms of money is given in table 1, and in terms of energy in table 2. The application of every kilogram of urea means an input of Rs 2 or 26·74 MJ energy, that of diammonium phosphate means an input of Rs 2·75 or 15·92 M J energy, that of muriate of potash means an input of Rs 1·15 or 4·02 M J energy, and that of FYM means an input of Rs 0·15 or 0·3 MJ. One man-day involves 6h of continuous work, and each man-hour work consumes 1·05 M J energy.

The energy efficiency of each plot was calculated as the ratio of output and input of energy, and the economic efficiency as the ratio of output and input of money.

Table 1. Monetary value (in rupee) for different input and output components based on local market.

Component	Unit	Rupees
Human labour	Man-day	40·00
Chemical fertilizers		
Urea	kg	2·00
Diammonium phosphate	kg	2·75
Muriate of potash	kg	1·15
Farm-yard manure	kg	0·15
Rice	kg	5·00

Table 2. Energy value (in MJ) for different input and output components.

Component	Unit	Energy(MJ)	Author(s)
Human labour	Man-hour	1·046	Revelle (1976)
Chemical fertilizers			Mittal and Dhawan (1989)
N	kg	60·1	
P_2O_5	kg	11·1	
K_2O	kg	6·7	
Farm-yard manure	kg	0·3	—do—
Rice	kg	14·52	—do—

The output was considered in terms of economic yield (rice grain). The energy input components like solar energy, slash energy and soil nutrient energy have not been taken into account while computing the energy input. Similarly, the left behind energy in form of agricultural refuse, accumulated litter and weeded biomass has not been considered in calculating the energy output. Since all these factors have been excluded in all the study plots, the energy budget as worked out in the present study would adequately serve the purpose of comparing the energy efficiency of jhum plots under different treatments.

3. Results

3.1 *Energy and monetary input*

Per hectare, input of energy and money for first year cropping was more in young than old field (tables 3, 4). Human labour is the principal form of energy input accounting to about 78% in young and 76% in old field. The balance input is through seeds. In monetary terms, the input through human labour accounts for more than 98 % with the balance input through seeds. Of all agricultural operations, weeding involved maximum input of energy, 48 % in young and 42 % in old field. Labour input for slashing the ground vegetation and felling the trees and bamboo was slightly more in old than young field. Harvesting is another important labour input, accounting to 160 MJ energy or Rs 1020 in both the fields.

Table 3. Energy input ($MJha^{-1}$) in different treatment plots in young and old jhum fields during first and second year cropping.

Jhuming operation	I:C	II:C	II:T	II:CF	II:FYM	II:CF + FYM
Young field						
Labour input	991	985	1164	951	952	970
Slashing	160	135	135	135	135	135
Burning	6	6	6	6	6	6
Tilling	0	0	298	91	91	91
Fertilizer application	0	0	0	6	13	19
Sowing	154	151	151	151	151	151
Weeding	480	524	414	405	399	402
Harvesting	160	138	132	129	129	135
Threshing	31	31	28	28	28	31
Seeds	272	272	272	272	272	272
Fertilizer	0	0	0	2600	900	3500
Total	1263	1257	1436	3823	2124	4742
Old field						
Labour input	878	975	1176	1041	1010	1086
Slashing	166	147	147	147	147	147
Burning	6	6	6	6	6	6
Tilling	0	0	298	91	91	91
Fertilizer application	0	0	0	6	13	19
Sowing	144	151	151	151	151	151
Weeding	367	496	408	468	439	490
Harvesting	160	144	135	141	135	147
Threshing	35	31	31	31	28	31
Seeds	272	272	272	272	272	272
Fertilizer	0	0	0	2600	900	3500
Total	1150	1247	1448	3913	2182	4854

During second year cropping, labour input for slashing and clearing the vegetation which grew during the intervening fallow period since the harvest of previous year crop declined by 16% in young and 11 % in old field (tables 3,4). The energy investment on weeding operation in no-treatment plot was increased by 9 % in young and 35 % in old field. Finally, total input (both in energy as well as monetary terms) required for second year cropping in no-treatment plot was almost equal to that required for first year cropping in young field, but it was about 9% more in old field.

Introduction of tilling during second year cropping involved an extra input of 298 M J energy or Rs 1900 (tables 3, 4). However, investment on weeding declined in tilled plots compared to that in no-treatment plot. Eventually, tilling costed a greater energy input by 14% in young and 16% in old field.

Fertilizer application treatments (CF, FYM, CF + FYM) involved high input of extra energy compared to no-treatment plot. The input through fertilizer was 2600 MJ or Rs 340 in CF treatment, 900 MJ or Rs 450 in FYM treatment, and 3500 MJ or Rs 790

Table 4. Monetary input (Rs ha^{-1}) in different treatment plots in young and old jhum fields during first and second year cropping.

