



Changes in Soil Fertility and Rice Productivity in Three Consecutive Years Cropping under Different Fallow Phases Following Shifting Cultivation

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/46087

Editor(s):

(1) Dr. Omer Kilic, Bingol University, Turkey.

(2) Dr. Alejandro Hurtado Salazar, Professor, Departamento de Produccion Agropecuaria, Universidad de Caldas, Colombia.

Reviewers:

(1) Paul Kweku Tandoh, Kwame Nkrumah University of Science and Technology, Ghana.

(2) Georges Kogge Kome, University of Dschang, Republic of Cameroon.

Complete Peer review History: <http://www.sciencedomain.org/review-history/28045>

Short Research Article

Received 12 October 2018
Accepted 21 December 2018
Published 01 January 2019

ABSTRACT

Shifting cultivation commonly known as *Jhum* is a primitive and traditional practice carried out by *Jhumias* for centuries. Soil microbes play a vital role in regulating soil fertility and nutrient cycling in different terrestrial ecosystems. The main objective of the present study is to examine changes in soil properties (soil organic carbon, SOC; total nitrogen, TN; available phosphorus, P_{avail} ; ammonium nitrogen, NH_4-N ; nitrate nitrogen, NO_3-N ; nitrogen mineralization, N_{min}) and rice productivity for three years cropping phase in shifting cultivation stand with different fallow phases (3 years old, FL-3; 5 years old, FL-5; and 10 years old fallow, FL-10) in Mizoram. The results indicated that soil physico-chemical properties were significantly higher ($p < 0.05$) in longer fallow (FL-10) compared to shorter fallow (FL-3). The rate of N_{min} showed significant differences among seasons and showed significant increase in longer fallow (FL-10) compared to shorter fallows (FL-3 and FL-5). Rice yield and productivity showed significant increase from 3 years to 10 years. Further, soil properties and rice productivity showed significant decline from first year to third year cropping. It appears that the longer fallow have conserved better soil nutrients compared to shorter fallow. Additionally, the addition of leaf litter and fine roots had strong effect on increasing fertility and organic carbon (SOC) pool in soil that helps to enhance plant productivity in different fallow lands in hilly region of Mizoram.

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Keywords: Soil properties; nitrogen mineralization; rice productivity; shifting cultivation, fallow lands.

1. INTRODUCTION

Shifting cultivation, commonly known as slash-and-burn cultivation, is a primitive and traditional practice commonly occurring in the moist tropical hilly regions of the world [1,2]. It has been estimated that about 200 million (M) people (7% of the world population) are still practicing this type of cultivation in about 300 M ha of various land i.e. 5% of cultivated land throughout the world. In India, shifting cultivation is widely practiced by tribal people in many states of India, for example, states of northeast India (Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Tripura and Mizoram), Madhya Pradesh, Orissa, Andhra Pradesh and Kerala. Around 2 M tribal people cultivate approximately 11 M ha of land under shifting cultivation [3]. This practice is locally known as *Jhum* in northeast India, *punam krishi* in Kerala, *podu* in Andhra Pradesh and Orissa, *bewar*, *mashan*, *penda* and *beera* in different parts of Madhya Pradesh. Paddy, buck wheat, maize, millets, tobacco, some vegetables and banana are grown on the burnt over clearings and the products shared jointly by the clan. Rice is the major crop grown in shifting cultivation-dominated landscape in this region. Northeast India consists of 8 sister states with a total geographical area of 26.2 M ha which is about 8% of the country's total land area that supports about 47.9 M populations people (2014 statistics). Rainfall occurs from May to November in the region. This region constitutes one of highest rainfall areas (i.e. Cherrapunji and Mawsynram) of the world which receive total annual rainfall of 11,465 and 11,873 mm respectively. In general, the total annual rainfall varies from 2,000-4,000 mm in different part of the northeast India. Nearly 90% of the population of the region depends on agriculture as the sole source of livelihood. Among the workers of the region, 60.1% are cultivators, 9.3% are agricultural labourers while 7.3% are connected with livestock, forestry, fishery and other allied activities [4]. Out of 4.0 M ha of net sown areas, about 1.6 M ha area is under *jhumming* with very low average productivity. *Jhum* cultivation involves several cultural operations to grow mixed crops on the hill slope for a year or two (cropping phase) followed by abandonment of the land as fallow for some years for regeneration of secondary forest vegetation [5]. It is observed that during the land abandonment fallow lands rejuvenate the level of soil fertility [6,7]. Slash-and-burn remained to be the easiest

way not only to sanitize the soil, minimizing the weeds and soil pathogens but also to release the locked nutrients within the biomass as ash load which is considered to provide more readily available soil nutrients [8].

