Catena 135 (2015) 321–327

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Potential of fallow chronosequence in shifting cultivation to conserve soil organic carbon in northeast India

Dibyendu Sarkar [a,*,1], Ch. Bungbungcha Meitei [a], Lohit K. Baishya [a], Anup Das [b], Subhadip Ghosh [c,d], Khumlo Levish Chongloi [a], Dipjyoti Rajkhowa [b]

[a] ICAR Research Complex for NEH Region, Imphal, Manipur 795 004, India
[b] ICAR Research Complex for NEH Region, Umiam, Meghalaya 793 103, India
[c] Centre for Urban Greenery and Ecology (Research), National Parks Board, 259 569, Singapore
[d] School of Environmental and Rural Sciences, University of New England, Armidale, NSW 2351, Australia

ARTICLE INFO

Article history:
Received 10 February 2015
Received in revised form 18 August 2015
Accepted 19 August 2015
Available online 27 September 2015

Keywords:
Shifting cultivation
Fallow chronosequence
Secondary forest
Soil organic C
C pools

ABSTRACT

Secondary forest in shifting cultivation might influence soil organic carbon (SOC) stock. However, information with respect to SOC accumulation or depletion in fallow stand with secondary forest in shifting cultivation is insufficient. We, therefore, undertaken this experiment with the objective to evaluate the impact of secondary forest on SOC stock and its allocation into pools of different oxidizability [very labile (C_{VL}), labile (C_L), less labile (C_{LL}) and nonlabile C (C_{NL})] along soil depth using three fallow chronosequences of shifting cultivation located in subtropical mid-hills of northeast India. Results showed that SOC content in 0–0.45 m depth increased with age of the fallow stand [the values being 78.4, 91.5 and 102.8 Mg ha^{-1} in young (5–9 years), mid-aged (18–20 years) and old (28–33 years) secondary forest, respectively] after land clearing (slashing and burning of forest) and exhaustive cropping (75.9 kg ha^{-1}). There was a decrease in SOC content with increasing soil depth, constituting 49.0, 27.8 and 23.2% of the total (for 0–0.45 m) for 0–0.15, 0.15–0.30 and 0.30–0.45 m, respectively. Among the analyzed C pools C_{VL}, C_L and C_{LL} were influenced by the fallow period and the active pools ($C_{VL} + C_L$) constituted 65.7% of the SOC. Most of the SOC pools were significantly correlated with each other and with fallow age. Results thus indicate that soil in shifting fallow conserves increasing amount of organic C during regeneration of forest vegetation and majority of the SOC is in active or labile pools of shorter residence time.

1. Introduction

Shifting cultivation has been one of the major indigenous agricultural practices in subtropical to tropical hilly areas of Southeast Asia, the Pacific, Latin America, the Caribbean and Africa for ages (Chaplot et al., 2010; FAO, 1957; Grogan et al., 2012). This form of agriculture is the basis of subsistence for almost half a billion people worldwide (Craswell et al., 1997). In north eastern region of India an estimated 1.47 million hectares of land is under shifting cultivation and about 0.44 million tribal families are dependent on this for their livelihood (Yadav, 2013). The practices under shifting cultivation vary greatly in this part of the country and the variability in the practices is largely attributed to the tribe inhabiting in an area. Generally, shifting cultivation involves slashing and burning of natural forest. After 2–3 years of intensive cultivation without any fertilizer inputs the land loses its fertility and the farmer shifts to another piece of forest land. Different cultivation intensities result in differences in the subsequent secondary forest following abandonment. The secondary forests in the fallow land, which regenerate during the fallow period, generally experience a fallow period of 2–15 years.

Information on the dynamics of organic C stock in forest soil is gaining importance because land use change in forests accounts for the second largest human-induced flux of CO_2 to the atmosphere following the combustion of fossil fuels (IPCC, 2007). Land use alters the structure and function of these forest ecosystems (Lawrence et al., 2007) with potential impact on the soil organic C reserve. Enrichment of C stock in soil helps to maintain soil health as well as to attenuate atmospheric C (Ghosh et al., 2012; Mandal et al., 2008). Soil organic C stock at any point of time reflects the balance between the addition of organic C through different sources over time and its loss through biogeochemical processes. Clearance of forest and subsequent agriculture (mostly without any fertilizer and organic inputs) associated with shifting cultivation might disturb such balance. Conversion of forest to crop land and resultant loss of SOC is well documented (Foote and Grogan, 2010; Grogan et al., 2012; Murty et al., 2002). Specifically, report of reduction in SOC stocks

* Corresponding author at: Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741 252, India.
E-mail address: dsarkar04@rediffmail.com (D. Sarkar).
[1] Present address: Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, 741 252, India.

http://dx.doi.org/10.1016/j.catena.2015.08.012
0341-8162/

through replacement of forest by shifting cultivation on sloping land is not uncommon (Wairiu and Lal, 2003). But, information in respect of SOC accumulation or depletion in fallow stand with secondary forest in shifting cultivation is scarce. Among the very few studies available, Chaplot et al. (2010) quantified the difference in SOC stocks between forests and fallows as 14% in Laos. Soil organic C stocks in soils under shifting cultivation vis-à-vis agricultural soils are also inconsistent in literature (Nye and Greenland, 1960; Palm et al., 1996).

