J. Biosci., Vol. 22, Number 5, December 1997, pp 615–625. © Printed in India.

Evaluating second year cropping on jhum fallows in Mizoram, north-eastern India: Soil fertility

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MS received 15 July 1995; revised 30 April 1996

Abstract. Changes in soil fertility were evaluated on young (6 year) and old (20 year) jhum fields in Mizoram, north-eastern India in response to various operations involved injhum such as slashing and burning of vegetation, cropping period, and intervening fallow period between first and second year cropping. The results demonstrate that the soil is richer in nutrients in old than young field prior to the start of jhum cultivation. Slash burning depletes soil acidity, carbon and nitrogen but elevates phosphorus and cations. Soil fertility declined during first cropping phase, and further declined during second cropping phase. After two cropping years, soil fertility of old field was almost at par with that of young field, signifying that the loss of soil fertility was more in old than young field. A short intervening fallow period between first and second year of cropping did not show any pronounced improvement in soil fertility, though it provided some biomass for second burning. Tilling caused maximum loss to soil fertility. The fertilizer treatments ended with comparable or better soil fertility in comparison to no-treatment plot. There seems to be none of the fertilizer treatments superior over others from the standpoint of ending soil fertility. The unifying conclusions of this series of investigations support the hypothesis that the second year cropping holds promise to reduce the demand for forested land for jhum, and lengthen the jhum cycle substantially.

Keywords. Jhum; soil fertility; fertilizer application; farm-yard manure; rice cultivation.

1. Introduction

The stability of jhum depends upon the recovery and maintenance of soil fertility. If the nutrients lost or displaced during cropping phase are balanced during the fallow phase, the system could continue sustainably. In humid tropics the major storehouse of nutrients is standing vegetation, not the soil (Greenland and Herrera 1975). Therefore, large fractions of nutrients freed after slashing and burning are lost, if not consumed in plant uptake, through leaching, runoff and soil erosion (Ruthenberg 1983). Maintenance of soil fertility is thus a serious problem under jhum.

To ensure sustainability, the decision of introduction of second year cropping should involve the care that the physical and chemical properties of the soil are conserved. Even if second year cropping is tenable from the viewpoint of ecological efficiency (Tawnenga *et al* 1996) and energy and economic efficiencies (Tawnenga *et al* 1997), it cannot be recommended unless soil fertility changes due to various activities involved

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in jhum are assessed. In this paper, we evaluate the changes in soil fertility, both in young and old fields, in response to slashing and burning of vegetation, cropping period, and intervening fallow period between first and second year cropping. We shall also compare the ending soil fertility after two successive years of cropping between plots cultivated in traditional manner (no-treatment) and those tilled or fertilized. The parameters selected as the indicators of soil fertility are pH, organic carbon, total nitrogen, extractable phosphorus, and exchangeable cations (K, Ca and Mg).

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 perior 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 soil was sampled at 0-10 and 10-20 cm depths following monolith excavation technique from five randomly selected locations within each plot at every sampling data. The sampling was done on following dates in both the fields: (i) before slashing the standing vegetation on fallow land (January 1988), (ii) after slashing and burning of vegetation (May 1988), (iii) after first year's crop harvested (October 1988), (iv) before second year slashing (January 1989), and (v) after second year slashing and burning (May 1989). Following second burning, each jhum field was divided into five plots to impose five different treatments during second year cropping. The sixth soil sampling was done from each treatment plot after crop harvest in October 1989. Soil samples were air-dried, passed through a 2 mm sieve and used for chemical analysis.

Al: 2·5 soil-water suspension was used to electrometrically determine the pH in soil samples. Organic carbon was determined by Walkley and Black's rapid titration method (Piper 1942). Total nitrogen was determined by micro-Kjeldahl digestion-distillation method (Allen *et al* 1974), and extractable phosphorus by phosphomolybdo blue colour method (Jackson 1958). Exchangeable cations (K, Ca and Mg) and cation exchange capacity (CEC) were determined using ammonium acetate (pH 7) as an extractant (Allen *et al* 1974).

