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Altitudinal and land use influence on soil properties in Nagaland

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ABSTRACT

Present investigation was executed during 2020-21 in the Department of Soil Science, SAS, Nagaland University, Medziphema to study altitudinal and land use impact on soil characteristics. Altogether fifty-six soil samples were collected from fourteen villages (seven villages each from < 200 m and > 300 m altitudes) of Dimapur district, Nagaland. From each village four soil samples (two each from cultivated and forest land use) collected and analyzed for physicochemical properties, fertility status and soil acidity components. Results revealed that irrespective of land use soil pH ranged from 4.30-5.20 and 4.40-5.29 in low (<200 m) and high (>300 m) altitude soils, respectively, indicated strongly to moderately acidic soil reaction, while electrical conductivity (EC) reported alike under both altitude soils. Slightly low bulk density and particle density noticed in high altitude and forest soils. Altitude and land use systems influenced remarkably CEC of soils and more values found in high altitude and forest soils. In general soils observed high in organic carbon, DTPA extractable Cu, Fe and Mn, medium in available N, K and Zn and low to medium in available P and S. Noticeable high amount of OC, available N, P, K and S found in high altitude soils. Minutely less concentration of micronutrients observed in high altitude soils. Forest soils showed elevated amount of OC, macro and micronutrients and lower values of bulk density. Reasonable quantity of acidity components reported in these soils and accounted for severe acidity problem. Low quantum of acidity components reported in high altitude and forest soils. Soil pH had negative significant correlation with soil acidity components. Both macro and micro nutrients significantly and positively correlated with OC. CEC had significant negative correlation with BD and positive with organic carbon. Therefore, regular monitoring of soil health and balanced nutrient addition through manures and fertilizers is essential for sustainable crop production.

Key words: Nagaland, altitude, land use systems, physicochemical properties, fertility status, acidity components.

INTRODUCTION

The natural resources of any nation are the national treasure and proper provision has to be made for its sustainability, in order to attain its benefits in the long run. Among the many natural resources, soil is one such resource on which the sustenance of most organisms is dependent upon, be it directly or indirectly; and is considered as the most basic and vital natural resource. Allowing primary production in terrestrial ecosystem, soil provides about 99% food for humanity and a precondition for existence of life on earth. Wise use of soil resource is essential for sustainable development and feeding the increasing world population (Arshad and Martin, 2002). The growth of plants and productivity of crops is mainly governed by soil fertility, which is the ability of soil to supply nutrients to crops in adequate amount and in suitable proportions (Patzel *et al.,* 2000). However, the soils today have been degraded because of anthropogenic disturbances and have become a global issue. This issue is more prevalent in developing countries having mountainous gradient (Bargali *et al.,* 2018; Manral *et al.,* 2020) where rapid land use transformation is taking place. The altitude of a place profoundly affects the soil's inherent fertility and runoff-erosion behavior (Bowman *et al.*, 2002). Level of rainfall and temperature variation affects organic matter decomposition which in turn affects the accumulation of organic matter with elevation. These changes in microenvironment may affect physicochemical properties of soil of the area.

There is a diverse variation of physicochemical properties among different regions of the world. The north-eastern region of India receives heavy rainfall, due to which soil acidity is a widespread problem for sustainable agriculture production.

Besides this, the undulating topography

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of the region adds up to the problems of crop production. The physicochemical properties and the biodiversity of soil ecosystems are highly influenced by altitude (Kumar *et al.,* 2019). Variation in altitude changes the climate which in turn influences the pedogenic processes and which ultimately affects physicochemical properties of the soils. Information on soil characteristics of an area in relation to altitude would help in planning of soil management strategies and sustainable viable alternatives in order to improve the overall productivity of the area and/or region. Therefore, with a view to have comprehensive knowledge the current investigation was undertaken to study the altitudinal and land use effect on soil properties.

