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Impact of Charcoal Production Activities on Selected Soil Properties in Mizoram

Lalmuankima H. T., Upadhyaya K., Kataki R.

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Abstract This paper assessed the effect of charcoal production on soil properties in the farm land of Tualpui village, Champhai district. The composite soil samples from 10 sampling points were collected randomly at a depth of 0-15 cm at charcoal production site (CA) and adjoining site (AS) . The collected soil samples were analyzed in the laboratory for different parameters such as pH, texture, bulk density, water holding capacity, available phosphorus, organic carbon, nitrogen, electrical conductivity, calcium, magnesium, sodium, potassium, exchangeable acidity, cation exchange capacity and base saturation. The analysis results on soil texture show that the silt content were increased significantly ($p< 0.01$) by 38.06% whereas clay and sand percentage at par in both the sites. Similarly, soil pH, electrical conductivity, available phosphorus, magnesium and sodium were significantly ($p<0.01$) higher at charcoal production soil. On the other hand calcium, potassium, cation exchange capacity, carbon percentage, nitrogen, exchangeable acidity and base saturation did not show significant variation in both the sites. From these results it can be suggested that charcoal and biomass residues left on the production sites ameliorate soil fertility by improving soil reaction, phosphorus availability and addition of important cations. However, further investigations on the effect on other micronutrients as well as biological properties of soil such as microbial population, enzyme activities and soil microbial biomass are necessary in order to have a holistic understanding of the impact of charcoal burning on soil properties.

Keywords Charcoal production site, Evaluation, Mizoram, Impact, Relative change.

Introduction

In Mizoram, agriculture is the main source of livelihood to the majority of the people. The practice of shifting cultivation that is known as jhuming in Mizoram is an integral part of the sociocultural life of Mizos. This involves slash and burn of forest trees where the felled trees are later used for charcoal production. These activities have culminated in a devastating impact on the surrounding environment. Subsequently, jhum cultivation along with charcoal production and agriculture contribute to woodland degradation and deforestation in Mizoram. Hence, the major reasons for deforestation in the country are the clearing of forests and woodlands for cultivating crops and the cutting of trees and shrubs for various purposes, notably for fuel wood, charcoal, construction materials. In Mizoram, fuel wood and

Lalmuankima H. T.*, Upadhyaya K.
Department of Forestry,
School of Earth Sciences & Natural Resources Management,
Mizoram University,
Aizawl - 796004
Mizoram, India

Kataki R.
Department of Energy, Tezpur University,
Napaam, Assam
India
email : htmuankima@gmail.com
*Corresponding author

charcoal constitute the most important sources of household fuel meeting the energy need of rural and urban households. The charcoal which are produced from these villages are transported to other towns and urban areas since there is demanding market within the state. According to DEF,Govt Mizo (2017) the revenue receipt from charcoal during 2016-2017 (upto January 2017) is Rs 1,57,029 amounting to 4,839 quintals. Apart from this, there are large number of quantities transported illicitly which could not be recorded or traced.

Since, charcoal production is usually practiced by the farmers in conjunction to agricultural farming it serves as an easy way of earning each for them. As there is a demanding market for various end-uses, income from charcoal has become a form of insurance against crop failures, emergency cash needs (Nigussie and Kissi 2011). Considering the low income and the unemployment situation of the rural poor, large numbers of the inhabitant of the study area have taken charcoal productions as their means of economic survival. In most of the developing countries, production of charcoal is so great that it is considered as a valuable cash product (Coomes and Burt 2001). Ultimately, the charcoal trade provides quick return on investment and income opportunities for many people in the urban areas, through small scale businesses and as a supplier.

In studies conceded in some parts of the world, it is revealed that the charcoal production have significant effect on several parameters on soil properties. Charcoal residues and charred biomass left on the kiln sites has been also found to serve to ameliorate and improve the soil fertility of tropical soils by direct nutrient addition and retention (Trossero 2003). According to Oguntunde et al. (2004, 2008) in Ghana, that the available phosphorus, exchangeable bases, nitrogen and base saturation was higher in soils of charcoal production sites than the adjacent lands. A study conducted in Ghana also showed that bulk density on charcoal site soils reduced by 9% compared to adjacent field soils. Nevertheless, further investigation to determine the long-term effects of charcoal production on the soil environment and the fertility of tropical soils is desirable. Therefore the objective of this investigation is to study the impact of charcoal production activities on the selected soil properties in Mizoram.

