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Recovery of Soil Carbon and Nutrients in Forest Chronosequence Following *Jhum* Cultivaion in Mizoram, Northeast India

Etsoshan Y. Ovung S K Tripathi

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ABSTRACT

The undesirable impact of shifting cultivation on soil fertility is one of the global issues whichis mainly becaus of decreased length of fallow periods due to exponential growth of human polulation particularly in tropics. This study is focused on evaluating the carbonrecovery pattern across a chronsequence of *Jhum* fallows in comoparison to natural forest. Two factoor ANOVA analysis showed that SOC and MBC were significantly affected by different *Jhum* fallow ages, soil depth and an interaction of both the cactors ($p<0.05$). In addition, various other soil parameters (WHC, BD, $P_{avail,}$ pH) varied across the different *Jhum* fallows indicating different patterns of nutrient recovery. Present study reflects significant variations in the soil fertility among different fallows and indicated that the soil fertility parameters were significantly correlated with fallow ages and negatively correlated with soil depths. Increase in soil fertility due to fallow is logical as the nutrient builds up during the course of ecosystem recovery. The study indicates that an abandoment period of at least 5-10 years would be required to sustain soil carbon and nutrients in shifting cultivation in this region.

Keywords *Jhum* cultivation, Fallow chronosequence, Nutrient recovery, Soil carbon stock.

Etsoshan Y. Ovung, S K Tripathi

Ecosystem Analys'ss Lab, Department of Forestry, Mizoram University, Tanhril 796004, Aizawl Mizaoram, India
E mail : etso123ovung@gmail.com,
sk_tripathi@rediffimail.com
* Corresponding author

INTRODUCTION

Land use change and deforestation are among the major environmental issues in the recent years, which are still continuing in different parts of the world as a result of growing human population and increasing demand for food and foddar (Tripathi 2009, Tripathi 2010). Such changes are more pronounced in tropical environments (Lalnunzira and Tripathi 20180 and lead to cause various alterations in the ecosystem propertie, for example changing vagetation and soil properties (Tripathi et al 2008, Wapongnungsang et al. 2018). Shifting cultivation is the most common agricultural practices in tropical hilly areas of South-east Asia, latin America, the pacific, Africa and the Caribbean over centuries (Thomaz 2009) . In the past 2 to 3 decades, across South-East Asia, it has been reported that fallow periods have been decreasing down to <5 years due to the rapid increase in the rural population (Anomymous 2009,Schmidt-Vogt et al. 2009). This has led to decrease forest cover, reduce soil fertility and increase soil erosion with reduced annual crop yield (Bruun et al. 2009, Ziegler et al. 2009, Wapongnungsang et al. 2018). In most tropical forest of Northeast India, shifiting cultivation is a common agricultural practice used by many rural populations which serves as the basis of subsistence for the majority of rural populatios (Cairns and Garrity 1999, Grogan et al. 2012). Shifting cultivation involves slashing of vegetation during dry period and burning of the biomass *in situ* after it dried followed by sowing of seeds which coincides with rains that promotes crop growth (Toky and Ramakrishnan1981). generally, after one or occasionally twoyears of cropping, land is abandoned for the recovery of vegetation and soil fertility through natural gegneration over a number of years (Hauchhum and Tripathi 207). During this period *Jhumias* move to other place to select fallow lands for cultivation.

Previously, shifting cultivation was considered as an economically and ecologically efficient cultivation system as long as the fallow period was long enough (~20-30 years) which allowed the vegetation to recover adequate soil nutrients (Bruun et al. 2009, Grogan et al. 2012, Wapongnunsang et al. 2018). In the past few decades, exponential increase in population has led to considerably decrease the length of fallow period (<5 years) which has posed a problem of food security and enviromnental imbalance in the region due to decreased soil fertility in Northeast India (Grogan etal. 2012). Therefore, it is important to know the pattern of recovery of soil carbon and nutrients during the course of ecosystem establishment following shifting cultivation and to suggest optimum fallow ages for the proper management of shifting cultivation in the region.

