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Slash Burning Influences Soil Properties of *Jhum* Land in Meghalaya, India

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ABSTRACT

The objectives of the present study was to evaluate the impact of vegetation slashing and burning for shifting cultivation on soil physical, chemical and biological properties. Soil samples at two depths (0-15) cm and (15-30) cm were collected from the study site twice before and after vegetation slashing and burning prior to shifting cultivation. The soil moisture increased after burning whereas the soil WHC, Bulk Density and Porosity decreased after burning. Soil pH, EC and soil available nutrients increased whereas CEC, Organic Carbon and Total Nitrogen decreased after fire. Among biological properties such as SMB, microbial population and soil enzymes (DHA) decreased with the effect of fire, whereas bacteria and actinomycetes were found resistant to fire more than fungi. The traditional practice of vegetation slashing and burning can have positive impact on tropical soil which sustains crop yield during cropping with reference to phase in jhum-lands.

Keywords Shifting cultivation, Vegetation slash and burn, Physical properties, Chemical properties, Biological properties.

INTRODUCTION

With the increase in human population, mostly in the developing countries, there has been a great pressure on lands. More than 6% area under tropical forests was converted to shifting cultivation and it is the most prevalent across all tropical countries. People in the north-eastern region of India practice shifting cultivation on hill slopes (Singh *et al.* 1992). Besides, the practice is also significant in the states of Andhra Pradesh, Kerala, Karnataka and Orissa (Deb *et al.* 2013). Shifting cultivation or *Jhum* is one of the main land uses in the state of Meghalaya, inhabited by three dominant tribes such as the Khasi, Jaintia and Garo.

Shifting cultivation being one of the primary forest based farming system was socially and ecologically sustainable when it was under low demand. With the increase in population pressure, increase in demand, it turns out to be unsustainable, economically unviable and causing damage to the natural resources (Srivastva 1997). It has the characteristics of poor nutrients in the soil, as the land requires years to recover after cultivation to become a sustainable

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or productive land again (Richards 1952). However, some researchers also argue that it as one of the system that assaults the bio-diversity and its ecological function (Ranjan *et al.* 1999).

Shifting cultivation helps conservation of soil moisture, enrichment of soil texture and soil structure and development of a good crop canopy due to mixed cropping. It is environmentally friendly because it is organic farming, helps to replenish lost nutrient of the soil, helps to fertilized the soil, reduces the soil borne pathogens and helps in pest and weed management, (Paul *et al*. 2009).

The process of shifting cultivation begins with slashing of vegetation and subsequent burning of slash. The slash burning is expected to alter of various soil properties and components such as the soil physical properties, soil organic matter content, the soil nutrient availability, and the number of micro-organisms present in it. The objectives of this study is to report our finding on how vegetation slashing and burning effects on different soil properties in jhum-lands.

MATERIALS AND METHODS

Study area: The study was conducted in Jirang Development Block of Ri-Bhoi district of Meghalaya, (25.7151° N latitude and 91.9970° E longitude). The average annual temperature of the study area was 21.8° C. About 3200 mm of rainfall is received by the area annually. The forest area under Jirang (C and RD) block is 19,803 ha, (The District Level Task Force 2019).

Soil sampling: Sampling was done twice prior to cropping i.e., immediately after vegetation slashing and one week after slashing and burning. The soil samples were collected from three randomly laid replicated plots (10 ×10 m) of a hillock recently slashed for jhum cultivation. 10 cores from each plot were collected with the help of a soil augar, from the surface (0-15) cm and sub-surface (15-30) cm depths. The replicated soil samples were pooled plot wise forming a composite soil sample, brought to the laboratory, sieved through 2 mm mesh screen. Sub-samples of sieved soil were kept in a refrigerator at 4°C for biological analysis and the rest were air dried prior to physico-chemical analysis.

Soil analysis

Physical analysis: Soil texture was determined using the Bouyoucos method (Bouyoucos 1936 and1962). Soil moisture content was determined gravimetrically by oven drying 10 g of fresh soil (Tripathi *et al.* 2009). Water holding capacity (WHC) was determined by Keen's box method as outlined by (Viji *et al.* 2012). Bulk density was determined by tapping method (Amidon *et al*. 2017). Porosity was calculated from bulk density assuming a particle density of 2.65 g cm^{-3} (Danielson and Sutherland 1986).