Mizoram is one of the seven sister states of northeastern India, located in tropical hilly areas dominated by tribal populations involved in shifting agricultural practice for their livelihood for a long time. During shifting cultivation, a piece of forest land is slashed and burnt *in situ* followed by sowing seeds of desired crops manually without tilling the soil [1,9]. Cropping is done for 1-2 years depending on the soil condition and then abandons the land for few years to recover soil fertility [10]. Decreased fallow length in recent years due to increased population density has created problems of food security for the small farmers and environmental degradation in the region. Mizoram's topography makes it unusual relative to many other areas in the Tropics where shifting cultivation is practiced. At least 70% of the state's total plan metric land area (2 M ha) is sloped at angles steeper than 33° [11]. Approximately half of all households in Mizoram are engaged in shifting cultivation [11], primarily in relatively undeveloped remote villages [12]. Remote sensing based estimates of the total area burned each year by farmers and wildfires ranges from 40,000-110,000 ha [13,11,14]. Mature sub-tropical wet hill and tropical wet evergreen forests that are the natural climax vegetation in the higher and lower altitudes of this region, respectively, [15] cover just 20% of the land area [12].

Cropping on *jhum* lands in Mizoram is predominantly practiced for one year. The second year cropping is scarce, and if done, it is only on old *jhum* fallows [13]. Even in other parts of north-eastern India, the land is often abandoned after first year of cropping while the second year of cropping is sometimes practiced with plantations of banana and pineapple [16]. Being organic state, resource intensive agriculture i.e. the excessive use of chemical fertilizers will be a major concern of the public and the Government in this region as they may contaminate the water through leaching and runoff losses of nutrients due to steep slopes. The main objectives of the present study were to estimate the crop productivity and to measure the changes in soil physico-chemical properties and Nitrogen mineralization (N_{\min}) in different

fallows for three consecutive years of crop cultivation following slash-and-burn.

2. MATERIALS AND METHODS

2.1 Study Area Description

The present study was conducted on a chronosequence at three fallow lands of 3 years (FL-3), 5 years (FL-5) and 10 years (FL-10) in Muallunthu village, Mizoram during 2013-15. The geographic coordinates of the study sites are between 23°36'30" N Lat. and 92°42'87" E Long, 23°35'69" N Lat. and 92°43'09" E Long, and 23°35'66" N Lat. and 92°48'08" E Long, respectively. All sites were almost similar in terms of topography, slope, aspect, hydrology, soil type, soil depth, and vegetation (age and composition) of adjacent forest fallow, and all have been managed using the same shifting cultivation practices up until the onset of the current fallow period. Forest fallow of different ages were slashed by the farmers in December 2012 and after drying the biomass present on the floor was burnt between 10th and 15th of March 2013. The intensity of burning on these sites varied with the amount of biomass burnt. Rice (*O. sativa*) was sown by dibbling method in the last week of April 2013 and in subsequent years during the same time. Soils of the present study were sandy to sandy loam in texture.

2.2 Soil Sampling and Analysis

A total of 27 (9 replicates per site) composited soil samples (100-150 g) were collected randomly from three fallow lands. Each

composite sample represents the collection of soil samples from three random locations from the upper 10 cm soil depth and mixed together at each fallow. Collected samples were enclosed in polyethylene bags and transported to the laboratory. The samples were divided into two parts, one part was used a fresh to determine soil moisture (SM), available nitrogen (NH₄⁺-N and NO₃⁻-N), and the other part was air-dried and used for the analysis of soil organic carbon (SOC), total nitrogen (TN), available Phosphorus (P_{avail}) and pH. Fresh samples were kept into a deep freezer unless the samples were not analyzed. Soil bulk density (BD) (g cm⁻³) was measured using a metallic tube of known inner volume to determine the dry weight of a unit volume of soil [17]. Soil pH was measured in a soil-water suspension (1:2.5 w/v H₂O) using a digital pH meter. Gravimetric soil moisture was determined as described by [18]. Air-dried and finely ground soil (2.0 mm) was used for determination of SOC by the potassium dichromate wet oxidation method and TN was determined by Heraeus CHN-O-S Rapid Auto-analyzer using sulphanilamide (C₆H₆N₂O₂S) standard. Bicarbonate P_{avail} was estimated using the method of ammonium molybdo-blue color [19].