Impact of Jhum cultivationon soil fertility in Mizoram

Mizoram is one of the eight sister states of North-Eastern part of India.It is tropically hilly areas dominated by tribal communities involved in shifting cultivation practices for their livelihood for centuries. The land for cultivatio in Mizoram is annually allotted to the farmers by the village head. Jhumias in Mizoram usually slash the forest area in the months of December to January and burn the slashed vegetation in-situ in the following months of February to March, followed by sowing /broadcasting of seed of desired crops manually to coincide with the monsoon rains and continue cropping for 1-2 years depending on the soil condition and abandon the land for few years to restore soil fertility (Tripathi et al. 2017). 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 topography is characterized by steep slopes that make the place unique from many others areas in the tropics where shifting cultivation is practiced (Hauchhum and Tripathi 2017). At least 70% of the state's total planimetric land area (@ M ha) is sloped at angles steeper than 33 (Grogan et al. 2012, Tripathi et al. 2017). In rural areas, approximately half of all households in Mizoram are engaged in shifting cultivation. Remote sensing based estimates of the total area burned each year by farmers and wildfires ranges from 40,000-110,000ha (Tawnenga and Tripathi 1996, Anonymous 2009). Basically, this study is focused on evaluating the carbon and nutrient recovery pattern under forest chronosequence following shifting cultivation and a natural forest as control. This study will significantly contribute to our understanding on how the soil properties change under different ages of shifting fallows and suggest management options to speed up the process of recovery in *Jhum* fallow.

MATERIALS AND METHODS

Study area

The study was carried out in Reiek Village in Mamit district of Mizoram. Reiek is located 29 km from the state capital Aizawl and is located between longitude 92°37´ and 93°28´ E and latitude 20°45´ N in the North West of Mizoram in Mamit District (Anonymous 2018). The highest point in Reiek village is the peak of Reiek Tlang which stands at 1465 m amsl. Thetemperature ranges between 8°C – 22°C in winter and 20°C – 28°C in summer. Rainfall is heavy, the average annual rainfall in the district for a period of ten years from 1998–2008 was 2681.97 mm (State Metrological Ceter 2017). The area cover of the various study sites selected for the study ranges within 0.7 to1 ha and the respective GPS coordinates, elevation and of the four study sites, i. e., 1 year *Jhum* fallow (IYJE), 5 year *Jhum* fallow (5YJF), 10 year

Table 1. Study sites along with their GPS coordinates, elevation and major plant species.

Study sites	Co-ordinates with elevation	Vegetative composition
1 year Jham fallow (IYJF)	N234238.3 E09238504 441 m amsl	Ageratum conyzoides, Curcuma longa Thysolaena maxima, Saccharum longiestosum, Bauhinia spp.
5 year Jhum fallow (5 YJF)	N234209.3 E923641.8 1028 m amal	Thysolaena maxima, Toona ciliata, Calicarpa arborea, Litsea chinensis, Melocana baccifera, Schima wallichii, Rhus semialata, Imperata cylindrical
15 year Jhum fallow (15 YJF)	N234238.3 E9238.50.4 690 m amsl	Schima wallichii, Elaeocarpus floribunda,Calicarpa arborea, Derris robusta, Erythrina indica, Albizia chinensis spp., Macaranga spp Castanopsis tribuloides, Michelia champaca, Sterculia villosa
Natural forest (NF)	N234435.7 E923630.8 1198m amsl	Trema orientalis, Toona ciliata, Derris robusta, Schima wallichii Macaranga spp. Melocana baccifera, Albizia spp. Castonopsis tribuloides, Rhus semialata, Litsea chinensis, Litsea chinensis, Derris robusta, Schima wallichii, Macaranga spp. Albizia chinensis , Erythrinaindica, Michelia champaca, Cinnamomum verum

Jhum fallow (10 YJF), 15 year *Jhum* fallow (15 YJF) and naturalforest (NF) mean elevation and some of the major species occurring in the respective sites are highlighted in Table 1.

Soil sampling and analysis

Soil samples were collected randomly from each site from three depths (i.e.0-10, 10-20 and 20-30) using a soil corer with inner diameter of about 5.2 cm. Composite samples (each comprising of 5 soil cores) were drawn at randomfrom the top, middle and base from each study site as well as depth and thus, a total of 45 samples (3 composite samples × 3 soil depths ×5 sites) were processed for analysis. In case of bulk density, 3 soil cores were drawn from each site and from each depth and thus a total of 45 soil samples were collected. Soil samples were then brought into the laboratory and passed through a 2 mm sieve. The soil samples were then divided into two different parts. One part was air dried and one part was freshly stored in -20°C for further bio-chemical analysis.

