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Effect of Land Use Changes on Soil Properties in Northeast India

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Abstract: Soil samples from (0- 20 cm depth) were collected from different villages of Tseminyu sub-division of Kohima district from jhum and forest lands, and was analysed for different soil physic-chemical and acidity parameters. The soils were strongly to moderately acidic in reaction. The CEC were low and at ranged from 8.12 to 13.7 and 11.0 to 16.2 cmol (p^+) kg^{-1} while organic carbon content ranged from 1.51 to 2.46 and 1.50 to 3.23 % under jhum and forest land use systems, respectively. The soils of both the land use systems were high in organic carbon, medium in available nitrogen, low to medium in available P and medium in available K. The mean of available N, P, K contents and organic carbon of both the land uses ranged from 393.3 to 473.6, 12.4 to 12.3, 223.6 to 232.5 kg ha^{-1} and 2.1 and 2.41% in soils respectively. In both the land use systems, each form of acidity *viz*., pH dependent acidity, exchangeable acidity, extractable acidity, exchangeable Al^{3+} and exchangeable H^+ contributed to total acidity in varying proportions. The pH-dependent acidity was the dominant form of acidity and its contribution to total acidity was more than 80% in both the land use systems.

Keywords: *Physicochemical properties, jhum, forest land use system, soil nutrient*

Introduction

Soil is a vital determinant of agriculture. World today is facing challenges for maintaining agricultural and environmental sustainability. Land use practices are considered to have caused definite deterioration in soil and environmental quality (Singh *et al*. 2014). Nagaland state (25°10' N to 27°4' N; 93°15' E to 95°20' E) is in the extreme northeast of India with a geographical area of about 1.66 million ha and an altitudinal variation from 100 m to 3826m above MSL. Soils of Nagaland are acidic and generally fertile. Nagaland's geography is characterized by its mountainous terrain, which influences the distribution of soils in the state. The most common soil types found in Nagaland is red loamy soil. The quality of soil is gradually declining due to accelerated conversion of forest land due to intensive agricultural activities, rapid urbanization and other human activities have resulted changes in land use and land cover pattern. Significant land use / land cover changes have been reported during the last 20-30 years both on spatial and temporal scale, mainly due to economic development and population growth. Due to rapid population growth, fresh forest areas were felled and cleared for shifting agriculture, timber and firewood *etc*. Thus physico-chemical status of soils of Nagaland needs to be critically examined so that modern agricultural technologies could be applied for more production. Shifting cultivation is pre-dominant in Nagaland which adversely affects soil properties. Jhum

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cultivation when practiced with a cycle of 15 to 20 years does not possess much threat as sufficient time for regeneration of forest and soil fertility is provided. However, due to the increase in population the cycle of jhum cultivation has been reduced to less than 10 years with more people engaged in this activity. There is also serious threat of forest degradation which is a major contributory factor to soil degradation in terms of erosion and organic carbon loss. In 6-7 years, the land degradation area increased by 2.55% (42,265 ha) to 50% (2018-19). The continuous practise of jhum cultivation may rapidly deteriorate soil quality which will result in permanent degradation of land productivity. Hence, to overcome these alarming problems, there is need to study the physico-chemical properties of soils so that farmers could be adverse for suitable agro-managements for maintaining the soil health for increased productivity.

Materials and Methods

Study area

The soil samples were collected from 15 different villages of Tseminyu sub-division in under Kohima district of Nagaland. Tseminyu is one of the oldest sub-division of Nagaland (25.92° N; 94.21° E) covering an area of 564 sq. kms, lies at an altitude of 1062m above sea level. Tseminyu has been classified as warm and temperate climate with temperature ranging from 16.2 to 24.6 °C. The average annual rainfall is 1885 mm.