Materials and Methods

Study area

The site of study was located 8 kms towards Rabung road from Tualpui village, Champhai District of Mizoram (Fig.1). Location is at $23^0 37'37.1''$ N and $93^0\ 13'08.3''$ E at an altitude of 1345 m above sea level. The annual rainfall of the study area during 2016-2017 was 1898.10 mm. The mean annual maximum and minimum temperature are 27.47 ^{0}C and 9.02 ^{0}C and the relative humidity are 96.73% and 77.06% respectively. The soils of the study area are dominated by Entisol (DAO, Champhai 2017).

Soil sampling and analysis

Soil samples were collected from the selected charcoal production site (CS) which is situated about 8 km from the village, where soils are collected from 10 different sites at a depth of 0-15 cm each from charcoal production and its adjacent sites (AS) randomly. Simultaneously unwanted stones, plant roots and debris are removed. A separate soil samples were taken with a tubular soil core forced manually into the soil for bulk density determination from each site. The soil samples were collected at the distance of 10-15 m away from the site of charcoal production site. The air dried soil samples were sieved through a 2 mm mesh sieve for different physical and chemical analysis in the laboratory. soil texture of air dried sample was determined by hydrometer method (Piper 2005). The texture classification according to the United States Department of Agriculture (USDA) was followed to give the nomenclature or textural class. The soil bulk density was measured after drying of core samples in an oven at 105 ^{0}C for 24 h and calculated as follows :

$$\text{Bulk density (g/cm}^3\text{)} = \frac{Wm - Wd}{V}$$

Where, Wm and Wd are weights of moist and oven dry soils respectively and V is the volume of cylindrical core.

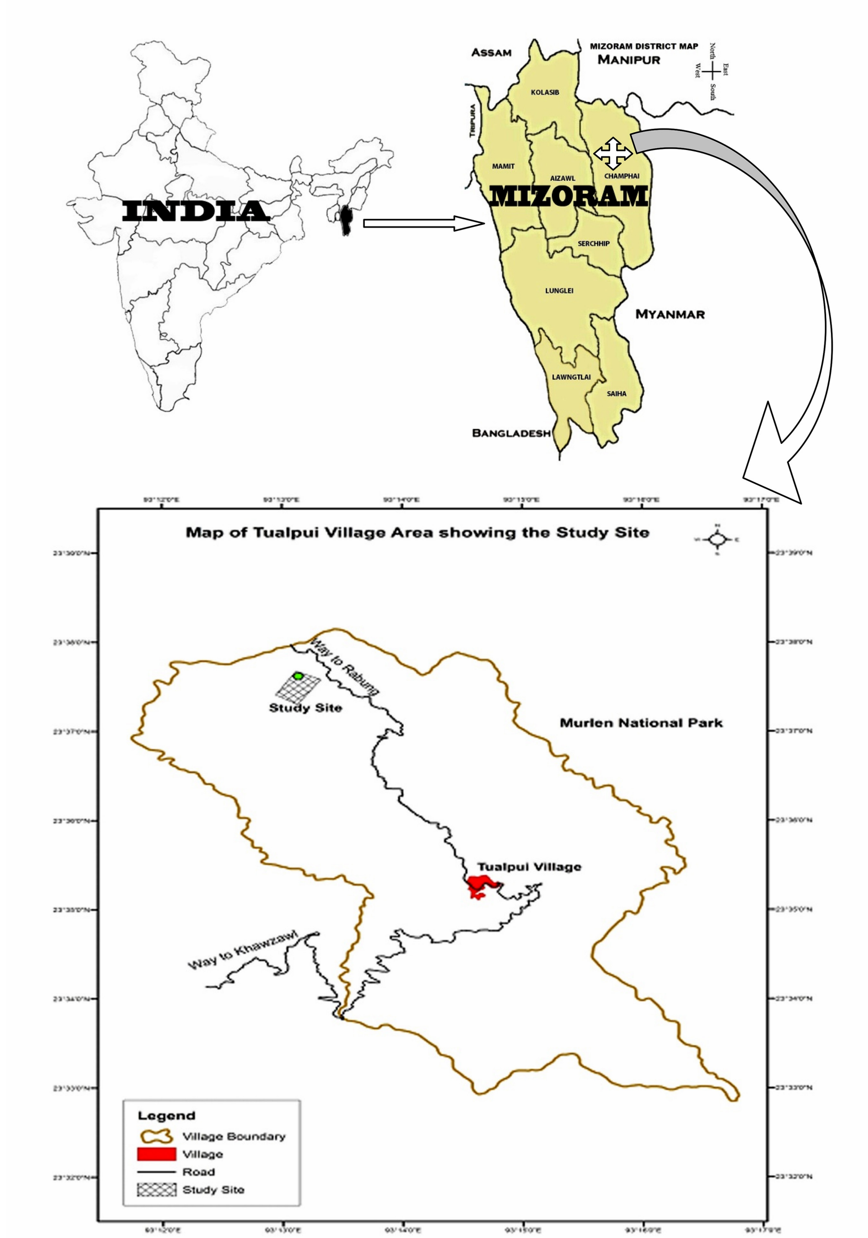

Fig. 1. Map of study site.

