Original Research

Science Vision 16 (3)
July-September
ISSN (print) 0975-6175
ISSN (online) 2229-6026

Impact of shifting cultivation on soil organic carbon in tropical hilly terrain of Mizoram, India

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Received 1 7 August 2016 | Revised 8 September 2016 | Accepted 17 September 2016

Abstract

Shifting cultivation is one of the main forms of crop husbandry in the hilly northeast India and is known to change the physico-chemical properties of soil. Data of soil organic carbon (SOC) in relation to shifting cultivation is not available in Mizoram. The study was conducted in an experimental plot of 1-acre area in the natural forest at Khawrihnim village located about 50 km southwest of Aizawl, Mizoram. Five random soil samples each were collected from shifting cultivation (experimental EXPTL) and natural forest (control CTRL) sites at monthly intervals between 2013 and 2015 at three different soil strata (i.e. 0-10 cm, 10-20 cm and 20-30 cm). SOC was estimated in percent by rapid dichromate oxidation method. Shifting cultivation has positive significant effect on SOC content. Compare to pre- and post-Jhum cultivation, the Two-Way ANOVA indicates significant increased of SOC (p<0.05) in the jhum cultivation year, which may be due to burning effect and the weeding practice that coincides with the onset of monsoon rains. The onset of monsoon after the burning of slashed vegetation and the first weeding accelerate the decomposition rate and soil microbial activity. The average of SOC in the surface layer increased from first year to third year by 1.34%. However, significant decreased of SOC content with increased in soil depth (p<0.001) was also recorded in both EXPTL and CTRL sites.

Key words: Shifting cultivation; jhuming; strata; soil organic carbon; Mizoram.

Introduction

Shifting cultivation basically involves three phases, conversion of forest by clearing a specific area by slashing vegetation and burning, cultivation of crops for a year or rarely two years, followed by a variable fallow period.[1-3] It is a common agricultural practice in tropical hilly areas of Southeast Asia, the Pacific, Latin America, the Caribbean and Africa.[4-11] Shifting cultivation is one of the main forms of crop husbandry in north east India and locally known as *jhuming* whereas the cultivators are known as the *jhumias.*[12] Shifting cultivation systems and their

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impacts on soil and vegetation have been studied by some research groups.[3,13-18]

It had been reported that the negative influence of shifting cultivation is lowering soil fertility, increased soil erosion, reduced annual crop yields and watershed siltation,[4,19-21] land degradation by encouraging erosion of fertile topsoil with ultimate exposure of rocks.[2] Washed away of considerable amount of nutrients from the upper 10 cm soil with run off sediments[22-23] and a significant reduction in the organic matter content also reported.[24] Reduced fallow cycle is reported as a threat to biodiversity and soil conservation.[25-26] There are reports that growing annual crops by slash and burn on steep slopes has adversely affected the forest, land and environment.[22,27-28]

In contrary to above observations, Sharma[29] observed that shifting cultivation causes least disturbance to soil, build up natural fertility through remains of mixed cropping in moderate to steep slopes with minimum tillage under rainfed condition depending on local resources. A number of scientists argued in favour of the positive environmental impacts of shifting cultivation.[3,30-31] In contrast to many policy-makers, shifting cultivation is now considered as highly ecologically and economically efficient agricultural practice provided that the fallow period is sufficiently long.[3,4,6,7,21,32]

Soil organic carbon is one of the most important indicators of soil quality and fertility. Soil holds a very important role in global carbon cycle, as soil is the largest pool of terrestrial organic carbon in the biosphere, storing more carbon than is contained in plants and the atmosphere.[33] The role of organic carbon as a key control of soil fertility and agricultural production has been recognized for more than a century.[34]

There is considerable concern that shifting cultivation may lead to a depletion of soil carbon and consequent increase of CO_2 in the atmosphere.[35] Detwiler[36] estimated that shifting cultivation results in an average 40% loss of soil carbon, each within 5 years. Indian Council of Agricultural Research[37] reported lost of soil organic carbon due to shifting cultivation.