Table 1. Chemical characteristics of topsoil(0-10cm)and subsoil (10-20 cm) in young and old jhum fallows before slashing of the vegetation for first year cropping (± SD, *n* = 3).

Soil characteristic	Young field		Old field	
	0–10 cm	10–20 cm	0–10 cm	10–20 cm
pH	5·9 ± 0·10	5·7 ± 0·11	6·3 ± 0·09	5·8 ± 0·09
Organic carbon (%)	2·15 ± 0·21	1·85 ± 0·18	2·65 ± 0·20	2·22 ± 0·18
C/N ratio	10·8	12·7	11·6	10·9
Total nitrogen (kg ha^{-1})	3900 ± 457	3000 ± 360	4500 ± 472	3900 ± 410
Extractable phosphorus (kg ha^{-1})	25·8 ± 3·1	20·6 ± 1·9	35·7 ± 5·0	24·6 ± 4·1
Cation exchange capacity (meq 100^{-1})	14·0 ± 1·1	11·3 ± 1·9	14·2 ± 1·3	11·5 ± 1·1
Exchangeable potassium (kg ha^{-1})	508·3 ± 36·4	469·2 ± 36·4	641·2 ± 43·6	492·6 ± 37·6
Exchangeable calcium (kg ha^{-1})	901·8 ± 70·1	713·4 ± 82·3	1250·5 ± 122·0	921·8 ± 110·6
Exchangeable magnesium (kg ha^{-1})	396·4 ± 39·4	262·6 ± 32·6	425·6 ± 46·4	277·2 ± 18·4

3. Results

Soil fertility of young (6 year) and old (20 year) jhum fields was assessed at various stages of jhum cycle. Old field soil is more fertile than young field soil at pre-slashed stage, as the concentrations of macronutrients prior to commencement of cultivation were significantly (P < 0·05) higher in old than young field (table 1).

3.1 *Soil fertility changes due to slashing and burning of vegetation*

Nutrient quantities in soil got altered from pre-slashed stage to after slashing and burning of vegetation during first as well as second year of cropping (figure 1). Organic carbon and total nitrogen declined, but p H, extractable phosphorus and exchangeable cations (K, Ca and Mg) increased in young and old fields. The increase in phosphorus and cation levels was significantly higher (P < 0·01) in old than young field. C/N ratio and cation exchange capacity (except in old field during second year) remained unaltered (P < 0·05).

3.2 *Soil fertility changes during cropping phase*

Soil fertility declined during cropping phase. The net change between pre-cropped stage and after first year's crop harvest included a decrease in organic matter, total nitrogen, extractable phosphorus and exchangeable magnesium in young as well as old field (figure 2). On the other hand, pH and exchangeable K (in young field only) and Ca increased. C/N ratio remained constant in young field, but increased in old field (figure 2c). CEC increased in old field, but declined in young field (figure 2f). Further change in soil fertility recorded after second year's crop harvest had varied patterns for various