Sample collection and analysis

Thirty composite soil samples were collected from 15 villages (0-20 cm depth), one from each land uses (Jhum field and forest) of each village. The collected soil samples were spread on polyethene sheets and air dried under shade. Stones, pebbles, plant roots, *etc* were removed and soil samples were processed (2mm) for laboratory analysis. The soil pH was determined in (1:2.5) water suspension. Bulk Density was determined by dividing weight of soil with the volume of soil, particle density by Pycnometer method as described by Baruah and Barthakur (1997). Oxidisable organic carbon (OC) in soil was estimated by Walkely and Black (1934) method, The cation exchange capacity (CEC) of soil was determined by NH_4OAC method at pH 7.0. The available nitrogen (N), phosphorus (P) and potassium (K) contents were determined by alkaline potassium permanganate method (Subbiah and Asija 1956), Bray's No-1 method (Bray and Kurtz 1945) and neutral normal ammonium acetate (pH 7.0), respectively. Total potential acidity was determined by $BaCl_3$–triethanolamine extract buffered at pH 8.0-8.2 (Baruah and Barthakur 1997). The lime requirement (LR) of the soil was determined by Shoemaker *et al*. method (1961) by suspending soil samples in buffer solution of para nitrophenol (pH 7.5) in soil: solution ratio of 1:2 and pH of buffer solution was measured. Exchangeable acidity was determined as per the method described by Mclean (1965). The extractable acidity was determined calorimetrically with aluminium reagent and exchangeable Al^{3+} by the method outlined by Barauh and Barthakar (1997). Exchangeable H^+ was estimated by the difference between exchange acidity and exchangeable Al^{3+}.

Results and Discussion

Physico-chemical properties of soils

Soil pH

The soils of different villages under jhum land use system had pH varying from 4.52 to 5.25 while it varied from 4.45 to 5.23 in forest land use system values of 4.78 (Table 1). This showed that the soils in both jhum and forest land use systems are strongly to moderate acidic in reaction. The low pH of these soils might be due to leaching of the basic cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) from the soils profile due to high rainfall (Patton *et al*. 2005; Amenla *et al*. 2010). Phenwhenyu village had highest pH (5.25) and soil of New Tesophenyu village showed the lowest pH (4.52) under jhum land use system. While, in forest land use system, the highest and lowest soil pH was found in Nsunyu village (5.23) and K. Station (4.45) village, respectively.

Soil organic carbon

The organic carbon content was found to be higher in forest ranging from 1.50% to 3.23 % (Table 4) than jhum land use system (1.51% to 2.46 %). This may be attributed to the continuous addition of decayed vegetation in the forest (Tripathi *et al*. 2007). The thick vegetation and relatively low temperature conditions favours slow rate of organic matter decomposition might have contributed to the high organic carbon content in the soil K. Station village had highest organic carbon content of 2.46% while Phenshunyu village possessed the lowest organic carbon content of 1.51% in jhum land use system. The highest and lowest soil organic carbon content of 3.23% and 1.50 % was observed in forest land use system of Nsunyu village and Terogvunyu village respectively. The organic carbon content in both the land use systems had been significant and positive correlation with available N and K (Table 7 and 8). Similar correlation was also reported by Tasung and Ahmed (2017). Significant and negative correlation with some forms of acidity was also observed under forest land use systems.

Cation exchange capacity

The cation exchange capacity of soils of different villages under jhum land use system varied from 8.12 to 14.25 cmol (p+) kg^{-1} while for forest land use system, it varied from 11.01 to 16.25 cmol (p+) kg^{-1} (Table 1). There was higher CEC under forest land system due to higher organic carbon of the soils (Rudramurthy *et al*. 2007). K. Station village had highest CEC to the tune of 14.25 cmol (p^+) kg^{-1} and Kandinyu village showed the lowest CEC of 8.12 cmol (p^+) kg^{-1} in jhum land use system. The highest and lowest CEC of 16.25 and 11.01 cmol (p^+) kg^{-1} in forest land use systems were observed in the soils of New Terogvunyu and T. South village. The cation exchange capacity had a significant and positive correlation with available N and K in both the land use systems. Similar correlation was also reported by Kundu *et al*. (2014)