Jhuming operation	I:C	II:C	II:T	II:CF	II:FYM	II:CF + FYM
Young field						
Labour input	6320	6280	7420	6060	6060	6210
Slashing	1020	860	860	860	860	860
Burning	40	40	40	40	40	40
Tilling	0	0	1900	580	580	580
Fertilizer application	0	0	0	40	80	120
Sowing	980	960	960	960	960	960
Weeding	3060	3340	2640	2580	2540	2560
Harvesting	1020	880	840	820	820	860
Threshing	200	200	180	180	180	200
Seeds	94	94	94	94	94	94
Fertilizer	0	0	0	340	450	790
Total	6414	6374	7514	6494	6604	7064
Old field						
Labour input	5600	6220	7500	6640	6440	6900
Slashing	1060	940	940	940	940	940
Burning	40	40	40	40	40	40
Tilling	0	0	1900	580	580	580
Fertilizer application	0	0	0	40	80	120
Sowing	920	960	960	960	960	960
Weeding	2340	3160	2600	2980	2800	3120
Harvesting	1020	920	860	900	860	940
Threshing	220	200	200	200	180	200
Seeds	94	94	94	94	94	94
Fertilizer	0	0	0	340	450	790
Total	5694	6314	7594	7074	6984	7784

in CF + FYM treatment plot in both young as well as old field (tables 3, 4). In addition to this, 91 M J energy or Rs 580 was invested in partial tilling of soil in each fertilizer treatment plot. As in the case with tilling, energy investment on weeding declined by about 25 % in all fertilizer treatment plots in young field and from 2-10% in old field. Overall, energy input compared to no-treatment plot was more by about 3 times in CF treatment, 1·7 times in FYM treatment and 3·8 times in CF + FYM treatment both in young and old fields (table 3). On the contrary, the monetary input in all the fertilizer treatment plots compared to no-treatment plot was only slightly higher in young as well as old field (table 4).

3.2 *Energy and monetary output*

Per hectare output in form of economic yield (rice grain) during first year cropping was more in old (1586 kg rice grain, or 23030 MJ energy, or Rs 793 l).than young (1462 kg

Table 5. Output in terms of rice grain production (kg ha^{-1}), energy ($MJha^{-1}$) and money (Rs ha^{-1}) in different treatment plots in young and old jhum fields during first and second year cropping.

Output term	I:C	II:C	II:T	II:CF	II:FYM	II:CF + FYM
Young field						
Rice grain	1462	1240	1215	1375	1300	1450
Energy	21233	18003	17640	19963	18874	21052
Money	7312	6200	6075	6875	6500	7250
Old field						
Rice grain	1586	1260	1247	1505	1402	1855
Energy	23030	18293	18112	21850	20362	26932
Money	7931	6300	6237	7525	7012	9275

Table 6. Output/input ratio in terms of energy (MJ) and money (Rs) in different treatment plots in young and old jhum fields during first and second year cropping.

Output term	I:C	II:C	II:T	II:CF	II:FYM	II:CF + FYM
Young field						
Energy	16·80	12·50	12·28	5·18	8·89	4·41
Money	1·14	0·97	0·80	1·11	1·05	1·15
Old field						
Energy	20·01	14·65	12·49	5·54	9·32	5·51
Money	1·39	0·99	0·82	1·11	1·07	1·32

rice grain, or 21233 M J energy, Rs 7312) field (table 5). When second year cropping was done without any treatment, the output declined by 15% in young and by 20% in old field. Tilling of soil did not have a significant impact on output in both the fields.

Fertilizer application increased the output in young as well as old field. The per cent increase under all the three fertilizer treatment plots was more in old than the respective plots in young field (table 5). The CF + FYM treatment was most effective, causing an increase in output up to 17% in young and 47% in old field. Thus the economic yield from CF + FYM treatment was comparable to that obtained in the first year in young field, and was even more in old field. The CF treatment was moderately effect-tive, causing an increase in output up to 11% in young and 19% in old field. The FYM treatment could enhance the economic yield up to only 5 % in young and 11% in old field.

3.3 *Energy and economic efficiencies*

The energy efficiency (output/input ratio) of first year cropping was more in old (20) than young (16·8) field (table 6). The economic efficiency of first year cropping, though more in old (1·4) than young (1·1) field, was very low compared to the energy efficiency. The energy as well as economic efficiencies declined consequent to second year cropping without any treatment. A further decrease in energy and economic efficiencies under tilling treatment is mostly because of additional labour input for tilling of soil (table 3) and lesser economic yield (table 5).

In fertilizer treated plots, energy efficiency declined even further and was much less compared to that in no-treatment plot, both in young as well as old fields (table 6). This decline in energy efficiency is obviously due to very high additional input of energy in form of fertilizers, and also investment of energy on partial tilling of soil (table 3). The economic efficiency in fertilizer treated plots was, on the other hand, greater than no-treatment plot. Under CF + FYM treatment, the economic efficiency almost equalled that obtained in first year (table 6).

4. Discussion

The essense of agriculture is to convert various forms of energy into food energy for human consumption. Jhum in the hill region of north-eastern India is the principal way of yielding food energy. The first interesting feature of traditional jhum system of cultivation, as is evident in the present study, is that it is a labour intensive agriculture in which food energy is produced by consuming mainly the human energy. The material input in jhum is only through seeds, which again is in fact a product of preceding year's human labour input. The energy input through human labour accounts for a little more than three-fourth of total energy input in the present case where rice in monoculture was cropped. But under mixed cropping, labour input of energy may go as high as 97% (Toky and Ramakrishnan 1982).