2.3 N_{min} Methods, Sampling and Analysis

N_{min} was measured *in situ* using buried bag technique [20] seasonally. At each site, soils from the upper 10 cm depth were sampled and divided into two parts; one part was brought to the laboratory to measure soil available N (NH₄⁺-N and NO₃⁻-N) and the other part after removing

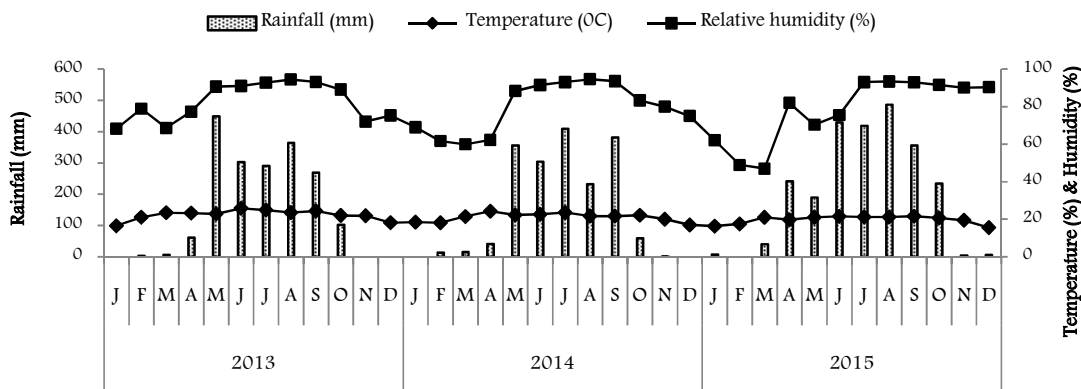


Fig. 1. Climate data of the study sites showing total monthly rainfall (mm), mean monthly temperature (°C) and mean monthly relative humidity for Aizawl district, Mizoram during 2013-2015. The climate data was collected from the weather forecast station of Pushpak, Zemabawk, Mizoram

large roots and organic debris was placed in polythene bags and incubated *in situ* and retrieved after two months for the estimation of N_{min} (nitrification and ammonification) rates. Ammonification and nitrification rates were obtained by subtracting initial concentration of NH_4-N and NO_3-N , respectively, from final concentration after one month and the resultant values were referred to as ammonification and nitrification rates. Net N_{min} was calculated as the sum of nitrification and ammonification rates per month.

2.4 Rice Production and Biomass Quantification

Total biomass of rice at maturity was measured by harvesting 15 random quadrats (1 m x 1 m) from each site for three successive years (2013-15). This way rice was harvested from 60 quadrats every year. The rice samples (~100 g) were brought to the laboratory and oven-dried separately at 70°C for 48 hours to constant weight. The rice samples were powdered and analyzed for C and N concentration using Heraeus CHN-O-S Rapid Auto-analyzer. Total above-ground production was calculated by using the biomass of different components of rice at maturity within a year. Belowground production was also calculated as the root biomass at the crop maturity.

2.5 Statistical Methods

All results were reported as means \pm standard error. Two-way ANOVA with fallow periods and sampling time as factors was performed. One-way ANOVA was employed for the soil and crop parameters to check the sampling time variability within and between the lengths of fallow period followed by Duncan's test ($p < 0.01$; $p < 0.05$) to

compare the means and its treatments. All statistical analysis was carried out by SPSS version 16.00 (USA).

3. RESULTS

3.1 Impact of Soil Physico-chemical Properties in Different Fallow Lands

The soil type in the present study was sandy to sandy loam in texture. Soil BD was highest in FL-3 (1.0 g cm⁻³) and lowest in FL-10 (0.7 g cm⁻³). Soil pH was lowest in FL3 (4.6) and maximum in FL-10 (5.0). Similarly, all other soil nutrients like SOC (34-36%), TN (29-36%), P_{avail} (26-39%), NH_4^+-N (30-36%) and $NO_3^- -N$ (29-38%) were lowest in FL-3 and highest in FL-10. Variation in soil pH and nutrients except soil BD were significant ($p < 0.05$) between FL-3 and FL-10 (Table 1).