Table 1. Chemical properties of the soils under jhum and forest land use systems

Name of the village	pH		Organic carbon		CEC	
	Jhum	Forest	Jhum	Forest	Jhum	Forest
Terogvunyu	5.03	4.75	2.40	1.50	12.12	11.63
New Terogv unyu	4.91	4.51	1.80	2.1	8.65	16.25
Phenwhenyu	5.25	4.79	2.17	2.54	9.09	16.11
Kashanyu	4.75	4.77	2.34	1.87	13.21	14.80
Phenshunyu	4.82	5.02	1.51	3.08	8.61	16.03
Sendenyu	4.85	4.92	1.95	2.78	8.32	12.79
T. South	4.71	4.67	2.21	1.88	13.73	11.01
T. Zisunyu	4.99	4.78	2.32	1.52	12.46	12.32
Tseminyu	4.61	4.82	2.40	2.26	12.21	11.29
Tesophenyu	4.86	4.49	2.12	2.12	13.23	15.61
New Tesophenyu	4.52	4.72	2.01	2.78	10.51	14.33
Nsunyu	4.65	5.23	2.23	3.23	13.61	16.02
Chunlikha	4.87	4.65	1.76	3.16	13.01	15.79
K. Station	4.77	4.45	2.46	2.29	14.25	16.01
Kandinyu	5.02	5.09	1.94	3.17	8.12	14.61
Mean	4.84	4.78	2.10	2.41	11.40	14.30

Total potential acidity

The total potential acidity of jhum land use system respectively and forest land use system ranged from 10.12- 14.18 cmol (p^+) kg^{-1}, 9.09- 14.63 cmol (p^+) kg^{-1}. Among the soils of jhum land use system, the highest total potential acidity of 14.18 cmol (p^+) kg^{-1} was recorded in soils of Nsunyu village while in forest land use system highest total potential acidity of 14.63 cmol (p^+) kg^{-1} was recorded in soils of New Terogvunyu village. Correlation studies (Table 7and 8) indicated that the total potential acidity in both the land use had a significant and negative correlation with pH. Similar correlation was also reported by Kumar *et al*. (1995).

pH dependent acidity

The data relating to pH-dependent acidity of different villages under jhum *a*nd forest land use systems are presented in table 2. The data showed that pH-dependent acidity of jhum land use system varied from 8.4 to 11.42 cmol (p^+) kg^{-1} while for forest land use system; it varied from 7.31 to 12.15 cmol (p^+) kg^{-1}. Among the soils of jhum land use system, highest pH-dependent acidity of 11.42 cmol (p^+) kg^{-1} was recorded in soils of Tseminyu and Chunlikha village while in forest land use system, highest pH-dependent acidity of 12.15 cmol (p^+) kg^{-1} was recorded in soils of Tseminyu village (Table 2). pH-dependent acidity significantly contributed in both the land use systems. Higher contribution of pH-dependent acidity towards total potential acidity has also been reported by Dolui and Battacharjee (2003). Correlation studies (Table 7 and 8) revealed that pH-dependent acidity had a significant and negative correlation with soil pH and significant and positive correlation with all other forms of acidity in both the land use systems. Bandyopadhyay and Chattopadhyay (1997) also reported similar findings.

Exchangeable acidity

Among the soils of jhum land use system, highest exchangeable acidity of 2.76 cmol (p^+) kg^{-1} was recorded in soils of Nsunyu village and the lowest exchangeable acidity of 1.64 cmol (p^+) kg^{-1} was in soils of Phenwhenyu village. In forest land use system, highest exchangeable acidity of 2.65 cmol (p^+) kg^{-1} was recorded in soils of K. Station (Table 2). It showed that the % contribution of exchangeable acidity towards total potential acidity was relatively lower. It contributed to an extend of 18.41% and 18.75 % in jhum and forest land use systems respectively. Similar contribution of exchangeable acidity towards total potential acidity was also reported by Laxminarayana (2010). Correlation studies (Table 7 and 8) indicated that exchangeable acidity had a significant and negative correlation with soil pH in both the land use systems.