Water holding capacity (WHC) was determined by the method of Emmanuel et al. (2010). The soil samples are oven dried at 105^{0}C for this experiment. Filter papers are kept inside the keen boxes to cover the perforated bottom of the box and measured the weight (*W1*), the oven dried soil samples are then transferred in the keen boxes and weight (*W2*). The soils are saturated with water and kept for overnight, then, the next day the box is whipped and record the weight (*W3*). The WHC was calculated as :

$$\text{WHC (\%)} = \frac{(W3-W2)}{(W2-W1)} \times 100$$

Soil pH was measured by using an electronic pH meter from a 1:2.5 soil to water suspension. Electrical conductivity was measured with the help of conductivity meter where soil to water ratio of 1:5. Available phosphorus (P) was determined by Bray and Kurtz (1945). Carbon and nitrogen content were determined by using CHNS/O Elemental Analyzer with auto-sampler and TCD detector –Euro Vector, Model : EuroEA3000. Exchangeable K, Ca, Mg and Na was extracted with IN ammonium acetate (NH_4OA_c) (pH 7.0) and determined by using the Microwave plasma atomic emission spectrophotometer (MPAES), Agilent's 4200 MP-AES. For the determination of exchangeable acidity and exchangeable aluminium, extraction was carried out with 1 N KCl solution followed by the addition of phenolphthalein indicator and titrated with 0.1 N NaOH solution to the permanent pink color. The volume of NaOH used was recorded for calculating the exchangeable acidity. Effective cation exchange capacity (ECEC) was determined by summing exchangeable cations to provide a measure of effective cation exchange capacity (ECEC) as described by (Gillman 1979).

Data analysis

The results of the laboratory analysis were thereafter investigated with students t-test in order to assess the significance difference in soil properties between soils at charcoal production and adjacent sites using Microsoft excel windows 7 data analysis. Then, the Relative change in soil properties was Figured as :

$$\text{Relative Change} = \frac{(Pk - Pa)}{Pa} \times 100$$

Where, *Pk* is the soil property measured on the charcoal production site and *Pa* is the soil property on the adjacent sites (Nigussie et al. 2011).

Results and Discussion

Soil physical properties

The soil and its biodiversity are highly damaged by fire and carbonization (Fontodji et al. 2010). However, the result of analysis shows that the particle size composition of soils in both charcoal production area and adjacent area was more or less similar. On the other hand, the amount of silt in the charcoal production area was increased significantly (p<0.01) compared with the adjacent site (Table 1). The difference in sand and clay content of the soil in both CA and CC are not statistically significant. This is unlike the contents of sand and clay that recorded a slight increase at the charcoal production area in some research findings which may be due to the deposition of wood ashes in the form of fine particles that contributes clay and sand percentages. However, the similarity in the values may probably be due to the formation of the soil of same parent material (Ogundele et al.2011). The bulk density of soil at the charcoal production is slightly decreased by 5.15% which may be because of loosening soil structure by the activities of charcoal production at the site. The reduction in density may also be due to the deposition of charcoal residues left on the site. In comparison with the adjacent site reduction in soil bulk density at charcoal production site is also reported by Ayodele et al. (2009). Likewise, there is a relative change of increase in water holding capacity at the charcoal production by 4.96%, but statistically there is no significant change between the two sites. The increase in water holding capacity at charcoal production soil samples could be due to the clay content and generation of charcoal fragments as well as bio charred in the soil. Since charcoal is porous in nature; it has the property to retain water and aggregate stability creating water availability in the soil. Glaser et al. (2002) also reported improvements of soil water retention by charcoal ameliorations.

Table 1. Statistic test and relative change for soil physical properties. ** p <0.01, NS = Not significant, BD = Bulk density, WHC = Water holding capacity, –ve relative change indicates the reduction in the particular properties of soil from AS to CS.

Soil physical parameters	CS	AS	t-statistic	p-value	Relative change (%)
Clay (%)	15.05 ± 0.85	7.80 ± 0.52	7.28	NS	92.95
Silt (%)	12.37 ± 0.44	8.96 ± 0.79	3.78	**	38.06
Sand (%)	72.58 ± 1.16	83.24 ± 0.70	7.84	NS	-12.8
BD (g/cm^3)	1.29 ± 0.05	1.36 ± 0.04	1.26	NS	-5.15
WHC	59.70 ± 1.71	56.88 ± 1.07	1.40	NS	4.96

Table 2. Statistic test and relative change for soil chemical properties. **p <0.01, NS = Not significant, EC = Electrical conductivity, CEC = Cation exchange capacity, – ve relative change indicates the reduction in the particular properties of soil from AS to CS.