Bulk density was measured by collecting a known volume of soil and determining the weight after drying (McKenzie et al. 2004). Soil moisture was determined by gravimetric method. Soil texture was determined using the hydrometer method (Bouyocus 1962). The textural classification according to the United States Department of Agriculture (USDA) was followed to give the nomenclature or textural class. The pH of the soil samples was determined using combined glass electrode in suspension of soil : water ratio ratio of 2 : 5 . Available phosphorus (P) was determined following the method outlined by Bray and Kurtz (1945). Soil organic carbon (SOC) was determined following the method given by Walkley and Black (1934). Microbial biomass carbon (MBC) was measured by using chloroforu fumigated and non-fumigated technique as described by vance et al. (1987). Keen box method (Piper 2005)) was followed for determination of water holding capacity (WHC) of soil samples. Soil carbon stock (Mg ha) was calculated by for each depth was computed following the formula given by of Blanco-Canqui and Lal (2008).

SOC stock (Mg ha^{-1}) = 10^4 (m^2/ha) *Soil depth (m)*
BD (Mg/m^3)* SOC % /100
Where, BD is bulk density and SOC is soil
organic carbon concentration

The SOC stock for all soil depths was summed to obtain the total SOC stock for 0—30 cm depth. The magnitude of loss in SOc stock was calculated by subtracting the SOC stock of the respective forest fallows from that for the control site (NF).

Table 2. Effects of different sites (1 year fallow-1 YF, 5 year fallow-5 YF, 15 year fallow- 15 YF and natural fallow/forest-NF) and soil depth (0-10, 10-20 and 20-30 cm) on soil physical properties (SMC-Soil moisture content, WHC-Water holding capacity, BD-Soil bulk density)*Two factor ANOVA following LSD result show significant difference between sites and depths at $p<0.05$. Represents sites and D-Indicates soil depth.

	Soil physical properties						
Sites	Sand %	Silt %	Clay %	Textural class	SMC%	WHC%	BD (g/cm^2)
1YF							
(0-10)	72.7 ± 1.2	9.6 ± 1.9	17.7 ± 0.9	Sandy loam	19.0 ± 0.4	41.8 ± 0.54	1.01 ± 0.01
(10-20)	66.7 ± 1.0	10.4 ± 0.3	22.9 ± 1.0	Sandy clay loam	19.3 ± 0.34	45.9 ± 0.34	1.25 ± 0.01
(20-30)	68.6 ± 1.4	5.62 ± 2.1	25.7 ± 1.2	Sandy clay loam	21.0 ± 0.7	48.3 ± 0.18	1.30 ± 0.10
5 YF							
(0-10)	70.5 ± 1.1	6.83 ± 0.9	22.6 ± 0.2	Sandy clay loam	19.1 ± 1.5	47.1 ± 0.64	1.21 ± 0.02
(10-20)	62.7 ± 0.9	11.6 ± 0.3	25.7 ± 1.3	Sandy clay loam	19.0 ± 0.7	52.9 ± 0.54	1.27 ± 0.18
(20-30)	63.6 ± 1.9	8.87 ± 0.4	27.5 ± 1.9	Sandy clay loam	21.2 ± 0.3	55.9 ± 0.57	1.28 ± 0.01
15YF							
(0-10)	64.4 ± 0.9	12.4 ± 08	23.0 ± 0.2	Sandy clay loam	24.2 ± 5.2	52.1 ± 0.64	1.16 ± 0.02
(10-20)	68.6 ± 0.9	7.6 ± 1.2	23.8 ± 0.3	Sandy clay loam	23.1 ± 3.6	58.9 ± 0.47	1.23 ± 0.01
(20-30)	62.6 ± 1.1	12.0 ± 0.9	2.5 4 ± 0.2	Sandy clay loam	23.4 ± 2.8	60.7 ± 0.81	1.26 ± 0.02
NF							
(0-10)	64.6 ±1.0	12.8 ±2.1	22.6 ± 1.0	Sandy clay loam	31.9 ± 0.6	56.3 ± 1.90	0.84 ± 0.01
(10-20)	62.5 ± 1.3	10.3 ±2.2	27.2 ±1.2	Sandy clay loam	26.2 ± 1.3	60.7 ± 1.69	1.09 ± 0.13
(20-30)	64.5 ± 1.4	4.6 ±0.9	30.98 ±1.4	Sandy clay loam	18.3 ± 3.2	65.8 ± 1.49	1.27 ± 0.04
$LSD_{0.05}$							
S=	2.007	NS	1.82	–	2.25	1.912	0.133
D=	1.738	2.02	1.576	–	1.949	NS	0.116
S × D	3.477	NS	3.153	–	3.897	3.312	NS

Statistical analysis and tools

Two way analysis of variance (ANOVA) followed by Least Significant Difference (LSD) were calculated and analyzed using open source OPSTAT free Online Agriculture Data Analyses Tool created by OP Sheoran, computer Program at CCS HAU, Hisar, India to compared the significant difference of sites × depths along with their interaction.