MATERIALS AND METHODS

Present study was undertaken during 2020-21 to study various properties of cultivated and forest soils of different altitudes. Fourteen villages (seven each from low and high altitude) of Dimapur district, Nagaland selected for investigation. Low (<200 m) and high (>300 m) altitude villages belong to Dhansiripar and Medziphema block of the district respectively. All together fifty-six surface (0-15 cm) soil samples collected for the study. Two cultivated fields and adjacent undisturbed forest fields in each village randomly selected for sampling purpose and from one village four soil samples (two each from cultivated and forest land use) were collected.Collected soil samples air dried and grinded with the help of wooden hammer and analyzed for physicochemical properties, fertility status, micronutrient cations and soil acidity components. Cation exchange capacity determined by leaching of soil with 1N ammonium acetate at pH 7.0 (Chapman, 1965). Bulk density, particle density and different forms of soil acidity determined using standard method of analysis described by Baruah and Borthakur (1997). Soil pH, EC, organic carbon, available N and available K determined following standard procedures (Jackson, 1973). Available phosphorus was extracted with Bray P-1 extractant (Bray and Kurtz, 1945) and phosphorus content in soil extract estimated using the procedure described by Jackson (1973). Available sulphur estimated by turbidimetric method (Chesnin and Yien, 1951). DTPA (diethyline-triamine-penta acetic acid) extractable micronutrient cations (Zn, Fe, Cu, Mn) determined by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Simple correlation coefficients were worked out to correlate physicochemical characteristics of soils with available nutrients and forms of soil acidity.

Description of study area

Dimapur district is located at latitude 2554′ 45′′ N and longitude 9344′ 30′′ E. It shares its boundaries with Kohima to the South and East, Karbi Anglong and stretch of Golaghat district of Assam to the West and North. The district lies at an altitude of 160-350 meters above mean sea level. Except Medziphema block, most areas of Dimapur district comes under plain sector. Dhansiripar block lies in the plains and is spread over 130 sq. km while Medziphema block lies in the hills and has a total area of 345 sq. km. The climate is hot and humid in the plains during summer, reaching a maximum of 36^0C or more with humidity up to 93% while the average annual rainfall of Dimapur district is 1504.7 mm. Dominant crops of the district are rice, maize, banana, papaya and vegetables.

RESULTS AND DISCUSSION

Physicochemical properties

Bulk density of the cultivated and forest soils of <200 m altitude fluctuated from 1.15 to 1.30 and 1.15 to 1.26 Mg m^{-3} with an average value of 1.22 and 1.20 Mg m^{-3}, respectively (Table 1). While in case of >300 m altitude, bulk density of cultivated and forest soils ranged from 1.15 to 1.30 Mg $m^{-3}$and 1.12 to 1.18 Mg m^{-3} with a mean value of 1.20 and 1.14 Mg m^{-3},respectively. Mean particle density of cultivated soils recorded 2.37 and 2.35 Mg m^{-3} and for forest soils mean values observed 2.35 and 2.34 Mg m^{-3} in case of <200 m and >300 m altitude, respectively. A minor reduction in bulk density and particle density observed with increasing altitude, possibly due to increased organic matter content (Wani *et al.,* 2017). It was also observed that bulk density and particle density of the soils of both altitudes increased when land use was changed from forest to cultivation might be due to declined organic matter. Higher pH value was observed in high altitude soils. Mean pH values of cultivated and forest soils of <200 m altitude was 4.50 and 4.70, while in case of

>300 m altitude, mean pH value observed 4.72 and 4.94 in cultivated and forest soils, respectively. On the basis of mean pH, soils of both altitudes indicated strongly acidic reaction. Slightly higher pH of high altitude soils might be due to accumulation and subsequent slow decomposition of organic matter which releases acids along the altitude (De Hann, 1997). The results are similar to those of reported by Mishra and Francaviglia (2021), where the pH of soil increased with increase in altitude. Electrical conductivity (EC) did not fluctuate appreciable in relation to altitude and slightly higher electrical conductivity recorded in forest soils. Higher value of EC might be due to high amount of organic carbon content which retained the cations in soils. Less accumulation of soluble salts in soil profile also attributed to excessive leaching on account of high rainfall. Similar findings have also been reported by Konyak *et al.* (2020) in case of Nagaland soils. Cation exchange capacity (CEC) of cultivated and forest soils for <200 m altitude varied from 7.98 to 12.00 and 9.74 to 13.20 cmol(p^+) kg^{-1} with a mean value of 9.97 and 11.92 cmol(p^+)kg^{-1}, while for >300 m altitude soils CEC differed from 9.8 to 11.30 and 12.10 to 14.80 cmol(p^+)kg^{-1} with a mean value of 11.30 and 13.51 cmol(p^+)kg^{-1},respectively. 13.3% elevated CEC observed in high altitude soils as compared to low altitude soils. Forest soils indicated higher CEC than cultivated soils under both altitudes. The possible reason for higher values of CEC of high altitude and forest soils might be high amount of organic carbon. These results are in accordance with those of Mishra and Francaviglia (2021); Longchari and Sharma (2022).