Literature on soil organic carbon under shifting cultivation in Indian context is scanty. Jenny and Raychaudhuri[38] studied carbon status in India. Choudhury *et al.*[39] reported the distribution on organic carbon stocks in northeast India excluding Mizoram. Devi and Choudhury[12] works on soil fertility status in relation to fallow cycles and landuse practices in shifting cultivated areas of Chandel district, Manipur. Hattar *et al.*[40] reported that the organic carbon was distinctly high (16.61%) in forest soil in comparison to jhum land (2.78%) in the surface soil from their studies in northeast India. Bhuyan *et al.* reported soil properties under agroforestry system of Arunachal Pradesh.[41] Bhunia *et al.* works on SOC under different landuse of West Bengal.[42] Namei *et al.* reported the impact of shifting cultivation on soil of Nagaland.[43]

There is a complete lack of information on the impact of shifting cultivation on soil organic carbon in Mizoram. Lalthanzara *et al.* carried out works on soil organic carbon under agroforestry system.[44] Vanlalfakawma *et al.* studied soil carbon pools of bamboo forests of Mizoram.[45] Apart from this, impacts of shifting cultivation on soil organic pool in tropical hilly terrain of Mizoram is not recorded. Hence, there is a need of systematic studies on the effects of shifting cultivation on soil organic carbon level. Thus the present work is undertaken to answer the questions on what are the levels of soil organic carbon in pre-jhuming, jhuming and post-jhuming soil. Are there any significant changes in soil organic carbon due to shifting cultivation (jhuming).

Materials and Methods

Study site

Mizoram having an area of 21,081 sq. km located in Northeast India lies between 21°56'N and 24°31'N latitude, 92°16'E and 93°26'E longitude and is sandwiched by Bangladesh in the west and Myanmar in the east and south. This hilly state covered with tropical and subtropical forests is a part of Indo-Myanmar Biodiversity Hotspot. We focus on the distinctive features of shifting cultivation by Mizo tribe in steep slope hilly regions of northeastern India. At least 70% of the state's total planimetric land area (2,108700 ha) is sloped at angles steeper than 33 and approximately more than half of all households in Mizoram state are engaged in shifting cultivation.[46,47] Shifting cultivation in this area involves cutting of vegetation in the month of December or early January, and then burned the dried vegetations in early March or even up to April. Sowing of seeds in the month of April/ May and the first weeding was carried out in June. The cropping system is of mixed cropping, where all kinds of crops were grown with rice as the main crop. Weeding using a hand hoe is usually carried out three times a year, whereby weeds were pulled-out along with roots and upper fertile soil was roughly tilled with hand hoe. Soil of Mizoram is slightly acidic; normally soil pH ranges from 4.5-7. It receives an annual rainfall of about 2500mm.

The study was conducted at an experimental plot of one acre of natural forest at Khawrihnim village (23°36'58" N and 92°38'04" E) located at 50 km south-west of Aizawl, the capital city of Mizoram. The plot was divided into control (CTRL, the natural forest) and experimental (EXPTL, Jhum cultivation) sites (figure 1). The land and vegetation have been left undisturbed since last 30 years. The landscape is steep with a slope percentage ranging from 55% to 80%.

Soil sampling and analysis

Five random samples of soil were collected from each site, located at least 10m apart at monthly intervals during January 2013 to July 2015.[48] Soil samples were collected by digging from three strata, at a depth of 0-10cm, 10-20cm and 20-30cm. The collected soil samples were then oven-dried at 104˚C for 24 hours, ground with a mortar and pestle, sieved through 0.2mm sieve and organic carbon was estimated by rapid dichromate oxidation method.[49]

Statistical analysis

Statistical analysis of soil organic carbon was performed using Normality test, independent T test and Two-Way ANOVA with SPSS 20.0 program. The data from three layers of soil depths and Jhum phases (Pre-Jhuming, Jhuming and Post-Jhuming) were analyzed separately.