Chemical analysis: Soil pH and Electrical Conductivity (EC) was determined electrochemically with the help of glass electrode (pH meter and EC meter) in soil:water suspension in the ratio (1:2.5), (Jackson 1973). The determination of soil organic carbon was based on the (Walkley-Black 1934) chromic acid wet oxidation method. Total nitrogen was determined by semi-micro Kjeldahl distillation (Bremner 1960), and expressed as a percentage. Mineralizable Nitrogen was determined by Alkaline Permanganate Method (Subbiah and Asija 1956). Available P was extracted by Bray I reagent (Bray and Kurtz 1945) and determined by blue color method. Available K was determined by extracting the soil by shaking with N neutral ammonium acetate solution (Metson 1956). Cation Exchange Capacity of soil was determined by NH_4OAc method, (Sankaram 1996).

Biological analysis: Chloroform fumigation-extraction method was used to estimate the Microbial Biomass Carbon (Silva *et al.* 2016). Chloroform fumigation-extraction method was used to estimate the Microbial Biomass Nitrogen (Brookes *et al*. 1985). Microbial Biomass Phosphorus was determined by Chloroform fumigation-extraction method, followed by extraction with the Bray-1 solution (Logah *et al.* 2010). Dehydogenase enzyme activity was assayed using modified 2, 3, 5-triphenyl tetrazolium chloride (TTC) reduction technique (Casida *et al*. 1964). Soil microbial population was determined by Spread - Plate Technique (Taylor *et al*. 1983).

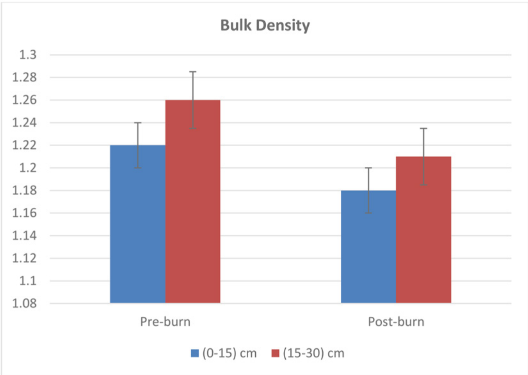

Fig. 1. Fire effect on soil bulk density (g/cc).

Statistical analysis: The data recorded during the investigation was analyzed using Two-Way-ANOVA, to test for significant variations using mean values of studied parameters and were compared using LSD test at 0.05 significance level. Correlation analysis was done to study the relationship between soil properties.

RESULTS AND DISCUSSION

Physical properties: Soil texture being one of the important soil indicators which regulate the other soil parameters. In the present, soil texture is found to be sandy clay to clayey in texture. Slash burning was found to increase soil moisture by 21.7 %. More moisture content was confined in the surface soil and declined gradually with depth. The increase in soil moisture content after burning was also reported by (Phillips 1930). The interaction between levels of burning and soil depth had non-significant effect on the moisture content of soil. Water holding capacity was high in the unburned soil by 4.35 % than in the burned soil and it decreases with soil depth. The reduction in WHC in the burned soil might be due to the loss of organic matter or the nutrient inputs after burning (Alauzis *et al*. 2004). Burning also tends to decrease WHC in unburned soil (Baishya *et al*. 2017). The interaction between levels of burning and soil depth had non-significant effect on sub-surface soil. Bulk density of soil was lower in pre-burn soil (1.18-1.21 g/cc) as compared to post-burn soil (1.20-1.21 g/cc) (Fig.1). Decreased bulk density in the burned soil by 3.17 % was recorded in this study and it increases with soil depth. The reduction in density can be because of the loosening of the structure of the soil due to the bio-char slash production in the burned soil, (Lalmuankima *et al.* 2019). The increase in density with soil depth is due the presence of low organic matter and compaction of soil aggregates down the profile (Kharlyngdoh *et al.* 2015), moreover density increases with ash depth (Cerdà *et al.* 2008). The interaction between levels of burning and soil depth had non-significant effect on soil bulk density. Likewise, soil total porosity decreased post burning and was higher in the surface than the sub-surface soil. The reduction in the soil total porosity after burning