Table 1: Physicochemical properties of the soils in relation to altitude and land use systems

Sl. No.	Altitude (m)	Name of the village	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		pH		EC (dS m^{-1})		CEC {cmol(p^+)kg^{-1}}	
			CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU
1	<200	Manglumukh	1.30	1.18	2.45	2.43	4.50	5.20	0.19	0.17	8.20	11.30
2		Doyapur	1.18	1.21	2.41	2.33	4.30	4.70	0.13	0.16	10.32	12.07
3		Shitovi	1.19	1.26	2.41	2.36	4.80	4.90	0.18	0.16	7.98	9.74
4		Amaluma	1.15	1.25	2.42	2.39	4.70	4.80	0.19	0.22	12.00	13.20
5		Dhansiripar	1.25	1.22	2.20	2.18	4.60	5.10	0.12	0.20	9.80	11.81
6		Daniel	1.25	1.17	2.32	2.40	4.40	4.80	0.23	0.16	10.26	12.14
7		Khekiho	1.22	1.15	2.40	2.35	4.50	5.10	0.13	0.32	11.20	13.15
Minimum			1.15	1.15	2.20	2.18	4.30	4.70	0.12	0.16	7.98	9.74
Maximum			1.30	1.26	2.45	2.43	4.80	5.20	0.23	0.32	12.00	13.20
Mean			1.22	1.20	2.37	2.35	4.50	4.70	0.17	0.20	9.97	11.92
1	>300	Sirhima	1.30	1.18	2.29	2.20	4.85	5.17	0.22	0.17	10.20	12.60
2		New Socunoma	1.15	1.12	2.34	2.28	4.40	4.80	0.24	0.26	13.10	14.80
3		Khaibung	1.20	1.14	2.24	2.37	4.60	5.29	0.16	0.19	11.30	13.50
4		Zhuikhu	1.25	1.13	2.36	2.44	4.50	4.60	0.21	0.23	10.50	13.30
5		Maova	1.16	1.17	2.37	2.33	4.90	5.14	0.13	0.11	9.80	12.10
6		Molvom	1.21	1.15	2.49	2.38	4.50	4.83	0.12	0.20	12.40	14.30
7		Bungsang	1.18	1.16	2.36	2.35	4.60	4.72	0.18	0.17	11.80	14.00
Minimum			1.15	1.12	2.24	2.20	4.40	4.60	0.12	0.11	9.80	12.10
Maximum			1.30	1.18	2.49	2.44	4.85	5.29	0.24	0.26	13.10	14.80
Mean			1.20	1.14	2.35	2.34	4.72	4.94	0.18	0.19	11.30	13.51

CLU= Cultivated land use; FLU= Forest land use

Soil fertility status

Wide variation observed in organic carbon (OC) content of cultivated and forest soils of both altitudes (Table 2). Irrespective of altitude, nutrient index values for OC of cultivated and forest soils recorded 3.00, indicated high amount of OC in these soils.Mean OC content observed 13.31 and 18.56 g kg^{-1} in cultivated and forest soils of <200 m altitude and 16.22 and 19.61 g kg^{-1} in >300 m altitude soils, respectively. 28.8% and 17.3% less organic carbon recorded in cultivated soils of <200 m and >300 m altitude, respectively as compared to forest soils. Cultivated and forest soils of >300 m altitude contained 22.8% and 5.7% higher amount of OC in comparison to <200 m altitude

Table 2: Fertility status of the soils in relation to altitude and land use systems