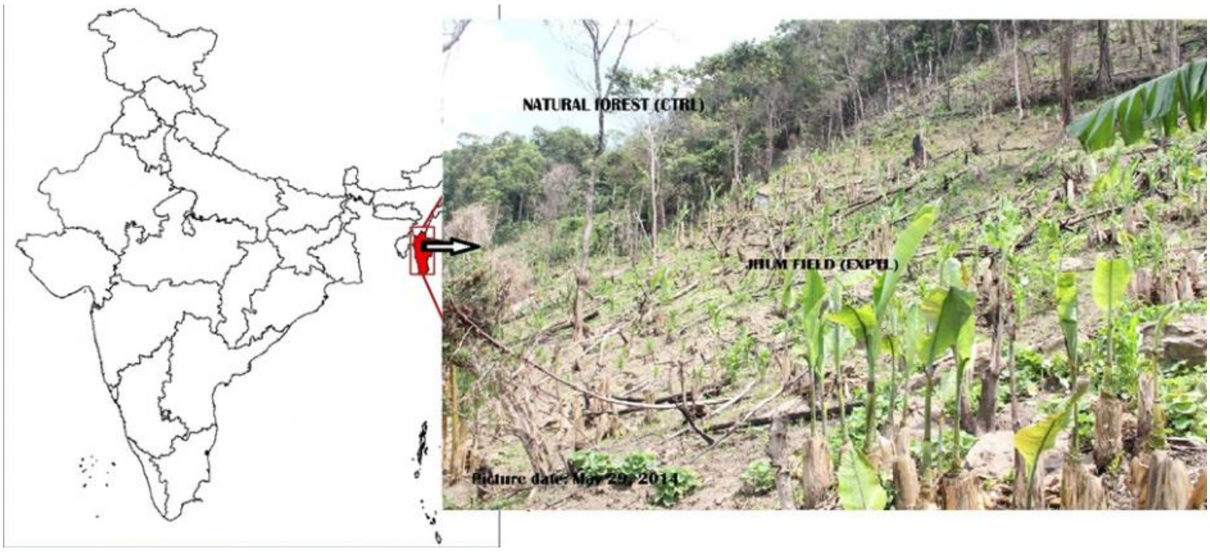

Figure 1. Study site

The data was first test for its fitness for T-test analysis by normality test. The normality test was performed by Shapiro Wilk Test and it was found that the data follows normal distribution at 5% level, and hence it fits for parametric analysis. Thus, the depth-wise comparative analysis of organic carbon was carried out by independent T test while the year-wise comparison was analyzed by Two-Way Anova.

RESULTS

The soil organic carbon content of three soil horizons 0-10 cm, 10-20 cm and 20-30 cm determined for pe-jhuming, jhuming and post- jhuming year at CTRL and EXPTL sites are presented in figure 2 and 3, and the mean values with standard error are presented in table 1. Soil organic carbon concentration was highest in the surface layer (0-10cm) with 2.255% at EXPTL and 2.278% at CTRL site respectively. The carbon concentration decreased with increased in depth (Table 1). In the uppermost layer (0-10cm), the highest value of organic carbon recorded is 3.28% in July 2014 at EXPTL whereas it is 3.18% at CTRL site in the month of March 2014, both in jhumed year. At a depth of 10-20cm, highest record is 2.73% and 2.54% at EXPTL (May 2014) and CTRL (February & April 2015) respectively. The lowest stratum (20-30cm) records a comparatively low carbon with the highest record of 2.0% (July 2014) and 1.49% (March 2013) at EXPTL and CTRL respectively. The mean values of SOC at 0-10cm are 2.255±0.51 and 2.278±0.40 at EXPTL and CTRL sites respectively. For 10-20cm and 20-30cm depths the SOC values are given in table 1.

Statistical analysis with independent T-test indicates that there is no significant variation of organic carbon between the two sites in all three layers (Table 1) (p=0.846 at 0-10cm, p=0.965 at 10-20cm and p=0.435 at 20-30cm depth. Meanwhile, a significant decline of SOC with increase in soil depth (p<0.001) was observed (table 2).

It was observed that the SOC was highest during rainy season that starts from May to September in EXPTL site in all three soil strata (fig.2). It was observed that there was a sharp increased in SOC during monsoon period in EXPTL site compared to CTRL site (fig. 2 & 3). Thus, a significant effects of jhuming on SOC was also noted in year-wise comparison of pre- and post- Jhuming by Two-Way ANOVA (p<0.05) in the jhum cultivation year (table 2) and the same has been depicted in figure 2. The SOC of the upper layer of the EXPTL site in pre -jhuming is 2.224±0.35, in jhumed year it is 2.490±0.47 and the post-jhuming value comes down to 2.255±0.51, but still higher than pre-jhuming.