Soil chemical parameters	CS	AS	t-statistic	p-value	Relative change (%)
pH	5.72 ±0.18	4.95 ±0.06	4.07	**	15.56
EC (dS/m)	0.54 ±0.10	0.25 ±0.02	2.78	**	116
C %	0.47 ±0.01	0.54 ±0.03	1.17	NS	-12.96
N %	0.37 ±0.01	0.33 ±0.01	1.33	NS	12.12
Avail P (mg/kg)	1.87 ±0.22	1.30 ±0.06	2.53	**	43.85
Ca (cmol/kg)	1.78 ±0.21	0.62 ±0.09	0.25	NS	187.09
Mg (cmol/kg)	0.64 ±0.04	0.38 ±0.09	2.73	**	68.42
Na (cmol/kg)	0.23 ±0.10	0.20 ±0.08	0.27	**	15
K (cmol/kg)	2.05 ±0.13	1.46 ±0.39	1.62	NS	40.41
Exch Acidity (cmol/kg)	0.51 ±0.03	0.44 ±0.01	0.46	NS	15.9
CEC (cmol/kg)	1.32 ±0.10	1.09 ±0.12	1.50	NS	21.1
Base saturation (%)	57.44	49.65	0.41	NS	15.69

Soil chemical properties

The mean pH of soil at the charcoal production is significantly ($p<0.01$) higher as compared to the adjacent site (Table 2). It was increased by 15.56% at the charcoal production site. However, the study area is rated acidic but at the charcoal production site the pH increases which could be due to the addition of ash in the site thereby accumulating the basic cations. Another reason for high soil pH at kiln site could be because of porous nature of the charcoal that increases CEC of the soil. Thus there could be a chance for Al and Fe to bind with the exchange site (Nigussie and Kissi 2011). Furthermore, the study conducted by Lehman et al. (2003) revealed that application of charcoal has a positive effect on acidic and aluminium toxicity soils. It is revealed that the mean organic carbon in the CS showed a slight increase over the adjacent field sites. At 5% confidence level the values are not statistically different. Similarly, the experiment result on electrical conductivity shows significant ($p<0.01$) difference more than 100%, which could be because of the deposition of ash and charcoal particles at the CS during the process of charcoal production and harvesting of charcoal. Oguntunde et al. (2004) also reported a significant increase in electrical conductivity at kiln site. Eventually, exchangeable acidity was also increased by 15.9% at CS as compared to AS. The mean carbon and nitrogen values in both the sites were also more or less similar, the result reveals that slight decrease in carbon at CS which may be probably due to the form of carbon present in the soil. The analysis also shows that there is significant increase in available phosphorus significantly ($p<0.01$) at CS comparing to AS, this inferred that the deposition of rich phosphorus wood ashes and heating at the kiln site enhanced release of microbial phosphorus (Trossero 2003). Increase in available phosphorus at the charcoal kiln site over the adjacent site was also unveiled by Blanca et al. (2008). The exchangeable bases also showed increase in values at CS, especially Mg and Na are increased significantly ($p<0.01$) by 68.42 and 15% respectively. Whereas Ca and K values found in CS also showed increase in their means as compared to AS by 187.09 and 40.41% respectively. The increase in amount of these bases could be due to the deposition of ash during the burning of wood for charcoal and the ash deposit increase the Ca contents of soil (Ogundele et al. 2011). Hence, from the above results the mean values of exchangeable bases are increased at CS as compared to the mean at the adjoining soils. Thereby, the cation exchange capacity of the charcoal production is also affected; the higher value of CEC is derived due to the presence of charcoal residues and organic matter at the production site. It is agreed that the charcoal site is indicative of the capacity to retain key nutrient cations in the soil in plant available form and minimize leaching loss which is a key factor where differences in crop productivity are observed (Sohi et al. 2009). Therefore, we may conclude that the charcoal production practice has significantly affected on base content due to the generation of ashes and charred biomass through pyrolysis of woods. This contributes to the augmentation in cation exchange capacity of the soil and other properties, except that the carbon content, silt and bulk density at charcoal production site is lessened. However, further investigations on the effect on other micronutrients as well as biological properties of soil viz., microbial population, enzyme activities and soil microbial biomass are necessary in order to have a holistic understanding of the impact of charcoal burning on soil properties. Therefore, choice of species for charcoal making and method of charcoal production may also be further assessed to ascertain the impact on environment and soil fertility of the charcoal production sites.

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