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Impact of secondary forest fallow period on soil microbial biomass carbon and enzyme activity dynamics under shifting cultivation in North Eastern Hill region, India

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ABSTRACT

Length of the secondary forest fallow period has often played an important role in affecting the soil fertility status for first year cultivation of crops in shifting cultivation system. However, information regarding the soils after the first year cultivation is limited. The objective of the study was to assess the effect of different shifting cultivation fallow period on the dynamics of soil health status during the first and second year. Results suggest that increase in the fallow period significantly ($p < 0.05$) decreased the bulk density (BD), while increasing the soil organic carbon (SOC), soil nutrients, MBC and enzyme activities. While the SOC decreases between 6.1 and 31.3% due to cultivation compared to the soil condition before burning during the first year, MBC decreases between 33.61 and 60.9%. The SOC was recovered at the end of second year, while the MBC increases sharply during the second year. Enzyme activities in general decreased after burning and increased gradually during the second year. PCA results indicated that length of fallow period > 10 year maintains one cluster where fallow period including 10 and below maintains another cluster during the first and second year. Results therefore suggest that MBC, MBC:SOC and soil enzyme activities played as an indicator of soil health and maintaining secondary forest fallow period > 10 years was better in conserving soil health for first and second year under shifting cultivation.

1. Introduction

Shifting cultivation involves burning of slashed native vegetation, followed by cultivation of crops. Shifting cultivation has been practiced as an indigenous subsistence farming in the hilly tracts of Latin America, Central Africa and Southeast Asia for ages (Inoue et al., 2010; van Vliet et al., 2012). Although the negative impact due to unabated deforestation, soil erosion and ecosystem degradation has been associated with it (Saha et al., 2007), but in many cases may be overestimated (Ziegler et al., 2009). Nevertheless, it still dominates the tropical agricultural system (van Vliet et al., 2012). In India, shifting cultivation is concentrated in the north east hill (NEH) regions with an estimated 1.47 million hectares of land being involved (Yadav, 2013) where the system of practice varies greatly among tribal communities. Ram and Singh, 1993 reported the loss of 702.9 kg of organic carbon (OC), 63.5 kg of phosphorus (P) and 5.9 kg of potassium (K) ha^{-1} from steep slopes (44–53%) of NEH region due to shifting cultivation. Finding technological alternatives and improvement remains a frontal challenge in steep slopes of NEH regions like Mizoram (Grogan et al., 2012). In order to take up the challenge, plantation of oil palm, rubber, arecanut has been introduced after the first year cultivation of slash and burn by the state government thereby slowly reducing the area under shifting cultivation system.

Information on shifting cultivation in relation to chemical and physical soil properties with length of the fallow period, before and after burning during the first year were reported from NE India region (Ramakrishnan and Toky, 1981; Arunachalam, 2002; Sarkar et al., 2015). Available reports indicated that the length of the fallow period often played a crucial role in conserving soil organic carbon (SOC) and soil available nutrients (Ramakrishnan and Toky, 1981; Sarkar et al., 2015). While the availability of nutrient P, K, calcium (Ca) and magnesium (Mg) increased after burning, SOC content decreased due to burning. Tawnenga et al., 1997 observed a decline in soil fertility from first year to second year cultivation for 6 and 20 year forest fallows in Mizoram. Although, soil nutrient constitutes the foundation for plant growth, high level microbial activity is widely accepted for

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maintenance of soil health. Soil enzyme activities such as phosphatase, β-glucosidase, arylsulphatase and dehydrogenase were often used as indicators of soil quality due by burning and anthropogenic disturbances (Ajwa et al., 1999; Boerner et al., 2005). Furthermore, soil enzymes play a crucial role in organic matter (OM) decomposition and nutrient cycling and thus have a direct link with microbial biomass carbon (Yao et al., 2006). In the process of SOC turnover, soil microbial biomass carbon (MBC) acts as a sensitive component (Marinari et al., 2006), rapidly responds to soil management and disturbance than native SOC (Shao et al., 2015).

The evaluation of second year shifting cultivation on soil fertility status by Tawnenga et al., 1997 involved cultivation of paddy during the second year where soil disturbances due to cultivation reduced the soil fertility. With the lack of available information on the second year soil health where plantation crops are grown, it was necessary to evaluate the fallow after the first year cultivation through dynamics of MBC and soil enzyme activities. We hypothesize that the length of fallow period has a strong positive influence on the soil health status of the second year after the first year cultivation. The objectives of this research work was to: 1) evaluate the effect of different length of secondary forest fallow periods on the dynamics of SOC, MBC and potential enzyme activities of the first and second year. 2) elucidate the relationship between SOC, MBC and enzyme activities as a potential indicator of soil health under shifting cultivation.

