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Research article

Soil Dynamics of Pre - and Post- Slash-and-Burn Jhum Fields of Tirap District, Arunachal Pradesh

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***Abstract*:** Jhum agriculture is widely practiced on Arunachal Pradesh's hill slopes, and it is more than just a means of subsistence; it is a way of life that has symbolic connotations for the socio-cultural life and natural landscapes, and it is an essential component of survival and economic existence. An attempt was made to study the soil characterization associated with pre-and post- burned jhum cultivation practiced by the ethnic Nocte and Tutsa tribes of Tirap district, Arunachal Pradesh. The soil samples were collected from the same location at the pre-and post-burnt fields from the various depth of soil profile A (0-20) cm, B (20-40) cm, and C (40-60) cm. The present study reveals an overall increase in porosity, temp, pH, Moisture, and bulk density because of the burning of the jhum field. In post-burned jhum fields of all the locations, there was an overall increase in the percentage of Sodium and Calcium in soil collected and a decrease in the percentage of Nitrogen, Phosphorus, and Potassium. The pH was mostly found to be acidic and increasing with the depth of the soil profile. There was a significant difference in total nitrogen content of the soils, whereas phosphorus, potassium, calcium, and sodium showed little differences for pre-and post-burned jhum fields. The effects of the slashing and burning process promote changes in soil physical as well as chemical properties, thereby influencing the nutrient status. Deterioration of soil nutrients starts after the burning of vegetation and continues subsequently throughout the various stages of jhum cultivation.

Keywords: Soil depth, Jhum field, Shifting cultivation, Physiochemical properties, Arunachal Pradesh

I. Introduction

Shifting cultivation has been defined as an age-old, primitive, and dominant land-use system in distant and steep mountainous locations of various regions throughout the world. Shifting cultivation or slash-and-burn cultivation (locally known as Jhum Kheti), also popularly known as 'Swidden agriculture' (Mertz et al. 2009) is extensively practiced on the hill slopes of Arunachal Pradesh. This practice has a dynamic role in driving the rural economy and sustenance of the indigenous folk (Wangpan and Tangjang, 2012). However, the techniques of farming may vary slightly among the various tribes, around the region. The general procedure of such farming commences with the clearing of vegetation from a patch of land, burning of sun-dried vegetation, followed by the cultivation of crops and vegetables for a period of about 18-20 months, and shifting to a new patch of forest land (Tangjang, 2009). Thus, the agricultural field will remain as fallow for about 7 to 8 years. Such a gap period allows the vigorous activity of microbes, followed by revamp of soil fertility. The length of the fallow period is critical that governs the sustainability of shifting cultivation (Abizaid and Coomes, 2004).

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Earlier, about 10-15 years of fallow period were considered to be ideal, but a gradual rise in human population has led to a shortage of farming plots, subsequently reducing the length of fallow in most part of India. Consequently, the land does not meet enough time for the rejuvenation of soil nutrients, which may lead to unsustainable farming practices. Thus, shifting cultivation has proven unsustainable both environmentally and economically, and many Asian countries are replacing it with permanent agriculture (Rasul and Thapa, 2003). However, the jhum has always been an integral part of rural tradition and most of the festivals celebrated by the ethnic communities are jhum oriented (Das et al. 2012, Basumatary et al. 2014).

The word soil comes from the Latin word solum, which means "substratum" or "ground." It is defined as loose inorganic particulate material formed from weathering of rocks and minerals through actions of nature, mechanical or chemical agents which support plant life (Venkatramaiah, 2006). Soils comprise vital natural resources, which support life and uplift the socio-economic status (Kire, 2006). By fixing carbon and nitrogen and aggregating the soil surface, soil microbial communities promote soil fertility and prevent erosion (Eldridge et al. 2000). According to Olson et al. (2000), soil microbes degrade plant and animal by-products that enter the soil and transform them to soil organic matter, which has an impact on the physical, chemical, and biological properties of the soil, thereby providing a complementary medium for biological reactions and life support in the soil environment. The biochemical properties of soil are more volatile and tend to change in the external environment, while the physicochemical properties are involved in soil functioning (Nannipieri et al. 1990).