Table 2. Tests of Between-Subjects Effect (Two-Way ANOVA)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Year	.914	2	.457	3.509	.032
Depth	31.111	2	15.556	119.431	.000

Table 1. Independent Sample T test of SOC at different soil strata

Soil Depth	Mean ± SEM		n	t	df	SE diff.	*p* value
	Control	Experiment					
0-10 cm	2.278±0.073	2.258±0.091	31	-0.195	60	0.117	0.846
10-20 cm	1.758±0.056	1.762±0.078	31	0.043	60	0.096	0.965
20-30 cm	1.285±0.024	1.228±0.069	31	-0.786	60	0.073	0.435

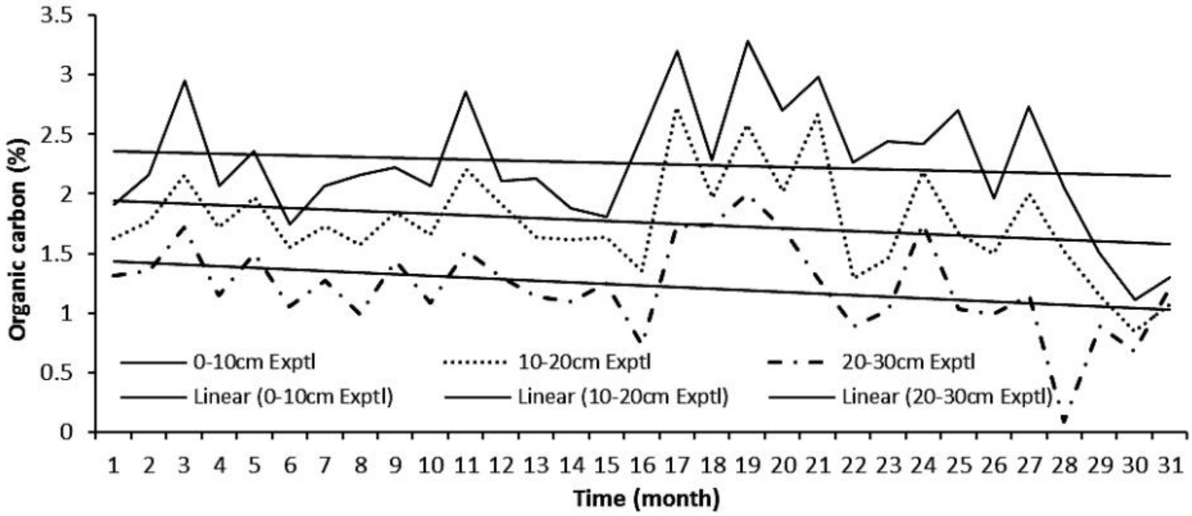

Figure 2. SOC (%) vertical distribution in EXPTL (Jhum) site (January 2013 – July 2015).

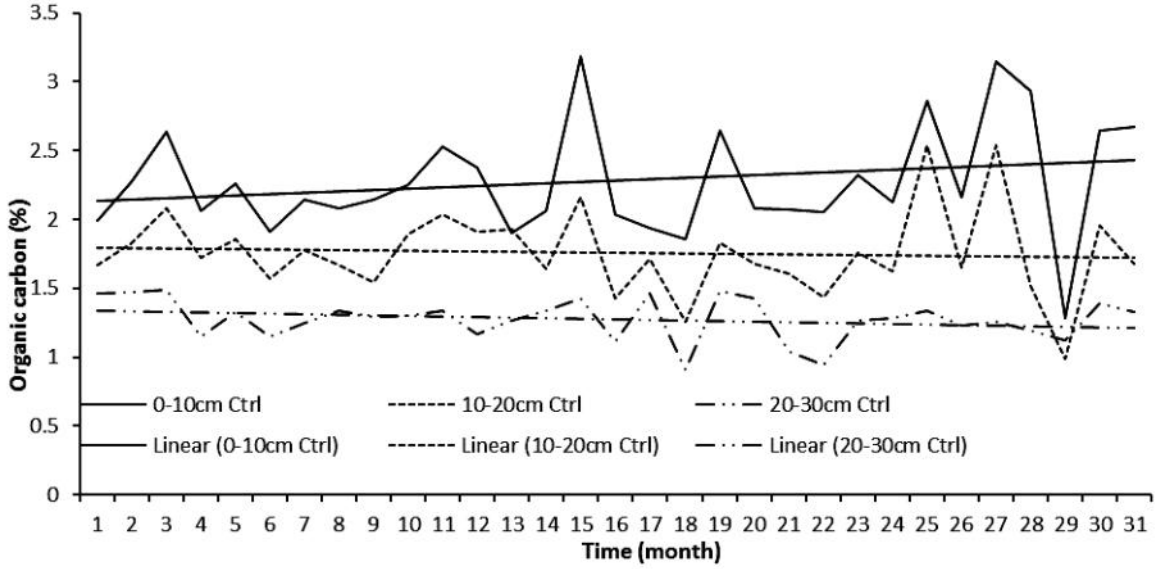

Figure 3. SOC (%) vertical distribution in CTRL (Natural forest) site (January 2013 – July 2015).