To better understand the mechanisms by which C is lost or stabilized in soil, the SOC stock is separated into labile or actively cycling pool and stable or resistant pool; those differ clearly in their residence times. The labile C pool is the fraction of SOC that has the most rapid turnover rates and therefore, its oxidation drives the flux of CO_2 from soils to atmosphere. At the same time, this pool is very important as it fuels the soil food web and, therefore, greatly influences nutrient cycling for maintaining the quality of soil and its productivity (Chan et al., 2001). Highly recalcitrant or passive pool is that fraction of SOC that is very slowly altered by microbial activities (Weil et al., 2003) and hence it hardly serves as a good indicator for soil quality but contributes significantly to the build-up of SOC stock. A number of studies have been conducted on the changes in the SOC pools due to different soil management practices, but most of them are restricted to the long term agricultural practices (Ghosh et al., 2010, 2012; Mandal et al., 2008; Sherrod et al., 2005). Rumpel et al. (2006) reported that black C, a stable soil organic C fraction, strongly influence SOC sequestration in tropical sloping land of Laos under slash and burn agriculture.

Some previous works have demonstrated that live above ground biomass increases rapidly (Do et al., 2010; Eaton and Lawrence, 2009; Yadava, 2010) with age of the forest and organic C in forest soil derives from above ground biomass. This led us to hypothesize that age of the secondary forest plays an important role in determining the size of soil C pools. This experiment was therefore, undertaken with the objective to evaluate the impact of secondary forest on SOC stock and its allocation into pools of different oxidizability along soil depth using the fallow chronosequences of shifting cultivation located in subtropical mid-hills of northeast India.

2. Materials and methods

2.1. Site characteristics

The study was carried out at three different shifting cultivation sites, which are representative of the northeast India, and located in the state of Manipur. As many as 70,000 tribal families of the state have been practicing shifting cultivation, which brings 90,000 ha of hilly area under this form of cultivation annually. All relevant information regarding these sites is given in Table 1. Elevation of the experimental sites ranged from 821 to 1434 m msl. Soil temperature regimes were mixed hyperthermic to thermic. Geologically, sedimentary rocks were subjected to tectonic activities, resulting in the present day hilly topography of the experimental sites and parent rock belong to sandstone and shale of Disang (Eocene) and Barail (Oligocene) group. All the sites had subtropical climate with an average annual maximum and minimum temperature of 25.3 ± 0.9 and 13.4 ± 0.9 °C, respectively and rainfall of 1244 ± 228 mm, ~80% of which falls during June to September. Shifting cultivation in these locations includes wide range of crops such as upland rice (*Oryza sativa*), maize (*Zea mays*), cowpea (*Vigna sinensis*), French bean (*Phaseolus vulgaris*), chillies (*Capsicum annuum*), eggplant or 'brinjal' (*Solanum melongena*), lady's finger (*Abelmoschus esculentus*), squash (*Sechium edule*), pineapple (*Ananas comosus*), cassava (*Manihot esculentum*) and mustard (*Brassica juncea*). The crops were grown under inherent soil fertility without addition of nutrients through chemical and/or organic sources. During the cultivation the land was weeded once or twice in a year.

2.2. Study plots

Chronosequences of the fallow with secondary forest in each site were identified by interviewing farmers for the knowledge of local land use and fallow age. Each chronosequence included a young (F_1; 5–9 years), mid-aged (F_2; 18–20 years) and old (F_3; 28–33 years) fallow stand as well as adjacent recently cultivated land (F_0) (Table 2). Reduction in fallow period under shifting cultivation due to excess demographic pressure has been causing land degradation as there is less

Table 1
Some important characteristics of the experimental sites.

Characteristics Location	Hengkot (24°20′ N, 93°38′ E)	Chandanpokpi (24°25′ N, 94° E)	Monsangpantha (24°20′ N, 94° E)
Altitude (m msl)	1434	821	1044
Slope (%)	37	26	33
Soil			
Taxonomy	Fine, Typic Haplahumults	Fine, Umbric Dystrochepts	Fine, Typic Paleudults
Description	Moderately shallow, excessively drained with loamy surface soil	Deep, excessively drained with clayey surface soil	Deep well drained with clayey surface soil
Temperature (°C)			
Maximum	24.2	25.8	25.8
Minimum	12.6	13.2	14.4
Mean annual rainfall (mm)	1506	1089	1138
Forest type	Subtropical broad leaved	Subtropical pine	Subtropical broad leaved
Major vegetation	*Castanopsis sp.*, *Cinnamomum sp.*, *Stereospermum personatum*, *Schima wallichi*, *Syzygium sp.*	Pine (*Pinus insularis*), thatch grass (*Erianthus ravennae*), *Schima wallichi*, *Castanopsis sp.*	*Quercus lamellosa*, *Castanopsis sp.*, *Rhus succedanea*, *Schima wallichii*

Table 2
Chronosequences of fallow with secondary forest in shifting cultivation as in November, 2013.

Fallow stand	Hengkot	Chandanpokpi	Monsangpantha
F_0	Land cleared[a] and cropped consecutive 3 years	Land cleared and cropped consecutive 2 years	Land cleared and cropped consecutive 3 years
Young (F_1)	9 years	7 years	5 years
Mid-aged (F_2)	(20 ± 2) years	(20 ± 2) years	(18 ± 2) years
Old (F_3)	(33 ± 2) years	(30 ± 2) years	(28 ± 2) years

[a] By slashing and burning of forest.