Sl. No.	Altitude (m)	Name of the village	Organic carbon (g kg^{-1})		Available nutrients (kg ha^{-1})							
					Nitrogen		Phosphorus		Potassium		Sulphur	
			CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU
1	<200	Manglumukh	10.60	21.07	250	349	7.9	11.1	165	201	12.0	18.8
2		Doyapur	12.30	19.34	354	320	8.0	9.2	217	235	23.4	22.5
3		Shitovi	14.70	16.35	293	329	10.8	11.2	184	165	17.3	23.5
4		Amaluma	15.30	16.72	398	437	8.7	8.9	246	293	26.1	22.6
5		Dhansiripar	11.30	17.61	269	370	8.3	10.1	166	260	15.8	19.8
6		Daniel	14.40	18.97	352	385	7.6	9.8	195	212	16.8	20.9
7		Khekiho	13.85	19.89	338	420	7.0	10.6	180	179	19.0	28.3
Minimum			10.60	16.35	250	320	7.0	9.2	165	165	12.0	18.8
Maximum			15.30	21.07	354	437	10.8	11.2	246	293	26.1	28.3
Mean			13.21	18.56	322	386	8.3	10.1	193	220	18.6	22.3
1	>300	Sirhima	14.70	17.80	295	370	13.1	12.7	164	205	17.4	23.5
2		New Socunoma	18.45	18.92	483	419	8.8	10.4	258	249	20.9	31.2
3		Khaibung	15.30	23.08	475	480	10.3	11.5	180	321	27.3	33.2
4		Zhuikhu	18.05	22.74	364	505	10.8	11.3	261	243	23.8	27.6
5		Maova	14.95	16.93	432	473	10.3	14.7	245	198	18.7	21.9
6		Molvom	16.95	19.30	330	509	10.1	10.3	238	260	14.8	26.0
7		Bungsang	15.15	18.50	428	370	10.3	12.1	220	226	21.4	29.4
Minimum			14.70	16.93	295	370	8.8	10.3	164	198	14.8	21.9
Maximum			1845	23.08	483	509	13.1	14.7	261	321	27.3	33.2
Mean			16.22	19.61	401	446	10.5	11.9	224	243	20.1	27.5
Nutrient index value			3.00	3.00	1.79	2.00	1.36	1.61	2.04	2.18	1.43	1.89
Nutrient index class			High	High	Medium	Medium	Low	Medium	Medium	Medium	Low	Medium

CLU= Cultivated land use; FLU= Forest land use

soils. Continuous addition of decayed vegetation in forest soils may be cause of high OC content (Tripathi *et al.,* 2007; Sharma, 2013). While more organic carbon content in high altitude soils might be due to change in temperature, which in turn renders the rate of decomposition by slowing down microbial and enzymatic activities (Kumar *et al.,* 2019). Mean available N, P, K and S contents in cultivated soils of <200 m altitude was observed 322, 8.3, 193 and 18.6 kg ha^{-1}, while in high altitude soils 401, 10.5, 224 and 20.1 kg ha^{-1},respectively. In forest soils of <200 m altitude mean values reported 386, 10.1, 220 and 22.3 kg ha^{-1} and in >300 m altitude soils 446, 11.9, 243 and 27.5 kg ha^{-1},respectively. Irrespective of altitude, cultivated soils belong to medium, low, medium and low category of available nitrogen, phosphorus, potassium and sulphur with a nutrient index value of 1.79, 1.36, 2.04 and 1.43, respectively. Forest soils fell in medium class of these nutrients with nutrient index value of 2.00, 1.61, 2.18 and 1.89, respectively, irrespective of land use, 16.6%, 21.6%, 13.1% and 16.4% higher N, P, K and S observed in high altitude soils in comparison to low altitude. Altogether, despite high in organic carbon, low and medium status of available nutrients might be due to low mineralization rate in cold climatic condition and/ or acidic soil environment. Cause of this trend might be lesser amount of organic carbon content in low altitude soils. Furthermore, in low altitude areas soils are almost level and cultivated intensively than high altitude soils. Because of this mining of nutrients might be more in low altitude soils resulted soils are low in these nutrients. Similar observations recorded by Qasba *et al.* (2017). Mean DTPA extractable Zn, Cu, Fe and Mn content in cultivated soils of <200 m altitude recorded 1.28, 1.40, 81.50 and 27.22 mg kg^{-1} and in forest soils of same altitude values of these micronutrients observed 1.67, 1.47, 82.54 and 28.62 mg kg^{-1},respectively (Table 3). In >300 m altitude cultivated soils amount of mean Zn, Cu, Fe and Mn observed 1.19, 1.38, 79.91 and 26.29 mg kg^{-1}, while in forest soils comparatively higher amount observed with mean value of 1.65, 1.43, 81.94 and 27.16 mg kg^{-1},respectively. Nutrient index of zinc for cultivated and forest soils calculated 1.79 and 2.18, which indicated medium zinc content in these soils. While, quantities of copper, iron and manganese observed high in both cultivated and forest soils with nutrient index value of 2.89 & 2.64, 3.00 & 3.00 and 3.00 & 3.00, respectively. Comparatively lesser amount of micronutrient cations recorded in cultivated soils might be due to more mining by crops and less organic matter. Low concentration of micronutrients in high altitude soils attributed to enhanced soil pH which retarded solubility of micronutrients resulted low quantity of cationic micronutrients. These results are in line with the observations of Sharma *et al.* (2005); Annepu *et al.* (2017).