The second established fact about jhum is that it is an efficient system of agriculture from the viewpoint of energy. Unlike mechanized agricultural systems which consume five to ten units of fuel energy to produce a single unit of food energy (Steinhard and Steinhard 1974), 17-20 times energy is obtained during first year cropping, and 13-15 times energy is obtained during second year cropping of rice in monoculture in the present study. The energy efficiency may still be higher, from 41-48 (Toky and Ramakrishnan 1982), or from 18-55 (Maikhuri and Ramakrishnan 1991) under mixed cropping system. Tsembaga people of the New Guinea Highlands also obtained an average of 16 units of food energy for each unit of human energy employed during farming, and this increased to 20 under more favourable conditions (Rappaport 1971). Lewis (1951), Norman (1978) and Uhl and Murphy (1981) have reported equally high energy effciency from slash-and-burn agriculture.

Energy and economic efficiencies are prominently higher in old than young field during first year cropping, but are comparable during second year cropping in its traditional form (without any treatment). The causal factor is greater weed infestation in young than old field during first year cropping (Tawnenga *et al* 1996), demanding greater labour input for weeding (table 3). During second year cropping, weed infestation remained as severe as in the first year in youag field, but aggravated considerably in old field (Tawnenga *et al* 1996). Consequently, investment on weeding rose in old field during second year which brought down energy and economic efficiencies to a level comparable with that in young field.

As is the case with ecosystem productivity and grain yield (Tawnenga *et al* 1996), energy and economic efficiencies declined from first to second year cropping in young as well as old field. This is a general phenomenon widely noticed in agroecosystems (Hauck 1971; Sanchez 1976). Reduction in grain yield may be associated with lowering in soil fertility (Tawnenga *et al* 1997) and/or aggravation in weed infestation (Tawnenga *et al* 1996) with successive croppings.

Mechanization of agriculture is expensive as returns of energy and money per unit investment decline. For instance, mechanization in the form of earth work (tilling) did not improve energy efficiency to any degree in either young or old jhum field, rather induced a cutback in economic returns. Not only extra investments of energy and money were required for earth work (tables 3, 4), but also economic yield declined in tilled plots (table 5). Even if economic yield is high, energy efficiency of mechanized systems, such as terrace cultivation in north-eastern India, may be drastically lower compared to non-mechanized systems (Toky and Ramakrishnan 1982; Kushwaha and Ramakrishnan 1987). Tilling is not only expensive but also unsuitable from the point of view of soil erosion. Although we did not measure soil erosion, there are many instances where similar observations have been made. For example, Okigbo (1984) while studying shifting cultivation at Ibadan in Nigeria observed that soil loss enhanced from 0 37t ha $^{-1}$ without tillage to 4 64t ha $^{-1}$ with conventional tillage, and further to 19 57t ha $^{-1}$ using crawler tractor. Water loss in the form of runoff also increased in the same fashion.

Industrialization of traditional jhum system with the application of fertilizers caused an increase in grain yield (table 5) as well as economic efficiency, but lowered energy efficiency dramatically (table 6). It is in compliance with the data compiled by Leach (1976) for shifting cultivation and partially mechanized systems with fertilizers. Why is it that fertilizer treatments push up, on one hand, the economic efficiency, but bring down, at the same time, the energy efficiency? It is because of astounding variation in the costs of different forms of energy. For example, every 100 MJ of human labour costs Rs 673·5, that of inorganic fertilizer costs Rs 13·1, that of organic fertilizer costs Rs 50·0, and that of inorganic and organic fertilizer in combination costs Rs 22·6. Understandably, the investment of energy in the form of fertilizers is though massive (causing a reduction in energy efficiency), it is economical (not causing a reduction in economic efficiency). It could be argued here that the application of fertilizers may though be profitable to the farmers, it may not be suitable from the standpoint of energy. It is because production of each unit of fertilizer energy requires many units of other forms of energy. For example, to produce every kilogram of urea (26·7 M J of fertilizer energy) 53·3 MJ of naphtha energy is needed apart from the energy required for processing (TEDDY 1992). Among the three fertilizer treatments, organic manuring was the most energy efficient in young as well as old field. But it gave marginally lower returns in terms of money compared to inorganic manuring or a combination of organic and inorganic manuring.

The following can be deduced from the foregoing discussion. Traditional jhum cultivation is labour intensive, i.e., food energy is produced mainly from labour energy. This system is quite energy efficient, producing almost 15-20 times of energy invested. Energy and economic efficiencies decline with shortening of jhum cycle. They decline further from first to second year of cropping. Tilling does not improve either energy or economic efficiency. Fertilizer application is though profitable from the point of view of economic efficiency, it is highly energy inefficient. Application of fertilizers during second year cropping can be recommended. Organic manuring may be a better option than others from the standpoint of energy efficiency. However, a combination of organic and inorganic manuring could be the best option from the viewpoint of economic efficiency.

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