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Research Article

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Physico-chemical properties of soils under different land uses in Longleng district soils of Nagaland

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Summary

Land use effect on soil physico-chemical properties were studied in four villages, *viz.,* Tamlu village, Tamlu town, Kangching and Namsang in Longleng district, Nagaland, under four land uses, *viz., Jhum*, lowland rice, forest and orange in each village. The soils were characterised by strong to moderate acidic in soil reaction (4.3 to 6.7), high in organic carbon content. The mean cation exchange capacity (CEC) ranged between 13.78 to 31.68 c mol (p^+) kg^{-1}. The mean bulk density and particle density ranged from 1.18 to 1.51g cm^{-3} and 2.2 to 2.34 g cm^{-3}, respectively which generally increased with profile depth and were influenced by organic carbon content and mechanical composition of soils. Water holding capacity (WHC) varied from 40.20 to 54.20 per cent and was higher in the soils under cultivated lowland rice land use as compared to other land uses. The maximum per cent aggregates (WSA> 0.25 mm) and mean weight diameter in surface soils was found under *Jhum* land use. The bulk density, particle density, WHC and mean weight diameter had significant correlation with organic C.

Key words : Land uses, Soil properties, Surface soil, Sub surface soil

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Introduction

Land use changes and agricultural practices, especially cultivation of deforested land may rapidly diminish soil quality. Severe deterioration in soil quality may lead to a permanent degradation of land productivity. Transformation of one land use system into another system and different management practices can affect soil structure, soil organic carbon and other nutrients reserve. The increasing intensity of land use may cause erosion and soil compaction through changes in soil physical and chemical properties. Land degradation due to soil erosion reduces the agricultural production and productivity through deterioration of physical land qualities and land degradation. Soil physical properties are changed gradually under crop cultivation. Changes in physical land qualities may vary depending upon the nature of crop and intensity of its cultivation. The increasing intensity of land use may cause erosion and soil compaction through changes in soil physical and chemical properties. The soil physical properties play an important role in determining its suitability for crop production. Productivity of the soil is the function of management practices which are determined by its dynamic physical and chemical characteristics. The data pertaining to the variability of physico-chemical properties of soils of Longleng district of Nagaland under different land use pattern is found scanty. Therefore, the present investigation was undertaken to evaluate the physico-chemical characteristics of soils under *Jhum*, lowland rice, forest and orange land uses in Longleng district soils of Nagaland.

Resource and Research Methods

Soil samples from 0-15 and 15-30 cm depth were collected from four different land uses, *viz.*, *Jhum*, lowland rice, forest and orange cultivation from four different locations around Tamlu sub division, the sub headquarters of Longleng district *viz.*, Tamlu village, Tamlu town, Kangching and Namsang. Longleng is located between longitude 94°E- 95°E and latitude 26°'N - 27°N of the Equator. It has an average elevation of 1066 metres above mean sea level. The climate of the study area is temperate to sub-tropical with mean annual temperature of 16ºC. The average annual rainfall ranges from 1800 mm to 2500 mm. These soil samples were processed and analysed for different physico-chemical properties. Undisturbed core soil samples were also collected for determination of bulk density. Particle-size distribution was determined following International Pipette method (Piper, 1996) using 0.5 N NaOH as a dispersing agent. Soil pH was determined in 1:2.5 soil water suspension using glass electrode pH meter (Jackson, 1973). Organic carbon and cation exchange capacity (CEC) of the soil was determined by the wet digestion method of Walkley and Black and NH_3 distillation method, respectively as described by Jackson (1973).