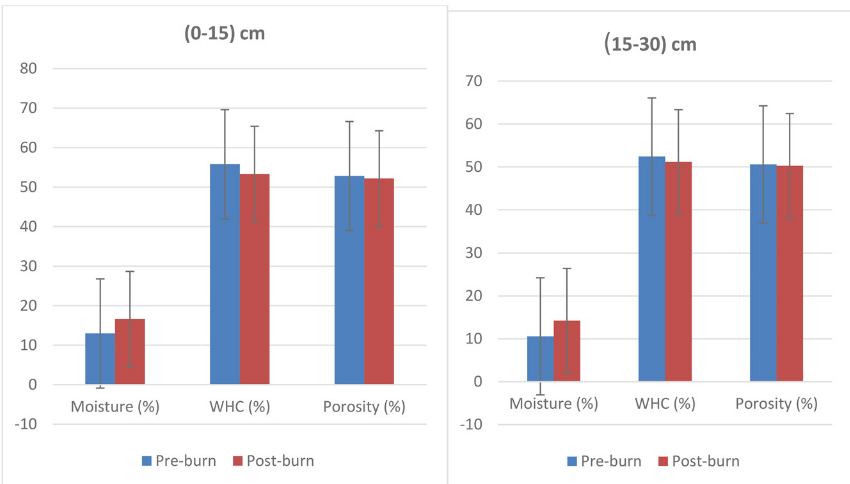

Fig. 2. Fire effect on the soil physical properties.

might be because the ash particles on the burned plot clog the soil pore. Thus the density of larger pores is reduce, with a concomitant increase in the density of smaller pores (Mallik *et al.* 1984). The interaction between levels of burning and soil depth had non-significant effect on total porosity of soil (Fig. 2).

Chemical properties: The soil pH and EC at the study area was higher in the burned soil when compared to the unburned soil and decreases with depth (Table 1). The increase in the soil pH and EC might be because burning releases ash and charcoal that contains the inorganic elements or due to the release of alkaline cations by the ashes that leads to increased pH and EC (Arevalo-Gardini *et al*. 2015). The decrease in soil pH and EC with depth (Table 1) was also reported by (Sherman *et al.* 2005, Berber *et al.* 2015). Fire directly alters the soil cation exchange capacity. This study shows a decreased soil cation exchange capacity with the effect of fire and even at a lower depth of (15-30) cm. The reason for lower cation exchange capacity following fire effect is due to the combustion and alteration of the soil organic matter (Zavala *et al.* 2014). The interaction between levels of burning and soil depth had non-significant effect on soil pH, EC and CEC. The analysis also shows a significant increase in the soil available nitrogen, phosphorus and potassium and they all exhibit a maximum value in the surface than in the sub-surface soil (Table 2). Soil available nitrogen, phosphorus and potassium was found higher post burning may be due to the contribution of ash, and the thermal mineralization of nutrients associated with the soil organic matter (Giardina *et al.* 2000). Since the surface soil has greater amount of all the available nutrients, so it tends to decrease with the increase in soil depth (Kharlyngdoh *et al*. 2015). Fire induced a decrease in soil organic carbon and total nitrogen and in this study, the soil organic carbon and total nitrogen was better recorded in the surface layer compared to deeper layer and decreased (Table 1). The loss in soil organic carbon and total nitrogen can be because burning causes volatilization of OC and TN and converts most of the organic matter into ash (Verma *et al.* 2012). The decrease in soil organic carbon and total nitrogen with depth was also reported by (Badia *et al.* 2017, Padalia 2018). The interaction between levels of burning and soil depth had non-significant effect on soil available phosphorus and soil OC and TN, but a significant effect with soil available nitrogen and potassium (p<0.05).

Table 2. Effect of slash burning on the soil available nutrients.

	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	(0-15) (cm)	(15-30) (cm)	(0-15) (cm)	(15-30) (cm)	(0-15) (cm)	(15-30) (cm)
Pre-burn	449.91	324.35	7.79	6.06	389.22	232.65
Post-burn	670.68	517.51	11.50	8.18	690.83	370.24
	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)
Levels of burning (A)	9.797*	2.777	1.311*	0.372	2.020*	0.573
Depth (B)	9.797*	2.777	1.311*	0.372	2.020*	0.573
A x B	13.855**	3.927	NS	0.526	2.856**	0.810

Biological properties: In this study, the soil microbial biomass continue to show a post-burning decreasing trend and the biomass of the organisms decreased with depth in both the burned and unburned field (Table 3). The reason for a decreased post-burned microbial biomass might be because fire altered soil microbial

Table 1. Effect of slash burning on the soil chemical properties.

	pH		EC (dS/m)		CEC (cmol p^+ kg^{-1})		Organic carbon (%)		Total nitrogen (%)	
	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0.15) cm	(15-30) cm	(0-15) cm	(15-30) cm
Pre-burn	5.47	5.17	0.17	0.13	9.94	8.69	1.55	1.01	0.090	0.071
Post-burn	6.45	5.51	0.29	0.23	7.84	6.77	1.17	0.45	0.077	0.047
	CD (P=0.05)	SE (m)	CD (P=0.05)	SE (m)	CD (P=0.05)	SE (m)	CD (P=0.05)	SE (m)	CD (P=0.05)	SE (m)
Levels of burning (A)	0.594*	0.168	0.045*	0.013	2.006*	0.569	0.199*	0.056	0.016*	0.004
Depth (B)	0.594*	0.168	0.045*	0.013	NS	0.569	0.199*	0.056	0.016*	0.004
A × B	NS	0.238	NS	0.018	NS	0.804	NS	0.08	NS	0.006

Table 3. Slash burning effect on the soil microbial biomass.