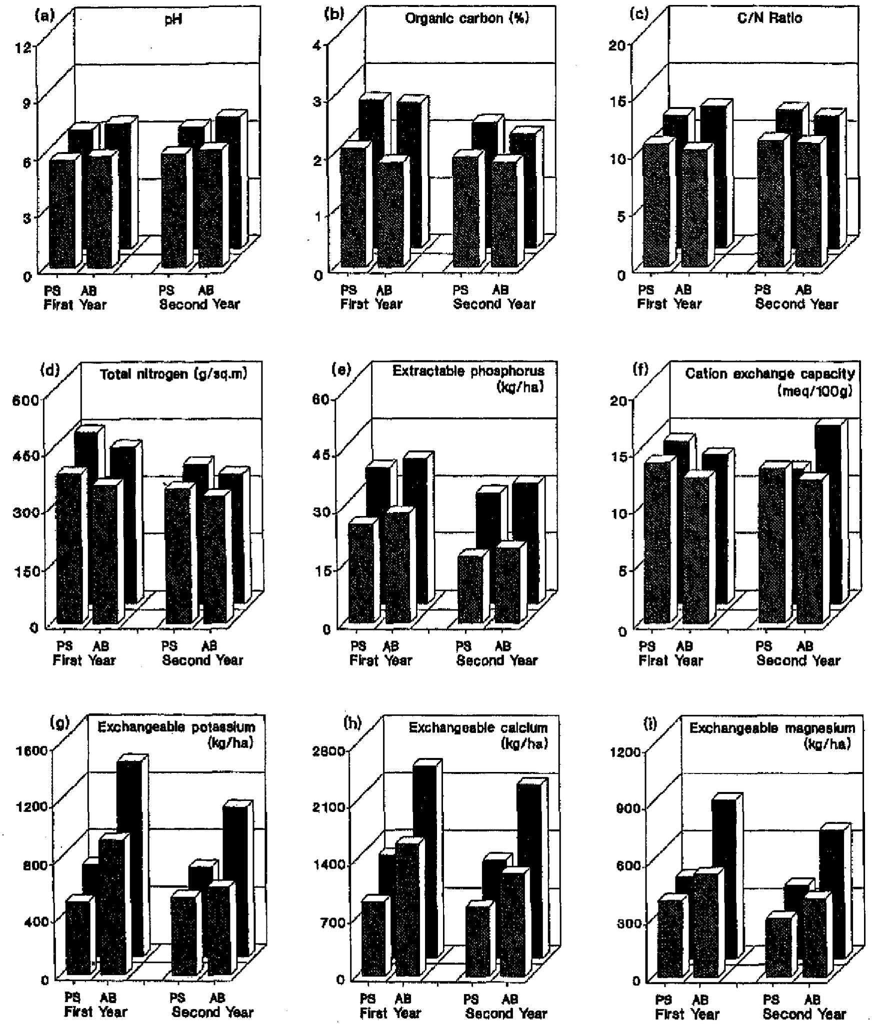

Figure 1. Changes on soil fertility due to slashing and burning of vegetation during first and second year of croping in old (black bar) and young (hatched bar) jhum fields. PS, Pre-slashed stage; AB, after burning of slash.

elements. While pH remained constant (figure 2a), organic carbon showed a substantial decline especially in old field (figure 2b). Total nitrogen and C/N ratio declined in old field but increased in young field (figure 2c, d). Extractable P, exchangeable K and cation exchange capacity declined both in young and old fields (figure 2e, f, g). Exchangeable Ca and Mg remained unchanged (figure 2h, i).

3.3 *Soil fertility changes aiming intervening fallow period between two croppings*

Changes in soil fertility during fallow period between first and second year of cropping included marginal decrease in pH and extractable phosphorus in young as well as old