Bulk density and particle density were determined by adopting procedures as suggested by Baruah and Barthakur (1997). Water holding capacity (WHC) was determined as per the procedure outlined by Piper (1996). Aggregate stability in terms of mean weight diameter (MWD) and per cent macro-aggregates were calculated by using the equation given by Van Bavel (1949). The statistical analysis of the data was done as per procedure outlined by Gomez and Gomez (1984).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

pH:

The pH of surface soils under *Jhum*, low land rice, forest and orange land uses ranged from 5.00 to 6.00, 5.30 to 6.40, 4.60 to 5.60 and 4.90 to 6.70 with an average of 5.60, 5.80, 5.20 and 5.80, respectively (Table 1). The highest mean pH in surface soil was recorded in Namsang soils followed by Kangching, Tamlu village and Tamlu town soils. The pH of the sub surface soils under *Jhum*, low land rice, forest and orange land uses varied from 4.70 to 5.20, 4.70 to 5.50, 4.00 to 4.60 and 4.50 to 4.80 with an average of 4.90, 5.00, 4.30 and 4.70, respectively. The highest mean pH in sub-surface layer was also found in Namsang soils followed by followed by Tamlu village, Tamlu town and Kangching soils. The soils of the study area were moderate to strong acidic in reaction. Similar results have also been reported by Bhaskar *et al.* (2004); Das (2007) and Laxminarayana (2010) for the soils of Meghalaya. In general, pH decreased with increase in soil depth. Such findings are also reported by Nayak and Srivastava (1995). The moderate to strong acid condition may be attributed to leaching of bases due to heavy rainfall and accumulation of acid forming cations like Al, Fe and Mn leading to increased acidity.

Organic C:

The organic C content of surface soils under *Jhum*, low land rice, forest and orange land uses varied from 2.87 to 3.00, 2.48 to 3.65, 3.00 to 4.58 and 1.04 to 3.85 per cent with an average of 2.98, 3.13, 3.74 and 2.78 per cent, respectively (Table 1). The organic C in 15-30 cm soils ranged from 1.17 to 1.31, 1.36 to 1.83, 2.10 to 3.39 and 0.56 to 1.75 per cent with an average of 1.24, 1.56, 2.71 and 1.30 per cent under *Jhum*, low land rice, forest and orange land uses, respectively. The Highest mean organic C in surface soils was found in Tamlu village followed by Namsang, Tamlu town and Kangching soils, whereas, in sub-surface soils the highest organic C was recorded in Tamlu town followed by Namsang, Tamlu villag, and Kangching soils. Variation in organic carbon in soils under various land uses may be due to varying degree of leaf litter and their rate of decomposition. In all the land use systems, the surface layer had higher organic C as compared to sub surface layer which could be due to deposition of leaf litter and residues. Similar findings were also reported by Kumar and Singh (2007) and Dutta *et al.* (2015).

The soils under forest have high organic carbon content compared to other land uses. The luxuriant vegetation and relatively low temperature conditions favouring slow rate of decomposition has been the major factor contributing to the high soil organic carbon level under forest land use system. Higher organic carbon in forest soils in comparison to other land uses have also been reported by Paul *et al.* (2011); Dadhwal *et al*. (2012) and Singh and Munth (2013).

Cation exchange capacity (CEC):

The CEC of surface soils under *Jhum*, low land rice, forest and orange land uses ranged from 17.50 to 26.50, 20.70 to 27.10, 24.50 to 37.40 and 17.40 to 32.70 c mol (p^+) kg^{-1} with an average of 20.98, 23.07, 31.68 and 25.30 c mol (p^+) kg^{-1}, respectively (Table 1). The CEC of 15-30 cm soils under *Jhum*, low land rice, forest and orange land uses varied from 13.00 to 17.40, 12.10 to 16.00, 15.20 to 18.60 and 11.20 to 16.50 c mol (p^+) kg^{-1} with an average of 14.65, 13.93, 16.38 and 13.78 c mol (p^+) kg^{-1}, respectively. The highest mean CEC in surface soil was recorded in *Jhum*, low land rice, forest and orange land uses,. The highest mean CEC in sub surface soil was observed in Tamlu town followed by Kangching, Namsang and Tamlu village soils. These results are in agreement with those reported by Sharma *et al.* (2012) for the soils of NE regions.

In general, forest land uses showed higher levels of CEC. The increase in humus content on decomposition of added organic sources may be responsible for increasing the negative charge on the organic colloid of the soil, which in turn would contribute to increase in CEC of the soil. Dutta *et al.* (2015) and Namie *et al.* (2016) also reported higher CEC on forest soils. Similar observations were also reported by Rudramurthy *et al.* (2007) and Paul *et al.* (2011).