3.2 Changes in Soil Physico-chemical Properties in Different Fallows for Three Consecutive Years Cropping

Soil physico-chemical properties showed reduced from the second year to third year of cropping (Table 2). The present study showed that 3-5% and 7-15% reduction in pH was observed in the second and third year compare to first year cropping. SOC ranged between 3-4% in 2014 and 7-8% in 2015. Similarly, TN ranged between 3-4% in 2014; 4-7% in 2015), P_{avail} between 3-4% in 2014; 5-6% in 2015), NH_4^+-N (2-6% in 2014; 1-7 in 2015) and $NO_3^- -N$ (5-6% in 2014; 6-12% in 2015) also showed declined in soil properties in this study site (Table 2). Additionally, a significant ($p < 0.01$) decline in the soil properties was noted from the second to third year of cropping.

Table 1. Annual soil physico-chemical properties in different fallow lands. Small letters indicates significant ($p < 0.05$) differences among fallow lands

	pH	SOC (%)	TN (%)	P_{avail} (mg kg ⁻¹)	NH_4^+-N (mg kg ⁻¹)	$NO_3^- -N$ (mg kg ⁻¹)
FL-3	4.63 ^a	1.90 ^a	0.058 ^a	5.87 ^a	40.48 ^a	32.54 ^a
	± 4.94	± 0.03	± 0.004	± 0.19	± 1.27	± 0.85
FL-5	4.79 ^b	2.16 ^b	0.069 ^b	7.63 ^b	44.44 ^b	37.32 ^b
	± 5.15	± 0.04	± 0.002	± 0.11	± 1.44	± 1.00
FL-10	5.08 ^c	2.27 ^b	0.072 ^c	8.76 ^c	48.48 ^c	43.37 ^c
	± 5.26	± 0.06	± 0.003	± 0.14	± 1.83	± 1.46

Notes: Lower case letters indicate significant ($p < 0.05$) differences among fallow lands.

Table 2. Soil physico-chemical properties in different fallows with three consecutive cropping phases. Small letters indicates significant ($p < 0.05$) differences among the fallows and capital letters indicates significant ($p < 0.05$) differences among three cropping stages

	2013			2014			2015		
	FL-3	FL-5	FL-10	FL-3	FL-5	FL-10	FL-3	FL-5	FL-10
pH	4.94 ^{aA}	5.15 ^{bA}	5.26 ^{cA}	4.71 ^{aB}	4.77 ^{bB}	5.08 ^{cB}	4.23 ^{aC}	4.46 ^{bC}	4.90 ^{cC}
SOC (%)	1.99 ^{aA}	2.25 ^{bA}	2.35 ^{cA}	1.83 ^{aB}	2.17 ^{bB}	2.28 ^{cB}	1.87 ^{aB}	2.06 ^{bB}	2.19 ^{cB}
TN (%)	0.060 ^{aA}	0.070 ^{bCA}	0.074 ^{cA}	0.058 ^{aA}	0.067 ^{bCA}	0.072 ^{cA}	0.056 ^{aA}	0.069 ^{bCA}	0.071 ^{cA}
P _{avail} (mg kg ⁻¹)	6.05 ^{aA}	7.74 ^{bA}	8.97 ^{cA}	5.87 ^{aB}	7.67 ^{bB}	8.74 ^{cB}	5.70 ^{aC}	7.47 ^{bC}	8.56 ^{cC}
NH ₄ ⁺ -N (mg kg ⁻¹)	41.77 ^{aA}	45.16 ^{bA}	50.07 ^{cA}	40.90 ^{aA}	43.86 ^{bA}	45.92 ^{cA}	38.76 ^{aA}	44.28 ^{bA}	49.47 ^{cA}
NO ₃ ⁻ -N (mg kg ⁻¹)	35.30 ^{aA}	39.19 ^{bA}	45.29 ^{cA}	33.21 ^{aA}	38.28 ^{bA}	42.41 ^{cA}	29.09 ^{aB}	34.50 ^{bB}	42.41 ^{cB}
	±0.03	±0.04	±0.06	±0.03	±0.03	±0.05	±0.10	±0.08	±0.07
	±0.004	±0.002	±0.003	±0.004	±0.002	±0.003	±0.003	±0.002	±0.003
	±0.19	±0.11	±0.14	±0.18	±0.09	±0.10	±0.26	±0.21	±0.14
	±1.27	±1.44	±1.83	±1.56	±1.12	±2.16	±1.69	±0.85	±2.46
	±0.85	±1.00	±1.46	±1.04	±1.63	±1.76	±1.04	±1.45	±1.64