Several studies and researches have been conducted on soil and nutrient loss due to shifting cultivation (Borggaard et al. 2003), however, the literature on the impacts of shifting cultivation in soil nutrient loss in Arunachal Pradesh was not reported so far.

II. Objectives

Study and analyze the soil physicochemical properties in pre-and post- burned jhum fields of Tirap district, Arunachal Pradesh.

III. Methodology

Study area

Tirap district is located in the South-eastern part of Arunachal Pradesh, which ranges from 26°38′–27°47′N Latitude and 96°16′–95°40′E Longitude (Fig 1). The district derived its name from the river Tirap which originates from a mountain in Laju Circle, Tirap district. This river flows from the southeast to the northeast part of the district and then crosses over to Changlang district and finally joins into the Buri-Dihing River near Ledo of Assam. The total geographical area occupied by the District is approximately 2362 Km^2 while the approximate elevation of ranges from 200 MSL to 4000 MSL (District Portal, Tirap).

Figure 1. Map of Study Area

Collection of soil samples

In Tirap district, jhum cultivation was found to be practiced from the elevation of 200 MSL to 1700 MSL. On the basis of elevation, the study site was divided into three sites Namsang (200-600) MSL, Khonsa (600-1000) MSL, and Sanliam (1000-1700) MSL. The triplicate of the soil samples was collected from various depths of the soil profile i.e. 0-20 cm, 20-40 cm, and 40-60 cm. The soil samples were collected before and after burning of the jhum land from each site. The samples were collected in sterile zipped poly bags with the help of an iron-made borer and brought to the laboratory. The fresh soil samples were sieved through a 2 mm mesh sieve to remove the unwanted residues were and stored at a temperature of 4°C for various measurements of physicochemical properties.

Measurement of soil physicochemical properties

Soil temperature was measured in the field itself by using a soil thermometer (Table 1). The soil pH was measured in the laboratory by using a digital pH meter, taking 1:2, soil and water ratio. For measuring bulk density [ρ, bulk density (g cm^{-3})] a known volume of core was used to dig out the soil sample by properly removing all the debris present on the top layer. The collected soil cores were used to determine the bulk density (ρ), by dividing the oven-dry mass of soil at 105 °C by the volume of the core soil sampler (Grossman and Reinsch, 2002).