Table 2. Physical properties of the soils under jhum and forest land use systems

Name of the Village	Total Potential acidity [cmol (p^+) Kg^{-1}]		pH dependent acidity [cmol (p^+) Kg^{-1}]		Exchangeable acidity [cmol (p^+) Kg^{-1}]	
	Jhum	Forest	Jhum	Forest	Jhum	Forest
Terogvunyu	10.89	12.03	9.01	9.76	1.88	2.27
New Terogvunyu	12.48	14.63	10.22	12.07	2.26	2.56
Phenwhenyu	10.82	10.16	9.18	8.4	1.64	1.76
Kashanyu	13.8	12.31	11.27	9.81	2.53	2.5
Phenshunyu	12.22	11.12	9.8	8.22	2.42	1.9
Sendenyu	11.21	10.56	9.2	8.88	2.01	1.68
T.South	11.37	14.04	8.86	11.48	2.51	2.56
T. Zisunyu	10.39	13.36	8.46	11.01	1.93	2.35
Tseminyu	14.02	14.23	11.42	12.15	2.6	2.08
Tesophenyu	13.16	13.3	9.01	10.7	2.61	2.7
New Tesophenyu	11.25	14.06	10.55	11.49	1.67	2.57
Nsunyu	14.18	9.09	9.58	7.31	2.76	1.78
Chunlikha	11.08	12.66	11.42	10.04	2.1	2.62
K. Station	13.09	10.93	8.98	10.28	2.61	2.65
Kandinyu	10.12	12.17	10.48	8.26	1.72	1.91
Mean	12	12.31	9.78	9.99	2.21	2.25

Extractable acidity

Extractable acidity of jhum land use system varied from 2.61 to 4.59 cmol (p^+) kg^{-1} while for forest land use system, it varied from 2.51 cmol (p^+) kg^{-1} to 4.47 cmol (p^+) kg^{-1} (Table 3). Among the soils of jhum land use system, highest extractable acidity of 4.59 cmol (p^+) kg^{-1} was recorded in soils of Tsemiynu village while in forest land use system highest extractable acidity of 4.47 cmol (p^+) kg^{-1} was reported in soils of New Terogvunyu village. The % contribution of extractable acidity towards total potential acidity were 30.91% and 29.83% in jhum and forest land use systems respectively. Correlation studies (Table 7 and 8) indicated that extractable acidity had a significant and negative correlation with soil pH and significant and positive correlation with all other forms of acidity in both the land use systems. Similar result has also been reported by Bandyopadhyay and Chattopadhyay (1997).

Exchangeable Al^{3+}

Exchangeable Al^{3+} of jhum land use system varied from 1.43 cmol (p^+) kg^{-1} to 2.34 cmol (p^+) kg^{-1} while for forest land use system, it varied from 1.54 to 2.34 cmol (p^+) kg^{-1} (Table 3). Among the soils of jhum land use system, highest exchangeable Al^{3+} of 2.34 cmol (p^+) kg^{-1} was found in soils of Kashanyu village while in forest land use system, highest exchangeable Al^{3+} of 2.34 cmol (p^+) kg^{-1} was recorded in soils of T. South village. The % contribution of exchangeable Al^{3+} towards exchangeable acidity and total potential acidity were 88.23% and 16.25% in jhum land use system, while in forest land use systems it was 81.33%. Correlation studies in (Table 7 and 8) indicated that exchangeable Al^{3+} had a significant and negative correlation with soil pH and significant and positive correlation with lime requirement of soils for both the land use systems. Also, Exchangeable Al^{3+} had a positive and significant correlation with pH-dependent acidity in both the land use systems. These similar observations were also reported by Talashilkar *et al.* (2006).

Exchangeable H^+

Exchangeable H^+ of jhum land use system varied from 0.13 to 0.71 cmol (p^+) kg^{-1} with a mean value of 0.31 cmol (p^+) kg^{-1}. In forest land use system, it varied from 0.11 to 0.97 cmol (p^+) kg^{-1} (mean 0.42 cmol (p^+) kg^{-1}). Among the soils of jhum land use system, highest exchangeable H^+ of 0.71 c mol (p^+) kg^{-1} was recorded in soils of New Tesophenyu village (Table 3) and the lowest exchangeable H^+ of 0.13 cmol (p^+) kg^{-1} was found in soils of Terogvunyu village, while in forest land use system, highest exchangeable H^+ of 0.97 cmol (p^+) kg^{-1} was observed in soils of Tesophenyu village. The % contribution of exchangeable H^+ towards exchangeable acidity and total potential acidity were 14.02% and 2.58 % in jhum land use system, while in forest land use system, the % contribution were 18.86% and 3.41% towards exchangeable acidity and total potential acidity. Exchangeable H^+ had a significant and positive correlation to soil pH in both the land use systems.