Table 3: Micronutrient cation contents of the soils in relation to altitude and land use systems

Sl. No.	Altitude (m)	Name of the village	Micronutrients (mg kg^{-1})							
			Zinc		Copper		Iron		Manganese	
			CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU
1		Manglumukh	0.38	2.12	0.82	1.47	58.58	71.69	24.71	33.06
2		Doyapur	1.80	2.31	1.16	1.87	89.60	91.08	27.17	29.73
3		Shitovi	1.13	1.26	1.70	1.14	74.60	80.88	29.70	23.73
4	<200	Amaluma	2.07	1.15	1.79	1.10	91.25	78.91	32.08	30.20
5		Dhansiripar	0.84	1.60	1.32	1.40	78.50	77.82	23.60	26.70
6		Daniel	1.62	1.36	1.58	1.61	90.75	87.40	28.04	29.51
7		Khekiho	1.09	1.91	1.44	1.73	87.21	90.01	25.24	27.42
	Minimum		0.38	1.15	0.82	1.10	58.58	71.69	23.60	23.73
	Maximum		2.07	2.31	1.79	1.87	91.25	91.08	32.08	33.06
	Mean		1.28	1.67	1.40	1.47	81.50	82.54	27.22	28.62
1		Sirhima	0.42	1.26	0.98	1.34	70.19	67.40	21.41	24.73
2		New Socunoma	1.70	1.67	1.62	1.61	80.60	83.10	28.26	22.53
3		Khaibung	0.53	2.41	1.62	1.63	85.08	90.23	23.41	32.54
4	>300	Zhuikhu	1.81	2.10	1.44	1.46	88.70	86.20	31.10	30.42
5		Maova	1.05	0.97	1.40	1.02	65.30	79.80	25.93	25.12
6		Molvom	1.11	1.78	1.39	1.53	87.35	84.70	28.45	27.07
7		Bungsang	1.69	1.42	1.15	1.44	82.20	82.17	25.48	27.77
	Minimum		0.42	0.97	0.98	1.02	65.30	67.40	21.41	22.53
	Maximum		1.81	2.41	1.62	1.63	88.70	90.23	31.10	30.42
	Mean		1.19	1.65	1.38	1.43	79.91	81.94	26.29	27.16
	Nutrient index value		1.79	2.18	2.89	2.64	3.00	3.00	3.00	3.00
	Nutrient index class		Medium	Medium	High	High	High	High	High	High

CLU= Cultivated land use; FLU= Forest land use

Soil acidity components

Mean values of pH-dependent acidity in cultivated and forest soils of <200 m altitude observed 10.89 and 10.21 cmol(p$^+$) kg^{-1} while in >300 m altitude soils of same land use recorded 10.26 and 9.70 cmol(p$^+$) kg^{-1},respectively (Table 4). Slightly lesser pH dependent acidity was recorded in high altitude and forest soils. Irrespective of altitude and land use, contribution of pH-dependent acidity to total potential acidity was recorded 83.4%. Irrespective of land use and altitude exchange acidity ranged from 0.87 to 3.47 cmol(p$^+$) kg^{-1}. Mean exchangeable acidity in cultivated and forest soils of low altitude recorded 2.51 and 1.81 cmol(p$^+$) kg^{-1} while in high altitude soils value observed 2.04 and 1.78 cmol(p$^+$) kg^{-1},respectively. Comparatively high amount of exchangeable acidity was noticed in low altitude and cultivated soils. Exchangeable acidity contributed 16.5% to total potential acidity. Reasonable exchange acidity in these soils may be due to presence of high exchangeable Al^{3+} (Laxminarayana, 2010).Exchangeable Al^{3+} and H^+ of <200 m altitude cultivated and forest soils varied from 0.81 to 2.41 & 0.86 to 1.17 and 0.90 to 1.91 & 0.59 to1.07 cmol(p$^+$) kg^{-1} with a mean value of 1.49, 1.02 and 1.38, 0.88 cmolp$^+$) kg^{-1}, respectively. While in cultivated and forest soils of >300 m altitude mean value of Al^{3+} and H^+ observed 1.49 & 0.57 and 1.29 & 0.54 cmolp$^+$) kg^{-1},respectively. Higher amount of exchangeable Al^{3+} and H^+ observed in low altitude and cultivated soils. 3.2% and 11.6% higher Al^{3+} content noticed in low altitude and cultivated soils in comparison to high altitude and forest soils. Variation in total potential acidity of <200 m altitude cultivated and forest soils