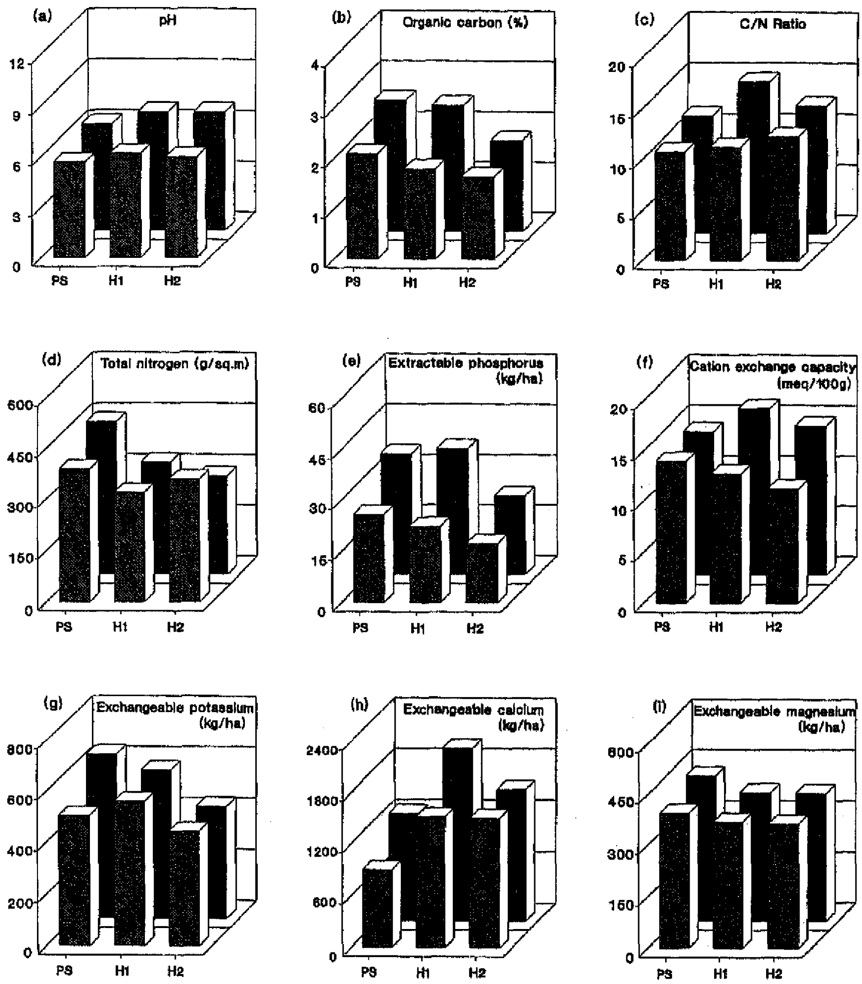

Figure 2. Changes in soil fertility during cropping phase in first and second year of cropping in old (black bar) and young (hatched bar) jhum fields. PS, pre-slashed stage; H1, after first year's harvest; H2, after second year's harvest.

field (table 2). Cations did not show any change in old field, though declined slightly in young field. Total nitrogen in both the fields and organic carbon in young field exhibited a rising trend.

3.4 *Eding soil fertility in response to fertilizer treatments*

Ending soil fertility after two years of cultivation differed in different treatment plots (figure 3). Organic carbon, pH, total nitrogen, and exchangeable calcium and magnsium lowered in tilled than other plots in both the fields. Ending soil fertility under three fertilizer treatments was either better (particularly in terms of extractable

Table 2. Changes in chemical characteristics of soil in young and old jhum fields during intervening fallow period between first year's crop harvest and slashing of vegetation for second year cropping (± SD, *n* = 3).

	Young field		Old field	
Soil characteristic	After crop harvest	Before slashing	After crop harvest	Before slashing
pH	6·2 ± 0·10	6·0 ± 0·10	7·0 ± 1·2	6·4 ± 1·0
Organic carbon (%)	1·80 ± 0·20	1·95 ± 0·20	2·50 ± 0·22	2·20 ± 0·21
C/N ratio	11·3	11·1	15·0	12·1
Total nitrogen (kg ha^{-1})	3200 ± 407	3500 ± 408	3300 ± 410	3660 ± 410
Extractable phosphorus (kg ha^{-1})	22·3 ± 3·0	17·3 ± 1·8	37·3 ± 4·3	29·0 ± 3·1
Cation exchange capacity (meq 100^{-1})	12·8 ± 1·0	13·5 ± 1·9	16·5 ± 1·5	11·8 ± 1·3
Exchangeable potassium (kg ha^{-1})	563 ± 42	469 ± 36	579 ± 48	626 ± 39
Exchangeable calcium (kg ha^{-1})	1529 ± 167	1898 ± 175	2014 ± 192	2190 ± 204
Exchangeable magnesium (kg ha^{-1})	370 ± 35	305 ± 32	377 ± 40	382 ± 28

phosphorus and exchangeable calcium) or comparable (in terms of pH, organic carbon, total nitrogen, C/N ratio, cation exchange capacity, and exchangeable potassium and magnesium) with no-treatment plot in young as well as old field. In general, none of the three fertilizer treatments showed relatively greater concentrations of soil nutrients over others.