Table 3. Nature of acidity in jhum and forest land use systems

Name of the Village	Extractable acidity [cmol (p^+) Kg^{-1}]		Exchangeable Al^{3+} [cmol (p^+) Kg^{-1}]		Exchangeable H^+ [cmol (p^+) Kg^{-1}]	
	Jhum	Forest	Jhum	Forest	Jhum	Forest
Terogvunyu	2.61	4.03	1.75	1.96	0.13	0.31
New Terogvunyu	4.53	4.47	2.08	2.02	0.18	0.54
Phenwhenyu	2.81	3.04	1.43	1.54	0.21	0.22
Kashanyu	3.71	4.2	2.34	2.08	0.19	0.42
Phenshunyu	3.83	2.71	1.95	1.66	0.47	0.24
Sendenyu	3.52	3.15	1.82	1.56	0.19	0.12
T. South	3.62	4.32	2.26	2.34	0.25	0.22
T. Zisunyu	3.51	4.02	1.78	1.81	0.15	0.54
Tseminyu	4.59	2.51	1.99	1.79	0.61	0.29
Tesophenyu	4.02	4.15	2.13	1.73	0.18	0.97
New Tesophenyu	4.51	4.11	1.96	1.79	0.71	0.78
Nsunyu	4.01	2.81	2.08	1.67	0.68	0.11
Chunlikha	3.61	3.6	1.92	1.73	0.18	0.89
K. Station	4.1	3.8	2.26	2.18	0.35	0.47
Kandinyu	2.81	2.87	1.55	1.66	0.17	0.25
Mean	3.71	3.58	1.95	1.83	0.31	0.42

Lime requirement

The LR at pH 6.0 and pH 6.4 for different soil samples of jhum and forest land use systems are given in table 4. It is evident that the LR to raise the pH of the soils to 6.0 and 6.4 under jhum land use system varied from 7.53-14.58 t ha^{-1} and 8.99-17.50 t ha^{-1} with a mean value of 15.10 t ha^{-1} and 17.78 t ha^{-1}. In forest land use system, it varied from 7.53 -15.79 t ha^{-1} and 8.99 – 18.71 t ha^{-1} with a mean value of 15.31 t ha^{-1} and 18.75 t ha^{-1} respectively. The highest LR to raise the soil pH to 6.0 and 6.4 under jhum cultivation was observed in New Tesophenyu village (14.58 t ha^{-1} and 17.50 t ha^{-1}) and lowest was reported in the soils of Phenwhenyu village (7.53 t ha^{-1} and 8.99 t ha^{1}). In forest land use system, the highest LR at pH 6.0 and 6.4 was recorded in the soils of Tesophenyu village (15.79 t ha^{-1} and 18.71 t ha^{-1}). The lowest LR at pH 6.0 and 6.4 was recorded in soils of Nsunyu village (7.53 t ha^{-1} and 8.99 t ha^{-1}). The higher lime requirement in jhum and forest soil may be attributed to the high acidity of the soils. Correlation studies presented in (Table 7and 8) revealed that lime requirement in both the land use systems had a significant and negative correlation with soil pH and positive and significant correlation with different forms of acidity. Similar results were also reported by Laekemariam and Kibret (2021).