RESULTS AND DISCUSSION

The soil physical and bio-chemical characteristics of the study sites are shown in Tables 2 and 3. The soil properties differed significantly among the various *Jhum* fallows and natura forest. Most of the soil properties were recorded postitively in the natural forest (NF) followed by 15 years *Jhum* fallow (15YJF). It could be observed that the soil physical properties varied significantly among the different depths.

Soil physical properties

Soil moisture content (SMC%) was found to be significantly affected by various depths as well as by different sites ($p<0.05$). In case of SMC, the highest value was observed in the surface layer (0-10cm) of NF (325) and the lowest was observed in 1YJF with as low as (19%). It was found that SMc decreased with increasing depth in NF, 15YJF and % YJF while in the 1 YJF effect of depth on soil moisture was found to be non-significant. The higher moisture content in the NF and 15 YJF may be attributed to the high organic matter deposition due to the higher and continuous vegetation cover. Soil bulk density (BD) wasrecorded to be the lowest in the surface soil (0-10 cm) of NF in comparison to all the other shifting fallows (Table 2) As a general trend, BD was found to increase with increase in soil depth and also varied significantly among the various sites ($p<0.05$). This may be well attributed to the decreasing organic matter with increasing depth. Lower BD values in the case of NF and 15 YJF can be a direct result of continuous vegetation over the years leading to higher organic matter build-up in the surface soil than in the lower depths as supported by similar findings by Biswas et al. (2012) and Lalnunzira and Tripathi (2018). It was also observed that clay content increased with increasing depth which may have contributed to the escalation of BD with increasing depth in all the study

Table 3. Effects of different sites (1) year fallow-1YF, 5year fallow-5YF, 15 year fallow-15YF and natural forest-NF) and soil depth (0-10, 10-20 and 20-30 cm) on soil pH, soil organic carbon (SOC), available phosphorus (P_{avail}) and soil microbial biomass carbon (SMBC). Two factor ANOVA following LSD result show significant difference between sites and depths at P<0.05 S-Represets sites and D -Indicates soil depth.

		Soil bio-chemical properties		
Study sites	pH	SOC %	Pavail (mg kg^{-1})	SMBC (mg/kg^{-1})
1 YJF				
(0-10)	4.4 ± 0.15	1.9 ± 0.16	1.70 ± 0.88	302.44 ± 23.51
(10-20)	4.1 ± 0.23	1.44 ± 0.14	1.10 ± 0.24	179.66 ±10.28
(20-30)	4.1 ± 0.07	0.96 ± 0.10	0.6 ± 0.13	94.79 ± 22.58
5 YJF				
(0-10)	4.6 ± 0.15	2.34 ± 0.12	2.45 ± 0.33	365.53 ± 22.15
(10-20)	4.4 ± 0.49	1.86 ± 0.07	1.91 ± 0.05	259.99 ± 18.6
(20-30)	4.1 ± 0.03	1.56 ± 0.19	1.45 ± 0.25	114.72 ± 15.8
15 YJF				
(0-10)	4.9 ± 0.26	3.12 ± 0.09	4.2 ± 0.83	428.22 ± 15.72
(10-20)	4.5 ± 0.30	2.44 ± 0.17	2.16 ± 0.37	312.02 ± 25.51
(20-30)	4.3 ± 0.09	1.78 ± 0.12	1.8 ±0.11	164.58 ± 13.98
NF				
(0-10)	5.8 ± 0.43	4.4 ± 0.12	5.4 ± 0.69	553.32 ± 67.85
(10-20)	4.7 ± 0.06	2.88 ± 0.22	2.52 ± 0.69	347.16 ± 25.51
(20-30)	4.4 ± 0.09	1.98 ± 0.17	1.57 ± 0.07	169.71 ± 9.61
LSD $_{0.05}$				
S=	0.121	0.251	0.291	33.495
D=	0.105	0.217	0.251	29.007
S × D=	0.21	0.435	0.504	58.015