4. Discussion

The hill soils of Mizoram are acidic (Singh and Datta 1987). As in conformity with several other workers (Prasad *et al* 1980; Toky and Ramakrishnan 1981; Andresse and Koopman 1984; Okigbo 1984; Kumada *et al* 1985), slashing and burning of vegetation caused an increase in pH in the present study. Two apparent reasons for this are incorporation of cations freed after burning of standing vegetation, and destruction of organic matter which releases humic acid. Nye and Greenland (1964) recorded a rise in pH from 5·2 to 8·1, and Lai and Cummings (1979) from 6·6 to 9·0 in top 5 cm soil soon after burning. Hrahsel (1988) found an increase in soil pH from 1·1 to 1·7 units due to burning and a subsequent decline during cultivation in Mizoram soil. Shifting cultivators in humid tropics use burning as a tool to combat soil acidity despite it depletes nitrogen and organic matter.

Destruction of organic matter in burning has several consequences on microenvironmental conditions of the soil, particularly soil surface. While porosity, aeration, field and water holding capacity, infiltration and surface moisture are lowered, erosion losses of soil and nutrients through runoff are intensified (Ahn 1974; Jha *et al* 1979) and solar radiation reaching the soil is increased. Consideration of soil erosion and nutrient loss assumes importance especially for slopy sites in hot, humid, high rainfed areas

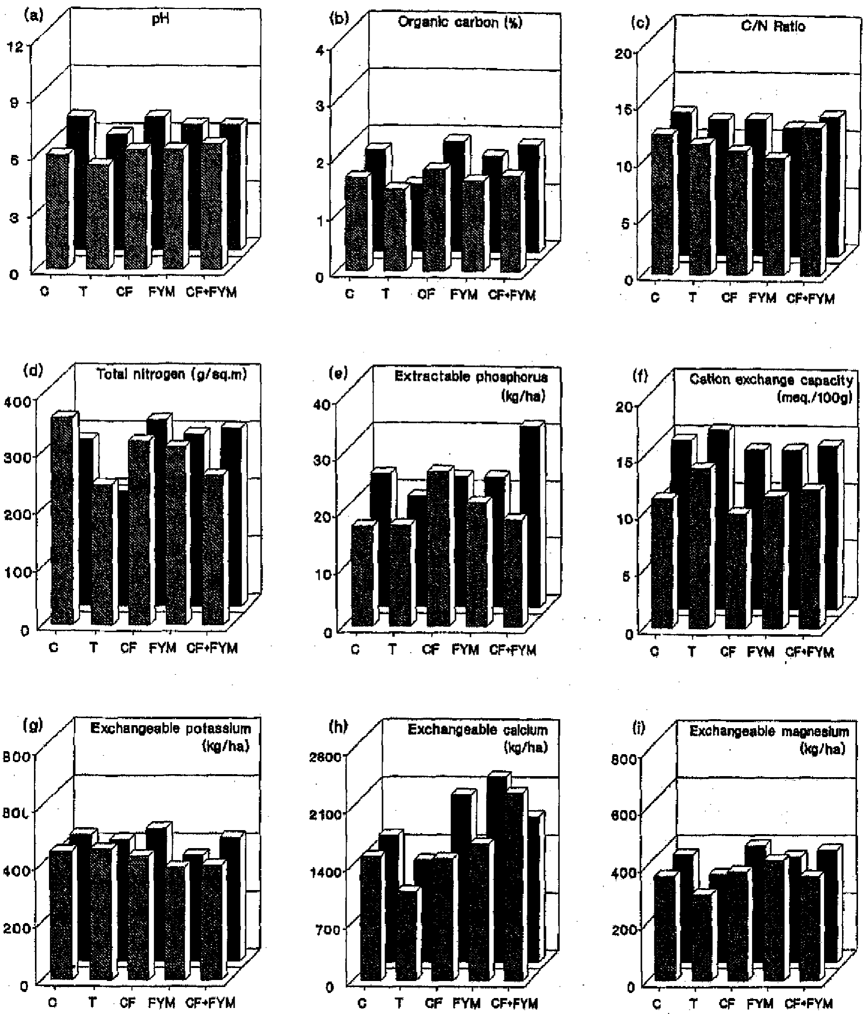

Figure 3. Ending soil fertility in various treatment plots after two successive years of jhum cultivation. C, Control or no-treatment plot; T, tilled plot; CF, the plot treated with chemical fertilizers; FYM, the plot treated with farm-yard manure; CF + FYM, the plot treated with a combination of chemical fertilizers and farm-yard manure.

such as Mizoram, where outflow of water is ample. The decrease in organic carbon is not as important in old as in young field during first year, perhaps due to the fact that old field started with higher carbon than young field.