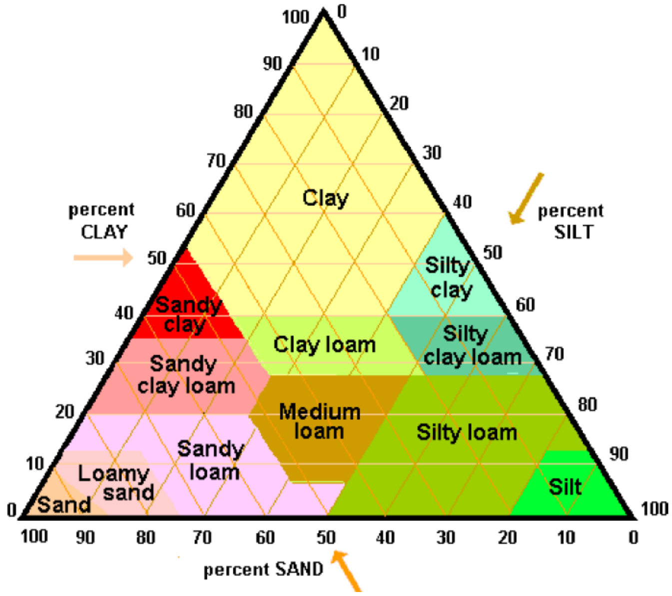


Figure 2. USDA textural triangle for demonstration of soil texture

Soil samples collected from the 0–20 cm depth were used to determine soil texture with the Bouyoucos hydrometer method (Gee and Bauder 1979; Gee and Or 2002; Huq and Alam, 2005) by finding the sand, silt, and clay percentages. Soil textural classification follows the USDA system (Soil Survey Staff, 1999). Figure 2 depicts the USDA system of Soil textural classification. The moisture content was measured by the oven drying method (Rowe, 2018). Total nitrogen was determined by the micro-Kjeldahl method (Jackson, 1973; Anderson and Ingram, 1994). To determine the phosphorus content, the sample was first digested. Here, tri-acid digestion was followed to determine the amount of phosphorus (Tandon, 1987). After digestion in the Kjeldahl apparatus (Jackson 1973, Anderson, and Ingram, 1994) the obtained aliquots are taken for estimation of potassium, sodium, and calcium using a flame photometer (Tandon, 1995)

IV. Results and Discussion

The temperature of the soil was found to be higher in the month of November than January and it ranges from 10 °C to 23 °C (Table 2). The pH of the soils was found to be increasing with the depth of the soil profile. The soil collected from Khonsa had the lowest average pH of 4.189, compared to Sanliam (4.51) and Namsang (4.801) (Table 2). Almost 84% of the soils of Arunachal Pradesh were found to be highly acidic in nature (Panda, 1998). Likewise, in our study, all the soil samples were slightly acidic in nature. The soil pH is also linked to the leaching of basic cations (Ca, Mg, and K) during the monsoon season, resulting in the retention of hydrogen, iron, and aluminum ions with strong binding forces with charged soil particles, resulting in increased soil acidity (Thungon et al. 2018). There was no significant difference in the proportion of sand, clay, and silt across the study sites (Table 1).

Table 1. Texture of soil samples collected from Namsang, Khonsa and Sanliam of Arunachal Pradesh, India.

Location	Soil Depth (cm)	Soil Texture

		Clay (%)	Sand (%)	Silt (%)	Soil class
Namsang	00-20	24	16	60	Sandy clay loam
	20-40	34	44	22	Silty clay loam
	40-60	38	42	20	Silty clay loam
Khonsa	00-20	18	44	38	Medium loam
	20-40	28	40	32	Silty loam
	40-60	28	38	34	Silty loam
Sanliam	00-20	16	26	58	Medium loam
	20-40	16	32	52	Medium loam
	40-60	16	34	50	Medium loam

Three types of soil texture were recorded viz. silty clay loam (Namsang), silty loam (Khonsa) and medium loam (Sanliam).

Table 2. Physiochemical characters of the soils from before-burned jhum field of of Namsang, Khonsa and Sanliam of Arunachal Pradesh, India

Location	Soil Depth (cm)	GPS Coordinates (Elevation)	Moisture %	pH	T (°C)	Bulk density (ρ) (g/cm^3)	Porosity %
Namsang	00-20	N 27°07.431' E 095°28.085' (202 MSL)	36.42	4.675	23	0.935	64.71
	20-40		33.68	4.738			
	40-60		32.27	4.992			
Khonsa	00-20	N 26°58.843' E 095°30. 205' (914 MSL)	51.74	3.889	16	0.965	63.58
	20-40		45.13	4.311			
	40-60		45.13	4.367			
Sanliam	00-20	N 26°55.752' E 095°32.589' (1676 MSL)	20.33	4.496	14	0.985	62.83
	20-40		26.58	4.488			
	40-60		24.06	4.560			

The present study reveals an overall increase in porosity, temp, pH, moisture, and bulk density (except in Sanlian soil) because of the burning of the jhum field. The bulk density was recorded low (0.935 g/cm3) with high porosity (64.71) in Namsang village compared to the samples from Khonsa (0.965 g/cm3 bulk density and 63.58 porosity) and Sanliam (0.985 g/cm3 bulk density and 62.83 porosity) (Table 2). The bulk density varies with the total pore space, or porosity, in the soil and provides a fair measure of its porosity. Soils with low bulk densities, on average, have better physical properties than soils with higher values. Besides, the pH reading of the soil samples from after-burnt fields of all three elevations was found comparatively more than the before-burnt field (Table 3).