Bulk density:

The bulk density of surface soils varied from 1.00

Table 1: Chemical properties of the soils under various land uses

Land use and location	pH		Organic C (%)		CEC [c mol (p^+) kg^{-1}]	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Jhum						
Tamlu village	6.00	5.20	2.94	1.17	18.60	13.00
Tamlu town	5.60	5.00	3.00	1.31	26.50	14.70
Kangching	5.00	4.80	3.08	1.17	21.30	17.40
Namsang	5.60	4.70	2.87	1.31	17.50	13.50
Mean	5.60	4.90	2.98	1.24	20.98	14.65
Lowland						
Tamlu village	5.30	5.00	3.13	1.48	21.70	14.80
Tamlu town	5.50	5.00	2.48	1.83	22.80	12.80
Kangching	6.40	4.70	3.65	1.36	20.70	12.10
Namsang	5.90	5.50	3.25	1.57	27.10	16.00
Mean	5.80	5.00	3.13	1.56	23.07	13.93
Forest						
Tamlu village	5.60	4.30	4.58	2.10	28.30	15.30
Tamlu town	4.60	4.40	3.60	3.00	36.50	16.40
Kangching	5.20	4.00	3.00	2.35	24.50	15.20
Namsang	5.40	4.60	3.77	3.39	37.40	18.60
Mean	5.20	4.30	3.74	2.71	31.68	16.38
Orange						
Tamlu village	5.40	4.80	3.85	1.75	17.40	12.30
Tamlu town	4.90	4.70	2.91	1.36	32.20	15.10
Kangching	6.50	4.50	1.04	0.56	32.70	16.50
Namsang	6.70	4.80	3.34	1.49	18.90	11.20
Mean	5.80	4.70	2.78	1.30	25.30	13.78
Average	5.60	4.75	3.16	1.70	25.26	14.68

to 1.30, 1.11 to 1.20, 1.32 to 1.70 and 1.04 to 1.40 g cm^{-3} with an average of 1.20, 1.21, 1.51 and 1.18 g cm^{-3} under *Jhum*, low land rice, forest and orange land uses, respectively (Table 2). The bulk density in sub surface soils under *Jhum*, low land rice, forest and orange land uses ranged from 1.20 to 1.41, 1.30 to 1.40, 1.30 to 1.80 and 1.22 to 1.50 g cm^{-3} with an average of 1.36, 1.35, 1.42 and 1.33 g cm^{-3}, respectively. Bulk density of sub- surface soils were higher than surface soils except in forest soils of Tamlu village, Kangching and Namsang. This might be due to presence of organic matter and clay content in surface soils. Higher compaction in the sub surface soils may be due to absence of cultivation. The influence of organic matter on bulk density was also reported by Khera and Kahlon (2005); Ray *et al.* (2006); Mandal *et al.* (2011); Gupta (2010); Dadhwal *et al.* (2012) and Ranjan *et al.* (2014). Bulk density showed significant negative correlation with organic C (r= -0. 54) and positive correlation with particle density (r= 0.91).

Particle density:

The particle density of surface soils ranged from 2.00 to 2.42, 2.10 to 2.31, 2.27 to 2.70 and 2.00 to 2.40 g cm^{-3} with an average of 2.28, 2.20, 2.56 and 2.13 g cm^{-3} under *Jhum*, low land rice, forest and orange land uses, respectively (Table 2). The lowest mean particle density in surface soils was recorded in Kangching and the highest was found in Namsang soils. The particle density of sub surface soils under *Jhum*, low land rice, forest and orange land uses varied from 2.19 to 2.72, 2.31 to 2.68, 2.30 to 2.82 and 2.17 to 2.34 g cm^{-3} with an average of 2.52, 2.41, 2.66 and 2.24 g cm^{-3}, respectively. The lowest and highest mean particle density in sub surface soils were found in Kangching and Tamlu town soils, respectively. The lower particle density in orange land use might be due to less biotic interference which