Although burning may intensify nitrification due to rise in pH and surface temperature (Moore and Jaiyebo 1963) or removal of chemical inhibitors (Smith *et al* 1968; Rice 1974), total nitrogen declines as in the present case (Joachim and Kandiah 1948; White *et al* 1973; Kumada *et al* 1985; Hrahsel 1988). Reduction in total nitrogen is attributed to the conversion of organic nitrogen to volatile forms during pyrolysis (Debell and Ralston 1980). Supply of available phosphorus is augmented by addition of ash after burning (Joachim and Kandiah 1948). Nye and Greenland (1960) estimated phosphorus as much as 27 kg ha^{-1} is provided by the ash of a 10 year forest fallow. In our study phosphorus addition ranges between 2 and 4kg ha^{-1}. Ash dramatically increased exchangeable cation concentrations which is in agreement with Toky and Ramakrishnan (1981), Oya and Tokashiki (1984) and Chidumayo (1987). The importance of fire in slash and burn agriculture is not only from the fact that there is a substantial decline in soil acidity, but also that there is a quick release of cations following fire on soil surface. The addition of phosphorus and cations was greater during first year's cropping than of second year cropping, and was more in old than young field. It is understandable from the fact that the standing stock on old fallow was greater than that on young fallow (Tawnenga 1990). Similarly, the standing stock for slashing was more during first than second year in both the fields.

A decline in soil fertility during cropping is naturally expected (Nye and Greenland 1964; Zinke *et al* 1978; Toky and Ramakrishnan 1981). Net uptake of nutrients by growing crop may be responsible partly for lowering the nutrient levels despite a continuous supply through mineralization. Organic carbon and total nitrogen, which depleted due to slashing and burning, decreased further during first cropping phase in both the fields, indicating a net loss after a year of cropping. Joachim and Kandiah (1948) have also recorded reduction in organic matter, nitrogen and cations during cropping under shifting cultivation in Sri Lanka. Juo and Lal (1977) found that soil quality deteriorates during three successive croppings, but it could be maintained by returning sufficient plant residue as mulch. Extractable phosphorus and exchangeable cations (K, Ca and Mg) which increased after slash burning also decreased during first cropping phase in both the fields. However, this decrease did not always result in a net loss due to jhum activity during first year of cropping. Phosphorus and calcium showed a net gain, and potassium and magnesium showed a net loss after a year of cropping in old field which is slightly different from the young field where potassium and calcium, showed a net gain, and phosphorus and magnesium showed a net loss. Furthermore, the net loss in potassium and magnesium in old field and phosphorus and magnesium in young fieldwas only marginal, expressing that these fields could sustain second year of cropping as far as is the concern of phosphorus and cations.

Nutrient concentrations (carbon, nitrogen, phosphorus and cations) in old field were significantly higher than young field at pre-cropped stage, and remained so till the end of first year cropping. After second year cropping, these concentrations were compareable between the two fields. Thus old field which started with higher levels of soil nutrients attained almost the same fertility level as did the young field after two years of cropping. In other words, the rate of soil fertility loss was faster in old than young field. Thus young field is superior to old field in that it can sustain two successive years of cropping with relatively lesser fertility loss. Nonetheless, economic yield is comparatively lesser in young than old field (Tawnenga *et al* 1997). Therefore it could be concluded that higher yields in oldfieldcost greater soil fertility loss, and lower yields in young field cost lesser soil fertility loss.