DISCUSSION

Shifting cultivation changes the physical, chemical and biological properties of the soil due to changes in quality and quantity of organic carbon inputs into the soil.[50] Conversion of forest into jhum field/cropland generally leads to reduction of organic carbon content.[51] The present finding agreed well with the findings of Bhuyan *et al.*[41] (Arunachal Pradesh, NE India), Bhunia *et al.*[42] (West Bengal, NE India) and Namei *et al.*[43] (Nagaland, NE India) under shifting cultivation in depth-wise reduction of soil organic carbon. Moreover, Haiderer, reported that similar pattern of SOC vertical distribution was observed in Europe.[52]

The maximum value of SOC coincide with mid-rainy season at EXPTL in this study may be attributed to rapid decomposition of seasonal weeds due to microbial activities and partial tilling of surface soil by local weeding practice that results in quick mineralization of plant carbon to soil. Carbon stocks in the soil could be affected by the accumulation and decay of organic matter in the areas. Thus, high level of SOC may also be attributed to burning of slashed vegetation in the month of March, which leaves ashes and incompletely combusted particulates depending on the intensity of the burn.[53] Furthermore, in line with our finding, Nye and Greenland opined that decaying roots from felled and burned forest vegetation might contribute soil organic matter following conversion of forest to jhum land.[54]

No significant difference of SOC between EXPTL and CTRL at all three soil layers (table 1) during the course of study may be due to consideration of the pre- and post- cultivation data in the analysis. Out of the three years duration, the cultivation time spans for one year only. However, a significant increased of SOC during Jhum cultivation (p<0.05) detected by comparing year-wise data of pre-jhuming, jhuming and post- Jhuming is attributed to decomposition of weeds and leaf litter and partial tilling of surface soil. Ellert and Gregorich explain the possibility by assuming that when soil is cultivated, decomposition is enhanced because disturbance or tillage physically fragments and redistributes residues.[55] Boyer and Groffman, also reported that the concentrations of water-soluble and bioavailable SOC were higher in agricultural soils than in forest soils.[56]

However, the trend line (Fig. 2) clearly shows a decline in average soil carbon in EXPTL site while it is more or less same in the CTRL site (Fig. 3). This kind of negative effect of jhuming/ slash and burn cultivation on SOC concentration has been recorded by a number of researchers. Davidson and Ackerman showed a decline in soil carbon after cultivation by about 30%.[57] Murty *et al.* observed a decline in soil organic carbon upon conversion of forest into agricultural land.[58] In support to this, Andriesse and Schelhaas report soil carbon losses from slash-and-burn in Thailand and Sri Lanka,[45] and Woomer *et al*. in coastal sand dune forests in Mozambique.[59] Rapid decline of SOC levels with continuous cultivation of crops in West Africa was reported by Bationo *et al*.[60] Ellert and Gregorich explain the possibility that after decomposition, soil C is rapidly oxidized to CO_2 and is lost to the atmosphere.[55] However, such declines are known to be site-specific and heavily depend on management practices such as the choice of the cropping system, soil tillage and the application of mineral and organic soil amendments.[61,62] Boyer and Groffman, reported the same observation and they are of the opinion that the difference was restricted to the surface layers only.[56]

In conclusion, SOC was increased by jhuming activities, which may be due to burning effect and the traditional weeding practice that coincides with the onset of monsoon rains, but gradually decreased in the subsequent years. Thus from our results and assessment of other studies it may be inferred that SOC in soil undergoing conversion by slash-and-burn is susceptible to loss under controlled burns and tillage. As observed elsewhere, we also recorded a significant decrease in organic carbon with increasing soil depth.

ACKNOWLEDGEMENT

We are thankful to Dr. Tawnenga, Principal, Pachhunga University College, Aizawl, Mizoram for warm administrative and infrastructural support. Thanks are also extended to Dr. K. Lalchhandama, Head, department of Zoology, P.U. College for constant encouragement and Mr. Lalpawimawha, department of Statistics, P.U. College for his help in data analysis. We are grateful to Mr. H. Zahmingthanga, Khawrihnim village, Mamit district, Mizoram for work permission to his jhum field for carrying out our experiment.

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