Table 3. Physiochemical characters of the soils from after-burned jhum field of Namsang, Khonsa and Sanliam of Arunachal Pradesh, India

Location	GPS Coordinates (Elevation)	Soil Depth (cm)	Moisture %	pH	T (°C)	Bulk density (ρ) (g/cm^3)	Porosity %
Namsang	N 27°07.431' E 095°28.085' (202 MSL)	00-20	31.23	5.426	19	0.965	63.58
		20-40	35.50	5.517			
		40-60	33.33	5.301			
Khonsa	N 26°58.843' E 095°30. 205' (914 MSL)	00-20	41.24	4.774	13	0.975	63.20
		20-40	43.88	4.492			
		40-60	40.64	4.612			
Sanliam	N 26°55.752' E 095°32.589' (1676 MSL)	00-20	19.33	5.258	10	0.98	62.83
		20-40	25.62	4.760			
		40-60	25.31	4.993			

This agrees with the findings of Tufeccioglu et al (2010) and Boerner (1982). Soil pH is generally increased after forest fire which may be due to the higher pH value of the ash and other burnt material. The bulk density recorded for the after-burnt soil samples was recorded higher than those of the before-burned field. Certini (2005) and Boerner et al (2009) also found that bulk density increases significantly as a result of a fire which ultimately affects the porosity of the soil. Comparatively, the Sanliam soil sample showed the highest bulk density (0.98 g/cm3) which is situated in a higher altitude (1676 MSL) than Khonsa (914 MSL) and Namsang (202 MSL) (Table 3).

Among the samples collected from the before-burned field, Khonsa village showed the highest content of average total N (0.23 %) followed by Sanliam (0.093 %) and Namsang (0.093 %) (Table 4). Whereas after burnt soil showed a decreased amount of average total N, for Khonsa (0.156 %), Sanliam (0.086 %), and Namsang (0.073 %).

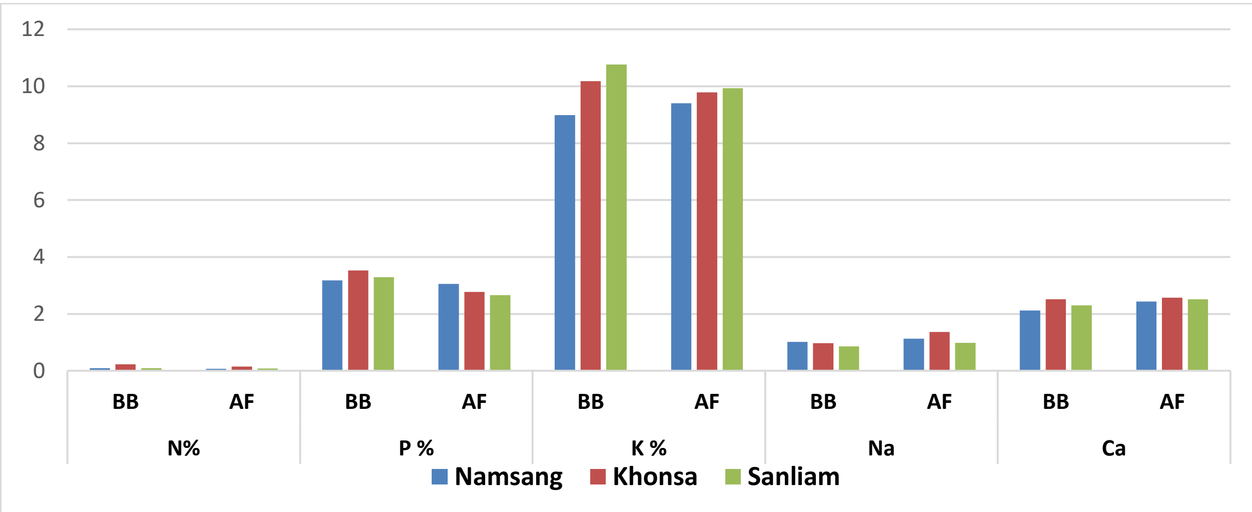
The total N of the soil showed a decreasing trend after the burning of the field. When substantial amounts of fuel are used at the surface layer, some of the soil's total N is lost through volatilization to the environment, resulting in such a scenario (Giardina et al. 2000). Moreover, during the thermal oxidation of organic matter in the form of oxidized N gases and N_2 at temperatures above 300°C, soil organic N is lost to the atmosphere in the form of oxidized N gases (Raison, 1979). The sandy soil texture in the study area, on the other hand, might be another factor speeding up the runoff and leaching of soil Total N in these farmlands. (Kendawang et al. 2004).