The decline in soil fertility during cropping may be due to other reasons also. Loss of nutrients in runoff and leaching, and conversion from available to non-available forms are two such important phenomena. For instance, available phosphorus in soil was reduced despite an addition of about 9 kg ha^{-1} in African forest soils and 3 kg ha^{-1} in African savanna soils during cropping period, primarily due to uptake by growing crop and conversion into non-soluble forms (Shukla and Agarwal 1984).

Umpteen number of reports support the view that soil fertility improves during resting period (the fallow period between two successive croppings). In the present study, data indicating better soil fertility in old than young field at pre-cropped stage (table 1) also support this view. Traditional jhum in Mizoram involves an alternation of a long resting period and a short cropping period. When successive second year cropping was done, the soil was occasioned with a short intervening fallow period between the harvest of first year's crop and slashing for second year cultivation. The soil fertility during this period though snowed some improvement, the changes were not highly pronounced. Understandably, the intervening fallow period is too short to infer any firm conclusion.

The ending soil fertility after two years of cropping was better in no-treatment plot than tilled plot in both the fields, signifying that tilling is unfit not only from the viewpoint of primary productivity (Tawnenga *et al* 1996) and energy and economic efficiencies (Tawnenga *et al* 1997), but also soil fertility. The reason for lower soil fertility in tilled plots may be the increased loss of soil and nutrients through runoff. The ending soil fertility in fertilizer treated plots was either at par or superior to no-treatment plot in young as well as old field. It is comprehencible since there was an extra addition of nutrients in fertilizer treated plots, which might have compensated for a large part of nutrients removed in crop harvest. Our results did not seclude any particular fertilizer treatment for its superiority over others from the standpoint of ending soil fertility. Therefore, the decision of the selection of fertilizer treatment rests mostly on the economics of the farmer.

The following can be inferred from the foregoing discussion. Burning of slash lowers soil acidity, organic matter and total nitrogen, but enhances phosphorus and cations. The addition of phosphorus and cations due to burning is greater in old than young field during first year cropping. Soil fertility declined during first year of cropping. The net change in soil available nutrient pool from pre-cropped stage through slashing-and-burning and subsequent cropping in the first year involved substantial lowering in carbon, nitrogen and magnesium, but not in phosphorus, potassium and calcium. The soil fertility declined further during second cropping phase. The decrease was more in old than young field during two years of cropping. The intervening fallow period did not show any pronounced improvement in soil fertility, though it provided some biomass for second burning. Tilling caused maximum loss to the soil fertility. The fertilizer treatments ended with comparable or better soil fertility compared to no-treatment; plot. There seems to be none of the fertilizer treatments superior over others from the standpoint of ending soil fertility.

5. Conclusions

There is extensive debate worldwide whether jhum is environmentally sustainable. The intent of this series of investigations (including Tawnenga *et al* 1996,1997) is not to address this issue. Even if it is not a sustainable option due mainly to shortening of jhum cycle, it cannot be brought to end abruptly. Practiced to the tune of 1·5 million ha every year, jhum provides employment, livehood and food to millions of people in India, especially tribal societies. Thus, we opine that j hum should be modified gradually, step-by-step to make it environmentally sustainable. The present investigations (including Tawnenga *et al* 1996,1997) clearly derrionstate that the second year cropping is a promising innovative choice to reduce the demand for forested land for jhum, and lengthen the jhum cycle substantially. However, these results should be viewed with the caveat that there are several variants of jhum currently in practice in north-eastern India, but we cover just one, though most widely practiced, in the present study.

Acknowledgements

This work was carried out at the Ecology Laboratory, Department of Botany, North-Eastern Hill University, Shillong. We express our gratitude to the farmers who provided access to their fields. Thanks are also due to the University Grants Commission, New Delhi for financial support in the form of a Teacher Fellowship to Tawnenga. US was supported during the tenure of processing this paper under a research programme in Conservation of Biodiversity and Environment jointly coordinated by the Tata Energy Research Institute, New Delhi and the University of Massachusetts, Boston with a grant from MacArthur Foundation.

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