sites. The higher clay content with increasing depth-which may have contributed to the escalation of BD with increasing depth in all the study sites. The higher clay content with increasing depth also explains the icreasing soil water holding capacity (WHC) since clay and silt particles are known to trap water readily. Sand content was high in almost all the study sites and it was observed that different sites, soil depth and an interaction of both factors had a significatnt effect ($p<0.05$) on both percent sand and clay contents. Sandy clay loam was the most common tetural class observed inalmost all the study sites and soil depths.

Soil biochemical properties

Soil pH was observed to be higherly acidic in the 1YJF with pH values as low as 4.4 in the 0-10 cm soil depth which decreases with incresing depth suggesting higher acidity in the lower depths than the upper surface (Table 3). Two-factor ANOVA revealed that soil pH was significantly affected by different sites as well as by different soil depths ($p<0.05$). NF and 15YJF showd higher pH in the surface layer in comparison to the rest of the sites. Available phosphorus (P_{avail}) was found to be significantly affected by different sites, soil depths as well as an interaction of both the factors ($p<0.05$). Concentration of P_{avail} was significantly higher in NF than in *Jhum* fallows (Table 3). Phillips and Fahey (2006) reflected that the root system of a tree enhances extractable P,presumably the mycorrhizal fungi and other microbes associated with roots induce the release of phosphatase enzymes which help to release organically bound P into plant available P. In addition, a significant amount of root exudates are released into the soil from plant roots. It enhances the availability of P in soil solution and therefore the higher values of available P in the NF soil than in soils of *Jhum* fallows.

Soil organic carbon (SOC) was significantly affected by different sites and soil depths ($p<0.05$). The interaction of both these factors were also significant ($p<0.05$). It was observed that SOC was higher in NF and decreased in the order of 15YJF<5YJF<1YJF (Table 3). The percent concenttration of carbon was higher in the surface layer of NF (4.4%) followed by 10-20 cm (2.88%) and 20-30 cm (1.98%0 while the least was observed in 1 YJF in all the soil depths with value as low as 0.96% (20-30 cm). The higher values of soil organic carbon in NF may be attributed to the dense vegetation cover leading to higher accumulation of organic matter supporting a larger population of micro-organisms. In addition, the profuse roots of the vegetation in NF and 15 YJF may lead to increase the concentration of soil C than the other younger *Jhum* fallow sites. Soil microbial biomass carbon (SMBC) was highest in the NF and decreased in the order : 15YJF<5YJF<1YJF (Table 3). SMBC decreased considerably with increasing depth and the highest value of SMBC was recorded in NF in the surface soil layer of 0-10 cm (522 mg kg) and the lowest in 1 YJF with value 302 mg kg at 0-10 cm soil depth. SMBC was found to be significantly affected by increasing depth and sites ($p<0.05$). Their interactions were also significant. Higher SMBC in NF is related to relatively higher plant litter inputs that support a larger microbial activity due to the availability of above and below ground carbon sources (Nsabimana et al. 2004, hauchhum and Tripathi 2017. Increased amount of SOC enhances the growth and multiplication of microbes leading to higher accumulation of microbial biomass in the soil. In general, SMBC is higher in ecosystems that experience permanent inputs of organic residues as found in native forest or regererated lands (Hackl et al. 2004) and decreases with increasing depth.

Impact of land use on soil carbon stock under shifting cultivation

Soil carbon stock (C stock) was highest in the surface layer (0-10 cm) of NF and decreased in the order of : 15 YJF<5YJF (Fig. 1). Significant variations in C stock among different sites and depths ($p<0.05$) was observed . Our results signify that trees and other potential shrub species are the most important components in these ecosystems for enhaning soil carbon storages and thus, improving soil heath in general. Total C stock (0-30 cm) was found to be significantly affected by different sites ($p<0.05$), where the highest C stock was recorded in NF with a value of 94.4 Mg/ha and followed a decreasing trend of c stock in the forest fallows in the order, 15YJF<5YJF<1Yjf (Fig. 2). It was also reported that the loss of C stock in the 30 cm soil layer was higher in the 1 YJF followed by 5 YJF and the lowst in 15 YJF (Fig. 3) with respect to