Notes: Lower case letters indicate significant ($p < 0.05$) differences among the fallows and upper case letters indicate significant ($p < 0.05$) differences among three cropping stages.

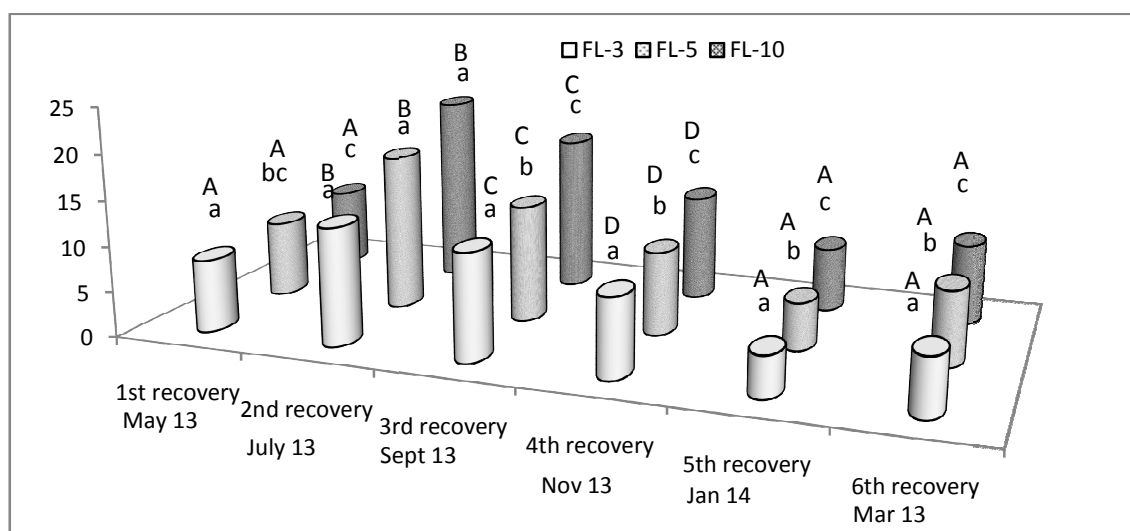


Fig. 2. Seasonal variation of N_{min} in different fallow lands. Lower case letters indicate significant differences among fallows. Upper case letters indicates significant differences among recovery

3.3 Seasonal Changes of N_{min} in Different Fallow Lands

Marked seasonal variations were observed in the level of N_{min} rates in all fallow lands. In all study sites, N_{min} rates were highest during rainy (13-21 mg kg⁻¹) seasons and lowest during winter (4-7 mg kg⁻¹) seasons. N_{min} rates were highest in FL-10 (7-20 mg kg⁻¹) and lowest in FL-3 (4-12 mg kg⁻¹) throughout the recoveries. Seasonal variations in N_{min} rates were significant ($p < 0.01$) in all sites, however, no significant differences were observed between July-January and July-

May. The mineralization rates increased significantly ($p < 0.05$) from 3 years to 10 years fallow (Fig. 2).

3.4 Rice Grain Productivity in Different Fallow Lands Following Three Consecutive Years Cropping

Fallow length has significantly ($p < 0.01$) increased the rice grain yield in first, second and third years. Rice grain was found maximum in FL-10 (80-146 g m⁻²) and minimum in FL-3 (18-111 g m⁻²). The grain yield was significantly

Table 3. Rice grain and productivity (aboveground and belowground) in different fallow lands for three years cropping. Small letters indicates significant ($p < 0.05$) differences among ages and bold letters indicates significant ($p < 0.05$) differences among cropping stages