Table 4. Lime requirement of the soils under jhum and forest land use systems

Name of the village	Lime requirement (t ha^{-1})			
	Jhum		Forest	
	Raising pH to 6.00	Raising pH to 6.4	Raising pH to 6.00	Raising pH to 6.4
Terogvunyu	9.48	11.42	12.64	15.07
New Terogvunyu	10.69	12.64	14.58	17.5
Phenwhenyu	7.53	8.99	12.64	15.07
Kashanyu	12.64	15.07	2.64	15.07
Phenshunyu	11.66	13.58	9.48	11.42
Sendenyu	11.66	13.58	10.69	12.64
T.South	12.64	15.07	13.61	16.28
T. Zisunyu	10.69	12.64	12.64	15.07
Tseminyu	13.61	16.28	11.66	13.85
Tesophenyu	11.66	13.85	15.79	18.71
New Tesophenyu	14.58	17.5	12.64	15.07
Nsunyu	13.61	16.28	7.53	8.99
Chunlikha	11.66	13.85	13.61	16.28
K. Station	12.64	15.07	15.79	18.71
Kandinyu	9.48	11.42	9.48	11.42
Mean	11.61	13.81	12.36	14.74

Bulk density

The lower bulk and particle densities were recorded in jhum land use system. The highest bulk density was observed in forest land use system. Tesophenyu village had highest BD in jhum land use system. In forest land use system, the highest BD was observed in Tseminyu village (Table 5). Low bulk densities might be due to higher content of organic matter present in the soil. Chaudhari *et al*. (2013) also reported similar findings.

Particle density

The particle density of soils of different villages under jhum land use system varied from 2.27 to 2.51 Mg m^{-3}. In forest land use system, it varied from 2.19 to 2.44 Mg cm^{-3}. Tseminyu village had the highest PD in jhum land use system. The highest PD was observed in Kandinyu village for forest land use system (Table 5). The particle density of forest land use system was comparatively lower than jhum land use system, which may be attributed due to less compaction and high content of organic matter in the soil.

Porosity

The porosity (%) of soils in different villages under jhum land use system varied from 44.74 to 53.85 % while for forest land use system, it varied from 47.52 to 55.61 %. Forest land use system exhibited higher porosity (51.13 %) than jhum (53.85%) land use system (Table 5).

Table 5. Bulk density, particle density and porosity of soils under jhum or forest land use systems

Name of the Village	Bulk Density (g cm^{-3})		Particle Density (g cm^{-3})		Porosity (%)	
	Jhum	Forest	Jhum	Forest	Jhum	Forest
Terogvunyu	1.12	2.41	2.41	2.21	53.53	48.42
New Terogvunyu	1.23	2.35	2.35	2.21	47.66	48.87
Phenwhenyu	1.12	2.36	2.36	2.26	52.55	51.77
Kashanyu	1.23	2.36	2.36	2.32	47.89	53.45
Phenshunyu	1.17	2.37	2.37	2.19	50.64	48.41
Sendenyu	1.21	2.32	2.32	2.27	47.85	52.43
T.South	1.14	2.47	2.47	2.39	53.85	49.38
T. Zisunyu	1.26	2.28	2.28	2.29	44.74	54.59
Tseminyu	1.25	2.51	2.51	2.32	50.2	55.61
Tesophenyu	1.28	2.47	2.47	2.24	48.18	52.68
New Tesophenyu	1.15	2.32	2.32	2.26	50.44	50.89
Nsunyu	1.18	2.28	2.28	2.21	48.25	47.52
Chunlikha	1.21	2.36	2.36	2.34	48.73	51.71
K. Station	1.25	2.33	2.33	2.28	46.36	50.44
Kandinyu	1.24	2.27	2.27	2.44	45.38	50.82
Mean	1.2	1.11	2.36	2.36	49.03	51.13

Nutrient status of the soil

The available N of soils in different villages under jhum land use system varied from 339.3 to 450.5 kg ha^{-1} (mean value 393.3 kg ha^{-1}). In forest land use system, it varied from 383.3 to 545.8 kg ha^{-1} (mean value 473.6 kg ha^{-1}). T. South village had the highest available N (450.5 kg ha^{-1}) in jhum land use system. The highest available N (545.8 kg ha^{-1}) in forest land use system was observed in the soils of Phenshunyu and T. Zisunyu village, respectively.