Table 2: Physical properties of the soils under different land uses

Land use and location	Bulk density (g cm^{-3})		Particle density (g cm^{-3})		WHC (%)		Aggregates > 0.25 mm (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Jhum								
Tamlu village	1.20	1.40	2.31	2.55	47.60	46.70	86.20	78.10
Tamlu town	1.30	1.40	2.32	2.60	46.34	45.69	87.20	86.10
Kangching	1.00	1.20	2.00	2.19	46.70	46.30	89.03	84.97
Namsang	1.20	1.41	2.42	2.72	41.70	40.20	71.60	70.16
Mean	1.20	1.36	2.28	2.52	45.59	44.72	83.51	79.83
Lowland								
Tamlu village	1.11	1.30	2.31	2.68	50.20	50.00	85.60	81.40
Tamlu town	1.20	1.40	2.20	2.31	51.81	50.80	73.30	71.20
Kangching	1.20	1.30	2.10	2.37	50.10	50.00	64.23	61.71
Namsang	1.20	1.40	2.20	2.31	49.80	49.70	89.67	67.12
Mean	1.21	1.35	2.20	2.41	50.48	49.80	72.95	70.36
Forest								
Tamlu village	1.60	1.30	2.70	2.80	51.20	50.70	77.40	72.10
Tamlu town	1.32	1.80	2.60	2.71	53.68	51.69	69.90	61.30
Kangching	1.70	1.30	2.27	2.30	54.20	53.80	81.40	80.20
Namsang	1.42	1.30	2.65	2.82	40.10	51.80	84.03	81.07
Mean	1.51	1.42	2.56	2.66	49.80	51.99	78.18	73.67
Orange								
Tamlu village	1.07	1.22	2.01	2.17	48.70	47.10	79.67	72.90
Tamlu town	1.20	1.30	2.10	2.24	50.90	50.66	75.70	74.00
Kangching	1.40	1.50	2.40	2.34	47.12	43.00	74.26	70.82
Namsang	1.04	1.30	2.00	2.21	51.20	38.05	68.06	67.29
Mean	1.18	1.33	2.13	2.24	49.48	44.70	74.42	71.25
Average	1.26	1.36	2.29	2.46	48.83	47.89	78.58	73.78

consequently led to less compaction and more organic matter in the soil. Similar results were also reported by Dadhwal *et al.* (2011) and Mandal *et al.* (2011). Particle density had a significant negatively correlated with organic carbon (r= -0.56) (Table 4).

Water holding capacity (WHC):

The WHC of surface soils ranged from 41.70 to 47.60, 49.80 to 51.81, 40.10 to 54.20 and 47.12 to 51.20 per cent with an average of 45.59, 50.48, 49.80 and 49.48 per cent, under *Jhum*, low land rice, forest and orange land uses, respectively (Table 2). The maximum mean WHC in surface soil was found in Tamlu town followed by Kangching, Tamlu village and Namsang soils. The WHC in sub surface soils ranged from 40.20 to 46.70, 49.70 to 50.80, 50.70 to 53.80 and 38.05 to 50.66 per cent with an average of 44.72, 49.80, 51.99 and 44.70 per cent under *Jhum*, low land rice, forest and orange

Table 3: Mechanical composition and mean weight diameter (MWD) of the soils under various land uses

Land use and location	Sand (%)		Silt (%)		Clay (%)		MWD (mm)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Jhum								
Tamlu village	46.82	38.10	19.47	20.18	32.71	40.72	0.82	0.62
Tamlu town	39.70	40.30	18.47	21.09	40.83	37.61	2.30	1.20
Kangching	37.17	39.80	22.32	16.97	39.01	42.03	2.21	1.18
Namsang	36.83	40.43	18.97	25.45	43.20	32.82	1.78	0.91
Mean	40.13	39.66	19.81	20.92	38.94	38.29	1.78	0.98
Lowland								
Tamlu village	38.06	29.23	10.21	21.64	50.13	48.13	0.91	0.78
Tamlu town	31.80	36.15	17.82	17.83	49.18	44.82	2.10	1.60
Kangching	28.18	30.70	29.08	21.06	40.64	47.14	2.14	1.23
Namsang	35.60	29.88	26.86	20.21	36.54	48.91	0.75	0.62
Mean	33.41	31.49	20.99	20.18	44.12	47.25	1.48	1.06
Forest								
Tamlu village	45.20	31.66	16.07	16.72	37.60	50.12	1.82	0.92
Tamlu town	42.08	28.37	17.81	21.43	39.81	38.90	1.87	1.32
Kangching	35.89	32.47	22.43	17.42	40.68	48.71	0.95	0.63
Namsang	42.56	34.89	20.75	22.17	35.69	41.74	1.82	0.96
Mean	40.93	34.85	19.77	19.44	39.23	44.87	1.62	0.95
Orange								
Tamlu village	39.24	44.47	17.84	14.80	41.72	38.63	1.13	0.81
Tamlu town	41.61	43.51	19.41	18.91	37.98	36.49	1.38	0.84
Kangching	36.06	39.54	22.63	20.74	40.31	37.82	0.89	0.62
Namsang	31.21	26.68	24.18	27.23	44.20	42.09	0.68	0.61
Mean	37.02	38.55	21.02	20.42	41.05	38.76	1.07	0.72
Average	37.87	36.14	20.40	20.24	40.84	42.29	1.47	0.93