Sites	Seeds (g m^{-2})			Total productivity (g m^{-2})		
	2013	2014	2015	2013	2014	2015
FL-3	111.1 ^{aa} ±1.9	58.5 ^{ab} ±2.2	18.5 ^{ac} ±1.3	409.3 ^{aa} ±11.8	213.7 ^{ab} ±10.1	75.1 ^{ac} ±7.8
FL-5	130.1 ^{aa} ±3.5	64.9 ^{ab} ±2.8	29.0 ^{ac} ±1.5	458.3 ^{aa} ±10.2	244.0 ^{ab} ±14.8	110.2 ^{ac} ±7.5
FL-10	146.1 ^{ba} ±3.4	94.1 ^{bb} ±3.3	80.0 ^{bc} ±2.1	581.7 ^{ba} ±12.4	354.5 ^{bb} ±18.7	276.6 ^{bc} ±5.3

Notes: Lower case letters indicate significant ($p < 0.05$) differences among ages and upper case letters indicate significant ($p < 0.05$) differences among cropping stages.

($p < 0.01$) highest in the first compared to second (53-64%) and third (17-55%) year of cropping. The total rice biomass was found maximum in FL-10 (276-581 g m^{-2}) and lowest in FL-3 (75-409 g m^{-2}). The total rice production (aboveground and belowground) significantly declined (52-61%) in second cropping year compared to the first year cropping. The decrease was more pronounced (18-48%) in the third year cropping (Table 3).

4. DISCUSSION

4.1 Changes in soil Physico-chemical Properties in Different Fallow Lands over Three Consecutive Years

It has been generally observed that the burning event and length of the fallow periods caused variations in the physico-chemical attributes of *Jhum* soil [21]. Many researchers reported that Mizoram soils are strongly acidic in nature [10,22] which is conformity with the present study. The lowest soil pH in FL-3 (4.63) and the highest pH values at FL-10 (5.08) may be due to the addition of more cations during burning and humid acid during the course of organic matter decomposition [23,22]. The significant decrease in BD from FL-3 (1.0 g cm^{-3}) to FL-10 (0.7 g cm^{-3}) may be due to the higher accumulation of soil organic matter in the longer fallow length [24]. Similarly, due to burning activities, organic matter content had been reduced from the secondary forests which reduce the bulk density [25].

The removal of organic matter and nutrients through runoff may not have significantly affected crop productivity in older fallow compared to younger fallow because of the huge accumulations of nutrients for longer period of time. The wide gap in carbon storage between FL-3 and FL-10 fallow lands could be regarded as rapid carbon accumulation as a result of

vegetation development [26]. Soil conservation measures may decrease the soil nutrient loss through erosion, leaching, etc during cropping periods every year. A fallow period of >10 years proves to conserve soil nutrients and soil health than shorter fallow during the cropping period throughout the year [27]. The present study indicated that the significant increase in SOC (30-36%) with increase in fallow length (FL-3 to FL-10) was due to increased accumulation of organic matter [24]. Almost all soil nutrients decreased after burning and increased during the onset of the monsoon. The intensity of the decrease or increase was significantly positively affected by the fallow ages. The findings clearly signify the fact that the combined impacts of burning and length of fallow period lead to deterioration of soil quality in shorter fallow (FL-3) length and eventually it gradually diminishes as the age of the fallow length increases (10 and 15/20 years) [28].

4.2 Comparison of Soil Physico-chemical Properties among Three Consecutive Cropping Phases

The present study revealed that the pH and other nutrients such as P_{avail} , $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ showed significantly ($p < 0.05$) declined from first year to third year of cropping (Table 1). Further, Lengthening of fallow period increased microbial biomass carbon in the surface soil layer due to greater accumulation of roots and forest litters [29,30]. An ecosystem with higher organic matter input normally tends to have higher microbial biomass due to rhizodeposition [31] thus, contributing to greater recovery of soil fertility status [32].

Decreased fertility level from second year and third year cropping has been reported to be related to exhaustion of nutrients through run-off, leaching and plant uptake in this study. Similar studies were reported by Ramakrishnan et al.