The available N was found to be higher in forest than jhum land use system, which can be attributed due to the higher organic carbon content as reported by Triparthi *et al.* (2007). Correlation studies (Table 7 and 8) indicated that available N in both the land use systems had a significant and positive correlation with organic carbon, indicating that available N content of the soils was greatly governed by the content of organic matter of the soils (Meena *et al*. 2006).

The available P of soils of different villages under jhum land use system varied from 8.78 to 17.09 kg ha^{-1}. In forest land use system, it varied from 8.1 to 16.64 kg ha^{-1} with a mean value of 12.34 kg ha^{-1}. New Terogvunyu village had the highest available P (17.09 kg ha^{-1}) in jhum land use system. The highest available P (16.64 kg ha^{-1}) in forest land use system were observed in the soils of Nsunyu and K. Station. The available P was found to be higher in jhum than forest land use system, which can be attributed where slash and burn is commonly followed, leading to addition of ash in the soils which in turn increases the pH leading to higher phosphorus availability (Butler *et al*. 2018). Correlation studies (Table 7 and 8) indicated that available phosphorus in both the land use systems had a significant and positive correlation with soil pH. Similar finding was also reported by Verma *et al*. (2021).

The available K of soils in different villages under jhum land use system varied from 190.67 to 246.33 kg ha^{-1}. In forest land use system, it varied from 195.92 to 272.33 kg ha^{-1}. The highest available K (246.33 kg ha^{-1}) was observed in the soils of Terogvunyu and Phenshunyu villages in respect to jhum land use system. The highest available K (272.33 kg ha^{-1}) in forest land use system was observed in the soils of Chunlikha and T. South village respectively. The available K was higher in forest land use system which may be due to the higher organic carbon content which promote the availability of potassium in forest soil (Singh *et al.* 1999). Correlation studies (Table 7 and 8) indicated that available K in both the land use systems had a significant and positive correlation with organic carbon. This result is in accordance with those of Meena *et al.* (2006).

Table 6. Fertility status of soils under jhum and forest land use system

Sl.no	Name of the Village	Available N (kg ha^{-1})		Available P(kg ha^{-1})		Available K(kg ha^{-1})	
		Jhum	Forest	Jhum	Forest	Jhum	Forest
1	Terogvunyu	420.11	391.7	13.45	13.67	246.03	212.33
2	New Terogvunyu	353.22	532.12	17.09	11.15	195.88	249.71
3	Phenwhenyu	375.67	510.13	16.83	11.01	236.32	250.51
4	Kashanyu	441.34	405.59	13.52	9.7	243.11	219.11
5	Phenshunyu	339.35	545.87	10.32	13.86	190.67	250.17
6	Sendenyu	402.65	459.66	12.26	12.16	194.44	248.31
7	T.South	450.55	443.11	14.35	10.2	232.45	195.92
8	T. Zisunyu	431.21	383.39	13.41	12.45	231.56	206.3
9	Tseminyu	405.33	430.63	10.98	16.26	229.31	201.66
10	Tesophenyu	380.41	461.61	12.09	9.15	206.23	234.96
11	New Tesophenyu	381.13	530.11	8.78	15.77	221.33	256.45
12	Nsunyu	402.67	498.21	9.34	16.64	246.33	238.11
13	Chunlikha	345.05	516.23	11.52	12.34	219.02	272.33
14	K. Station	420.12	456.19	10.17	8.1	245.43	234.31
15	Kandinyu	350.98	540.12	12.89	12.72	216.45	201.66
Mean		393.31	473.64	12.46	12.34	49.03	232.52

Conclusion

The study on physio-chemical properties of soils of Kohima district under jhum and forest land use system indicated high level of organic carbon in both type of land use system and it was significantly and positively correlated with available nitrogen. The available N was medium in both land use system, while P was low to medium and K was medium in jhum and forest land use system respectively. It is evident that soil acidity components are the major governing factors of soil quality in the prevailing land use types of the region. Therefore, it is necessary to adopt suitable and cost effective remedial measures for the improvement of productivity of these soils. Lime application for alleviation of soil acidity-induced stresses is advocated. Soil erosion control measures, organic residues incorporation, conservation agriculture could enhance the overall soil quality and its productivity under different land uses in the Dystrudepts of Nagaland.