	Carbon (μg g^{-1})		Nitrogen (μg g^{-1})		Phosphorus (μg g^{-1})	
	(0-15) cm	(15-30) cm	(0-15)cm	(15-30) cm	(0-15)cm	(15-30) cm
Pre-burn	436.16	355.62	16.25	14.46	14.77	10.76
Post-burn	225.07	127.12	12.34	10.48	8.47	6.85
	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)
Levels of burning (A)	2.863*	0.812	1.038*	0.294	2.336*	0.662
Depth (B)	2.863*	0.812	1.038*	0.294	2.336*	0.662
A x B	4.049**	1.148	NS	0.416	NS	0.937

abundance and lead to microbial mortality, (Hart *et al.* 2005). MBC, MBN and MBP decreases with depth which was also reported by (Ekelund *et al.* 2001). The interaction between levels of burning and soil depth had non-significant effect with soil MBN and MBP, but a significant effect on soil MBC ($p<0.05$).

The result of the present study shows that bacteria are more tolerable to heat than fungi (Table 4). Fungi being sensitive to heat shows a decreasing population in the post-burned soil. This is due to ash deposition and the fact that the bacteria have a greater ability to use the soluble organic compounds released by the heat (Vazquez *et al*. 1993). The actinomycetes population in this study was found to be lower than that of the other micro-organisms. Similar to bacterial populations and unlike fungi, actinomycetes population increase post burning. Nutrient release by ash is probably the main cause for the increase in actinomycetes population as reported by (Mataix-Solera *et al.* 2009). The microbial population shows a decreasing trend with the increase in soil depth. There was a decline in the number of colonies of fungi present in the surface soil, while at lower depths there was a slight increase in colony numbers after the burn. Similar results were also reported by (Cooke 1970). The interaction between levels of burning and soil depth had significant ($p<0.05$) effect with soil bacteria and fungi population but a non-significant effect on actinomycetes. Fire affected soil enzymatic activity too.

Fire reduced the soil de-hydrogenase activity which decreased with the increase in soil depth. The decrease in soil enzymatic activity after burning may be due to the thermal enzyme denaturalization, inactivation of enzymes associated with soil colloids or the changes in the composition of soil microflora in response to the fire (Hernandez *et al.* 1997). (Reza *et al*. 2014) also reported a decreased soil DHA with depth. The interaction between levels of burning and soil depth had significant effect with soil DHA ($p<0.05$) (Table 4).

CONCLUSION

The study revealed that slash burning of land for shifting cultivation had influenced various soil properties differently. Among physico-chemical properties, soil moisture content, pH, EC, available Nitrogen, available Phosphorus and available Potassium increased

Table 4. Slash burning effect on the soil microbial population and DHA.

	Bacteria (10^7)		Fungi (10^6)		Actinomycetes (10^7)		De-hydrogenase activity (μg TPF g^{-1} dry soil 24 h^{-1})	
	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm	(0-15) cm	(15-30) cm
Pre-burn	0.59	0.19	1.34	0.41	0.11	0.03	36.39	27.60
Post-burn	1.01	0.77	0.04	0.17	0.29	0.13	27.64	12.04
	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)	CD (P=0.05)	SE(m)
Levels of burning (A)	0.087*	0.025	0.438*	0.124	0.048*	0.013	2.799*	0.793
Depth (B)	0.087*	0.025	NS	0.124	0.048*	0.013	2.799*	0.793
A × B	0.123**	0.035	0.619**	0.176	NS	0.019	3.958**	1.122

whereas soil characteristics such as Water Holding Capacity, Bulk Density, Porosity, Cation Exchange Capacity, Organic Carbon and Total Nitrogen decreased significantly after burning. Slash burning significantly reduced Fungi population, Microbial Biomass Carbon, Microbial Biomass Nitrogen, Microbial Biomass Phosphorus and Dehydrogenase activity. On the other hand, it favored the growth of Bacteria and Actinomycetes population.

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