[33] and Pandey et al. [34]. Net uptake of nutrients from the soil by crops may be responsible for lowering the nutrients level [35,36] which was observed in the present study. Nutrient concentration was significantly higher in FL-10 as compare to FL-3 during the three consecutive cropping phases in the study sites. However, a significant decline was observed during the second and third year of cropping. The decline in soil fertility during the second and third year may be due other reasons like loss of nutrients, runoff, leaching, etc. [10]. Soil nutrients like TN, $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ (2013-14) showed marginal decrease in the second year of cropping and may be due to the fact that older fallows which started losing higher levels of soil nutrients during the first year cropping attained almost the same fertility level with the young fallow during the second year. In other words, the rate of soil fertility loss was faster in old fallows due to the maximum uptake of nutrients by the crops than shorter fallow [36]. Therefore, it could be concluded that higher yields in FL-10 cost greater soil fertility loss compared to FL-3 and FL-5.

4.3 Seasonal Changes in N mineralization (N_{min}) Rates in Fallow Lands

Marked seasonal variations were observed in the level of N_{min} rates in all fallow lands. In all study sites, N_{min} rates were highest during rainy (13-21 mg kg^{-1}) seasons and lowest during winter (4-7 mg kg^{-1}) seasons (Fig 2). This may be due to higher nutrients concentrations in forest floor as soil rich in organic matter tend to have high N_{min} rates [37]. Higher mineralization rates in wet season might also be due to elevated soil temperature and moisture content during this period in the forest ecosystems [38,39]. Favorable microclimate in rainy season may induce microbial activity that accelerates the rate of N_{min} . Decreased N_{min} rates during the winter period could be associated with the low rates of decomposition due to decreased microbial activity and greater immobilization of inorganic N [37]. Seasonal variations in N_{min} rates were significant ($p < 0.05$) in all fallow sites. However, there were no significant N_{min} rates between July 13-Jan 14 and July 13-May 14. The mineralization rates increased significantly ($p < 0.05$) from 3 years to 10 years fallow. This may be due to the accumulation of organic matter and nutrients that have been released to the soil through decomposition during the monsoon season [24].

4.4 Changes in Rice Grain Yield and Productivity in Different Fallows for Three Years Cropping

In a tropical agro-ecosystem, measurement of crop biological productivity is important for agronomic as well as ecological point of view [40]. Fallow length significantly ($p < 0.01$) increased the rice grain yield in the first, second and third years. The grain yield was significantly ($p < 0.01$) greater in the first year cropping compared to the second and third year cropping (Table 3). In the present study, significant enhancement of crop productivity with the length of fallow periods (FL-3 Vs FL-10) has been found to be related to the organic matter accumulation (2 and 12 t ha^{-1}). Addition of greater soil nutrients through previous organic matter accumulation following burning in FL-10 fallow compared to FL-3 fallow may enhance the level of crop productivity in longer fallow. In the present study, maximum rice productivity was recorded in FL-10 compared to FL-3 and FL-5. Higher crop productivity in longer fallow was also reported earlier [41,42]. Greater crop uptake of soil nutrients in the first year cropping to compensate high crop productivity [42] may reduce the soil fertility in the second year and subsequent cropping. This has led to an increase in total productivity and grain yield in first year compared to the second and third year of cropping in all fallows. Decreased productivity from the second and third year cropping has been reported to be related to exhaustion of soil nutrients through run-off, leaching and plant uptake [6,34]. The rice grain yield in the present study was recorded highest (1.1-1.4 $\text{t ha}^{-1} \text{ year}^{-1}$) in the first year followed by (0.58-0.94 $\text{t ha}^{-1} \text{ year}^{-1}$) in the second year and (0.18-0.80 $\text{t ha}^{-1} \text{ year}^{-1}$) in the third year. Higher rice yield in the first year of cropping compared to the second and third could be due to the accumulation of good quality organic matter during burning event [13,24]. The rice yield in the present study is within the range reported in Indian dry-land conditions 600-1800 kg ha^{-1} by Ghoshal and Singh [43], 800-1200 kg ha^{-1} by Kushwaha and Singh [44].

5. CONCLUSION

The length of fallow period plays a vital role in conserving the soil health of shifting cultivation sites in northeast India, particularly in Mizoram. SOC is one of the important parameters that help to affect soil fertility during cropping periods. A fallow period of ca. >10 years can conserve soil

health better during the cropping stages. This study also demonstrates that the fallow age significantly affects total productivity and grain yield during the cropping, especially during first year, possibly as a result of increased accumulation of carbon pool belowground due to mortality of fine roots. Further, the decomposition of fine root helps to improve soil nutrient availability which enhances crop productivity during cropping.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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