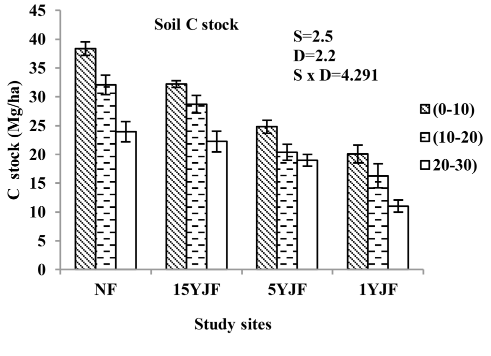

Fig. 1. Changes in soil carbon stock in forest chronosequence (1) year fallow-1 YF, 5 year fallow-5 YF, 15 year fallow-15 YF and natural fallow/forest -NF) and soil depth (0-10, 10-20 and 20-30 cm). Two factor ANOVA following LSD result show significant difference between sites and depths at $p<0.05$). Interaction of sites and soil depth was also significant S represents sites and D indicates soil depth.

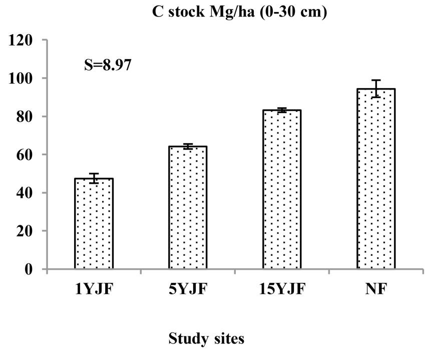

Fig 2. Total soil carbon stock in forest chronosequence (1 year fallow-1 Yf, 5 year fallow-5YF, 15 year fallow-15YF and natural fallow/forest-NF cm). One way ANOVA following LSD result showing significant difference between sites and depthas at $p<0.05$).

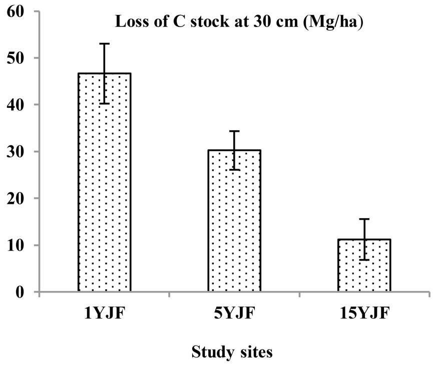

Fig. 3. Loss of C stock following-conversion from NF to different fallow ages (1 year fallow-1 YJF fallow-5YJF fallow-5YF, 15 year fallow-15 YJF) at 30 cm soil depth.

Table 4. Coefficients of Pearson's correlation between soil paramaters at 0-10 cm depth in varions land use types (*) : $p<0.05$, (**) $p<0.01$.

(0-10) cm	Sand	Silt	Clay	WHC	MC	BD	pH	P_{avail}	MBC	SOC
Sand	1									
Silt	**-0.881**	1								
Clay	-0.436^{NS}	-0.042^{NS}	1							
WHC	-0.799*	0.447^{NS}	**0.836****	1						
MC	-0.579^{NS}	0.514^{NS}	0.245^{NS}	0.380^{NS}	1					
BD	0.343^{NS}	-0.501^{NS}	0.228^{NS}	0.054^{NS}	**-0.819***	1				
Soil pH	-0.507^{NS}	0.573^{NS}	-0.018^{NS}	0.331^{NS}	**0.751***	-0.689^{NS}	1			
P_{avail}	**-0.735***	0.411^{NS}	**0.770***	**0.799***	0.689^{NS}	-0.363^{NS}	0.373^{NS}	1		
MBC	**-0.713***	0.465^{NS}	0.621^{NS}	0.704^{NS}	**0.877****	-0.534^{NS}	0.641^{NS}	**0.912****	1	
SOC	**-0.752***	0.553^{NS}	0.535^{NS}	0.691^{NS}	**0.900****	-0.651^{NS}	0.704^{NS}	**0.903****	**0.959****	1

NF. this is obvious since longer recovery period leads to larger accumulation of litter inputs which gradully sequesters maximum soil C.