Table 1. Average percentage of soil nutrients present in before burn and after burn soils of jhum field of Namsang, Khonsa and Sanliam of Arunachal Pradesh, India.

Average percentage of soil nutrients in before burnt soils of Jhum land					
	Total N %	P %	K %	Na	Ca

Namsang	0.093	3.18	8.99	1.013	2.126
Khonsa	0.23	3.53	10.18	0.973	2.51
Sanliam	0.093	3.29	10.76	0.856	2.306
Average percentage of soil nutrient in after burnt soils of Jhum land					
	Total N %	P %	K %	Na	Ca
Namsang	0.073	3.053	9.403	1.13	2.44
Khonsa	0.156	2.77	9.78	1.37	2.57
Sanliam	0.086	2.66	9.93	0.98	2.52

In the present study, there was an overall increase in the percentage of Sodium and Calcium in soil collected from all the locations after burning of jhum field (Fig 3). Whereas, there was an overall decrease in the percentage of Nitrogen, Phosphorus, and Potassium (except Namsang soil) in the soil after burning of jhum field (Fig 3).



Note: BB= Before-Burned jhum field, AB= After-burned jhum field

Figure 3. The average percentage of soil nutrients present in before burn and after burn soils of jhum land of Namsang, Khonsa and Sanliam of Arunachal Pradesh, India.

The average phosphorus content was recorded highest in the soil of Namsang (3.18 %), followed by Khonsa (3.53 %) and Sanliam (3.29 %). Whereas, average potassium content was highest in the soil of Sanliam (10.76 %), followed by Khonsa (10.18 %) and Namsang (8.99 %) (Table 4). There was a considerable change in the content of phosphorus and potassium after burning this was corroborated with the findings of DeBano and Conrad (1978) which states that phosphorus and potassium are partially affected in high-intensity fire compared to the total N content. Moreover, lime treatment to acid soils during crop cultivation might also boost P availability in the soil compared to low pH soils without lime application (Ghosh et al. 1980). The study also shows an increase in the amount of calcium in the soil after burning of field. The soil collected from Khonsa showed the highest amount of calcium deposit (2.57 %) compared to Sanliam (2.52 %) and Namsang (2.13) in the before burnt jhum land. DeBano (1990) also stated that Ca are relatively less sensitive in comparison to nitrogen because of the high threshold temperature of 1484 ℃

V. Conclusion

The study concludes that the burning of the vegetation has resulted in a decrease in the soil nutrient, thereby, productivity from the shifting cultivation. Additionally, due to the increase in population and less cultivable lands, there is a reduction in a fallow period, which directly or indirectly affects the overall nutrients present in the jhum lands. However, there was little difference in soil physicochemical properties in pre-and post-burned jhum fields. From a glance of future perspective, the known soil physiochemical properties of soil may help in enlightening farmers in adopting an alternative farming system; viz. agroforestry, mixed farming, cultivation of cash crop, etc. to mitigate the nutrient loss.

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