Table 7. Correlation between various soil properties of jhum land use system

	pH	**CEC**	**PD**	**BD**	**Porosity**	**OC**	**N**	**P**	**K**	**TPA**	**PDA**	**Ex-A**	**Extr-A**	AB+	**H+**	**LR**
pH	1															
CEC	-0.39	1														
PD	-0.12	0.17	1													
BD	-0.19	0.31	-0.03	1												
Porosity	-0.01	0.03	**-0.82****	**0.59***	1											
OC	-0.07	**0.63****	0.08	0.20	0.03	1										
N	-0.23	**0.62****	-0.02	0.19	0.12	**0.84****	1									
P	**0.69****	-.29	-0.12	0.11	0.15	0.008	0.03	1								
K	-0.03	**0.66****	-0.21	-0.01	0.16	**0.83****	**0.65***	-0.06	1							
TPA	-0.57	0.45	0.33	0.32	-0.07	0.27	0.19	-0.32	0.17	1						
PDA	**-0.55***	0.37	0.29	0.27	-0.06	0.27	0.14	-0.31	0.18	**0.98****	1					
Ex-A	**-0.53***	**0.59***	0.37	0.40	-0.06	0.20	0.28	-0.28	0.10	**0.86****	**0.75****	1				
Extra-A	**-0.77***	0.20	0.38	0.20	-0.18	-0.07	-0.04	-0.39	-0.23	**0.64***	**0.63****	**0.54***	1			
AB+	**-0.72****	**0.62****	0.29	0.31	-0.05	0.19	0.41	-0.27	0.11	**0.70****	**0.61***	**0.81****	**0.64***	1		
H+	**-0.74****	0.10	-0.16	0.006	0.14	0.01	-0.05	**-0.71****	0.11	0.47	**0.51***	0.27	**0.60***	0.21	1	
LR	**-0.98****	0.46	0.19	0.14	-0.70	0.10	0.26	**-0.72****	0.06	**0.58***	**0.55***	**0.56***	**0.77***	**0.73****	**0.70****	1

Table 8. Correlation between various soil properties of forest land use system

	pH	CEC	PD	BD	Porosity	OC	N	P	K	TPA	PDA	Ex-A	Extr-A	AB+	H+	LR
pH	1															
CEC	-0.04	1														
PD	0.22	0.10	1													
BD	0.04	-0.33	0.29	1												
Porosity	-0.19	-0.31	**-0.78****	0.36	1											
OC	0.54	**0.54***	-0.31	0.06	-0.27	1										
N	0.21	**0.66****	**0.52***	-0.06	-0.44	**0.80****	1									
P	**0.65****	-0.21	**0.66****	-0.18	-0.10	0.38	0.19	1								
K	0.17	**0.67****	-0.21	-0.31	-0.37	**0.61***	**0.57***	0.05	1							
TPA	**-0.54***	-0.38	**0.67****	0.27	0.33	-0.45	-0.13	-0.05	**-0.60***	1						
PDA	**-0.72****	-0.40	-0.38	0.12	0.38	**-0.57***	-0.30	-0.14	-0.46	**0.90****	1					
Ex-A	**-0.82****	0.02	-0.40	0.10	0.09	-0.45	-0.20	-0.47	-0.34	**0.65****	**0.71****	1				
Extra-A	**-0.72****	-0.07	0.02	-0.03	-0.05	**-0.64****	-0.32	-0.53	-0.39	**0.53***	**0.58***	**0.81****	1			
AB+	**-0.54***	-0.28	-0.07	0.20	-0.15	**-0.60***	-0.41	-0.45	-0.27	0.42	**0.54***	**0.67****	**0.66****	1		
H+	**-0.65***	0.27	-0.28	-0.03	0.26	-0.10	0.06	-0.24	-0.23	**0.52***	0.49	**0.77****	0.54	0.06	1	
LR	**-0.99****	0.03	0.22	0.27	0.01	0.23	**-0.55***	-0.25	**-0.70****	-0.22	**0.51***	**0.68****	**0.72****	**0.53***	**0.65***	1

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