2. Materials and methods

2.1. Site description and selection

The study was conducted at Bilkhawthlir and Thingdawl blocks of Kolasib district, Mizoram, North eastern India. The area falls under subtropical, humid to per humid climate and the present soil was formed from parent rock of sandstone, siltstone and shale of Bhuban formation (Miocene). The soils from this region are moderately shallow to moderately deep (80 to 120 cm) mostly dark yellowish brown to yellowish brown (Fine, Typic Haplahumults). Detailed information regarding the study sites and weather conditions are displayed (Table 1; Fig. 1). Shifting cultivation in Mizoram consists of cultivation of local landraces of upland paddy (*Oryza sativa*) during the first year as sole crop or as an intercrop with maize (*Zea mays*), cowpea (*Vigna sinensis*), sesame (*Sesamum indicaum*), chilli (*Capsicum spp*), pumpkin (*Cucurbita peto*), brinjal (*Solanum melongena*), etc. without external application of pesticides and chemical fertilizers. Site selection was done through questioning the farmers who would currently undergo the operation at the site and farmers who had operated the site before. The forest vegetation was slashed during December, 2013 and January, 2014 and burned during the month of March, 2014 before the onset of monsoon. Cleaning and one weeding was done before sowing after which paddy was sown during the month of May. Three weeding was done during rice growth period.

Secondary forest fallows facing southward slopes were selected chronologically to represent young and old fallow namely - 23, 21, 14, 10, 6, 3 and 1 year represented as F_{23}, F_{21}, F_{14}, F_{10}, F_6, F_3 and F_1 respectively. For example, after cultivation, the site has been kept uncultivated and left for forest regeneration for 23 years (F_{23}) and so on. One year fallow represent site where paddy was cultivated after 14 years of forest fallow during May to October 2013 and the site was again cultivated for second year during 2014 after cleaning the leftover paddy straw but without burning. We included T_1 in order to check the soil variability as affected by cultivation without burning. In all the selected forest fallow sites, farmer's cultivated upland paddy (*Trai*, a local paddy landrace) till maturity with their own traditional cultivation practice as described above.

2.2. Soil sampling and processing

In the first year, surface soil samples (0–10 cm) were collected with soil core during January 2014 from all the sites, just before the vegetation was slashed (T_1). Second sampling was carried out in the month of May (T_2) 45 days after burning to represent the soil condition during the sowing time for paddy and third sampling during the month of October immediately after final harvest (T_3). In the second year, similar soil samples were collected during February (T_4), July (T_5) and November (T_6). Three plots (10 × 10 m^2) were demarcated from each site to represent the entire slope and soil samples were collected homogenously from each plot (6 points per plot to make a composite sample) representing three replications per site. Field moist soil samples were sieved to pass through 2 mm size and preserved at 4 °C for the determination of soil moisture, MBC and soil enzymatic activities. The other part of the soil was air dried to determine initial soil properties and passed through a 0.5 mm sieve for SOC determination.

2.3. Soil analysis

Gravimetric water content of the soil was determined and BD by core method. Soil pH was measured at soil: water suspension of 1:2.5 (pH meter; WPH-10, Wensar, India). Determination of SOC was carried out by $K_2Cr_2O_7$ wet oxidation method (Walkley and Black, 1934). Available N was determined by $KMnO_4$ oxidation method (Subbiah and Asija, 1956); total N by kjeldahl digestion (Distyl-EM, Pelicans, India) method (Jackson, 1973). Available P was extracted by Bray no 1 reagent, total P by digestion with $HClO_3$ and finally determined by ascorbic acid method (Kuo, 1996). Determination of NH_4OAc extractable K was done using flame photometer (ESICO-1382, India).

Table 1
Important characteristics of the experimental site.

Code	Altitude (m msl)	Slope (°)	Location	Major vegetation	Soil texture
F_{23}	834	18	24 23.855 N 92 44.925 E	*Dendrocalamus longispathus, Melocanna baccifera, Tectona grandis*	CL
F_{21}	861	24	24 22.072 N 92 44.065 E	*Dendrocalamus longispathus, Melocanna baccifera*	CL
F_{14}	1122	18	24 21.135 N 92 43.465 E	*Dendrocalamus longispathus, Schima wallichii, Artocarpus chaplasha.*	CL
F_{10}	836	17	24 11.222 N 92 40.193 E	*Melocanna baccifera, Dendrocalamus longispathus, Ficus racemosa, Baccaurea ramiflora.*	SC
F_6	1040	16	24 11.175 N 92 40.219 E	*Saccharum arundinaceum, Melocanna baccifera, Imperata cylindrica*	SC
F_3	1980	18	24 12.651 N 92 40.420 E	*Imperata cylindrica, Saccharum arundinaceum*	CL
F_1	855	16	24 21.772 N 92 44.746 E	*Oryza sativa*	CL

Cl: Clay loam; SC: Sandy clay.