Pearson's correlation analysis between different soil parameters at different soil depths

It is evident from the correlation matrices (Tables 4—6) that a strong negative correlation of sand with WHC, Pavail, MBC and SOC is observed in the surface soil layer (0-10), whereas strong positive correlations of MBC and SOC with WHC could be observed throughout the soil depths observed (0-10, 10-20 and 20-30 cm). SMC was found to have a strong positive correlation with SOC and MBC at the surface and sub-surface layer i.e. 0-10 and 10-20 cm. This indicates that soil moisture content and WHC affects the concentration of soil chemical properties and also enhances soil biological activity and vice-versa.

Table 5. Coefficients of Pearson's correlation between soil parameters at 10-20 cm depth in various land use types (*), $p<0.05$, (**) $p<0.01$.

(10-20) cm	Sand	Silt	Clay	WHC	MC	BD	pH	Pavail	MBC	SOC
Sand	1	**-0.722***	**-0.723***	-0.034^{NS}	-0384^{NS}	0.437^{NS}	-0.384^{NS}	0.436^{NS}	-0.251^{NS}	-0.234^{NS}
Silt		1	0.043^{NS}	-0.503^{NS}	0.053^{NS}	-0.185^{NS}	0.385^{NS}	-0.527^{NS}	-0.286^{NS}	-0.351^{NS}
Clay			1	0.550^{NS}	0.502^{NS}	-0.446^{NS}	0.170^{NS}	-0.104^{NS}	0.649NS	0.688^{NS}
WHC				1	0.624^{NS}	-0.441^{NS}	0.105^{NS}	0.416^{NS}	**0.933****	**00.959****
MC					1	-0550^{NS}	**0.818***	0.032^{NS}	0.691^{NS}	0.766*
BD						1	-0.427^{NS}	0.025^{NS}	-0.487^{NS}	-0.496^{NS}
pH							1	-0.359^{NS}	0.170^{NS}	0.272^{NS}
P_{avail}								1	0.502^{NS}	0.375^{NS}
MBC									1	**0.974****
SOC										1

Table 6. Coefficients of Pearson's correlation between soil parameters at 20-30 cm depth in various land use types. (*) : $p<0.05$, (**) : $p<0.01$.

(20-30) cm	Sand	Silt	Clay	WHC	MC	BD	pH	Pavail	MBC	SOC
Sand	1									
Silt	-0.634^{NS}	1								
Clay	-0.279^{NS}	-0.566^{NS}	1							
WHC	-0.633^{NS}	0.385^{NS}	0195^{NS}	1						
MC	0.145^{NS}	0.310^{NS}	-0.540^{NS}	-0.290^{NS}	1					
BD	-0.035	0.221^{NS}	-0.238^{NS}	-0.130^{NS}	-0.040^{NS}	1				
pH	-0.253^{NS}	0.504^{NS}	-0.356^{NS}	**0.741***	0.045^{NS}	0.274^{NS}	1			
P_{avail}	-0.109^{NS}	0.123^{NS}	-0.037^{NS}	**0.781***	-0.1664^{NS}	-0.427^{NS}	0.669^{NS}	1		
MBC	-0.732*	0.352^{NS}	0.343^{NS}	**0.965****	-0.395^{NS}	-0.026^{NS}	0.638^{NS}	0.606^{NS}	1	
SOC	-0.567^{NS}	0.010^{NS}	0.592^{NS}	**0.774***	-0.574^{NS}	-0.202^{NS}	0.245^{NS}	0.463^{NS}	**0.857****	1

Similar positive significant correlation has also been found between SMBC and SOC from a study by Bhuyan et al. (2013) in Arunachal study by Bhuyan et al. (2013) in Arunachal Pradesh Agro-ecosystems.

CONCLUSION

The present stuy reflects significant variatioons in the soil fertility among different fallow and indicated that the soil fertility parameters were significantly correlated with fallow ages and negatively correlated with soil depths. Increase in soil fertility due to fallow is logical as the nutrient builds up during the course of ecosystem recovery. The study indicates that an abandonment period of at least 5—10 years is recommendable for satisfactory recovery of soil carbon and nutrients in Mizoram for sustained crop production practices. However, due to increased demands, the fallow period has been drastically reduced to 2-3 years which is quite deleterious to soil health and can cause an irreversible damage to land. Thus, there isa need for intervention of innovative policies and sustainable management practices (e.g.,fast growing and N fixing trees/ shrubs as fallow species) so as to improve soil health and promote sustainable use of fallow lands without compromising the economic as well as the ecological aspects.

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