Table 4: Correlation co-efficient among different soil properties

Soil properties	Water holding capacity	Mean weight diameter	Bulk density	Particle density	Per cent aggregates
Mean weight diameter	-0.53*				
Bulk density	-0.20	-0.13			
Particle density	-0.25	-0.05	0.91**		
Per cent aggregates	0.12	0.01	-0.13	-0.13	
Organic carbon	0.72**	0.53*	-0.54*	-0.56*	0.08

*and ** indicate significance of values at P=0.05 and P=0.01, respectively land uses, respectively. The highest mean WHC in sub surface soil was also in Tamlu town and lowest was in Namsang soils. The WHC was greatly influenced by mechanical composition and organic matter content in soils which can be depicted from significant positive correlation of WHC with organic carbon (r= 0.72) and clay (r= 0.38) (Table 4). Similar observations were also reported by Dutta and Dhiman (2001); Mehta *et al.* (2005); Ray *et al.* (2006) and Pati *et al*. (2016).

Per cent aggregation:

The aggregates >0.25 mm of surface soils under *Jhum*, low land rice, forest and orange land uses ranged from 71.60 to 89.03, 64.23 to 89.67, 69.90 to 84.03 and 68.06 to 79.67 per cent with an average of 83.51, 72.95, 78.18 and 74.42 per cent, respectively (Table 2). The aggregates >0.25 mm of 15-30 cm soils ranged from 70.16 to 86.10, 61.71 to 81.40, 61.30 to 81.07 and 67.29 to 74.00 per cent with an average of 79.83, 70.36, 73.67 and 71.25 per cent under *Jhum*, low land rice, forest and orange land uses, respectively. The highest per cent aggregation in both surface and sub-surface soils was found in Tamlu village soils followed by Kangching, Tamlu town and Namsang soils. The higher per cent aggregation in all these land uses might be because of higher organic matter content in these soils that together with clay and other soil constituents favour particle aggregation. The per cent aggregates and organic C content showed similar trend. Similar results were also reported by Sharma and Kumar (2010); Kumar and Singh (2007); Singh and Khera (2008); Mainuri and Owino (2013) and Ranjan *et al*. (2014).

Mean weight diameter (MWD):

The MWD of surface soils under *Jhum*, low land rice, forest and orange land uses ranged from 0.82 to 2.30, 0.75 to 2.14, 0.95 to 1.87 and 0.68 to 1.38 mm with an average of 1.78, 1.48, 1.62 and 1.07 mm, respectively (Table 3). The MWD of sub-surface soils varied from 0.62 to 1.20, 0.62 to 1.60, 0.63 to 1.32 and 0.61 to 0.84 mm with an average of 0.98, 1.06, 0.95 and 0.72 mm under *Jhum*, low land rice, forest and orange land uses, respectively. The maximum MWD both in surface and sub-surface soils was observed in Tamlu town soils followed by Kangching soils. The MWD showed a significant positive correlation with organic C (r= 0.53). Similar observations were also made by Kumar and Singh (2007); Ayoubi *et al*. (2011) and Pati *et al*. (2016).

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