400observed in the range of 10.70 to 16.17 and 9.99 to 13.89 cmol(p^+) kg^{-1} with a mean value of 13.40 and 11.91 cmol(p^+) kg^{-1}, respectively. While, variation for >300 m altitude cultivated and forest soils observed in the range of 10.40 to 14.28 and 8.80 to 14.91 cmol(p^+) kg^{-1} with a mean value of 12.30 and 11.58 cmol(p^+) kg^{-1}, respectively. Slightly lesser amount of total potential acidity observed in high altitude and forest soils. Overall, comparatively higher quantum of acidity components found in low (<200 m) altitude soils. Because low altitude soils are near to level in topography which favors water stagnation due to less runoff. Stagnation of plenty water favors leaching of basic cations (Ca^{2+}, Mg^{2+}, Na^+) resulted concentration of acidity components might have increased. These results are similar to the findings of Sannigrahi and Pandey (2000); Tsanglao *et al.* (2014).

Table 4: Acidity components of the soils in relation to altitude and land use systems

Sl. No.	Altitude (m)	Name of the village	Soil acidity components {cmol(p^+)kg^{-1}}									
			PDA		ExA		Ex Al^{3+}		Ex H^+		TPA	
			CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU
1	<200	Manglumukh	9.56	8.41	2.08	1.58	0.93	1.57	1.15	0.59	11.64	9.99
2		Doyapur	12.70	11.74	3.47	2.02	2.41	1.91	1.06	1.07	16.17	13.89
3		Shitovi	8.98	11.28	1.72	2.15	0.81	1.49	0.91	1.01	10.70	13.30
4		Amaluma	11.43	11.89	2.87	1.62	1.70	1.70	1.17	0.89	14.30	13.51
5		Dhansiripar	10.15	10.08	2.10	1.19	1.24	1.20	0.86	0.81	12.25	11.27
6		Daniel	12.29	8.73	3.14	1.47	2.16	0.90	0.98	0.93	15.43	10.20
7		Khekiho	11.12	9.33	2.18	1.91	1.20	1.69	0.98	0.89	13.30	11.24
Minimum			8.98	8.41	1.72	1.19	0.81	0.90	0.86	0.59	10.70	9.99
Maximum			12.70	11.89	3.47	2.15	2.41	1.91	1.17	1.07	16.17	13.89
Mean			10.89	10.21	2.51	1.81	1.49	1.38	1.02	0.88	13.40	11.91
1	>300	Sirhima	11.09	10.00	1.00	1.00	0.82	0.79	0.18	0.38	12.09	11.16
2		New Socunoma	11.07	9.50	3.21	2.27	2.38	1.19	0.83	0.71	14.28	11.44
3		Khaibung	10.15	8.09	2.11	0.87	1.62	0.33	0.49	0.39	12.26	8.80
4		Zhuikhu	10.89	11.59	2.17	2.19	1.62	2.53	0.55	0.94	13.04	14.91
5		Maova	8.96	7.66	1.44	1.19	0.87	0.97	0.57	0.23	10.40	8.85
6		Molvom	8.81	10.36	2.27	3.33	1.75	1.27	0.52	0.78	11.07	12.56
7		Bungsang	10.88	10.73	2.12	2.35	1.39	1.98	0.73	0.70	13.00	13.40
Minimum			8.81	7.66	1.00	0.87	0.82	0.33	0.18	0.23	10.40	8.80
Maximum			11.09	11.59	3.21	3.33	2.38	2.53	0.83	0.94	14.28	14.91
Mean			10.26	9.70	2.04	1.78	1.49	1.29	0.57	0.54	12.30	11.58

PDA= pH dependent acidity, Ex. A= Exchangeable acidity, Ex. Al^{3+}=Exchangeable aluminium, Ex. H^+=Exchangeable hydrogen, TPA= Total potential acidity, CLU= Cultivated land use; FLU= Forest land use

Correlation studies

CEC of cultivated and forest soils had significant negative correlation with BD and positive correlation with organic carbon (Table 5). In case of forest soils, CEC showed significant positive correlation with PD (0.442^*) and EC (0.453^*). Available N of cultivated soils appeared significant negative correlation with BD ($r=-0.604^{**}$) while, both cultivated and forest soils had positive correlation with organic carbon ($r=0.617^{**}$, 0.442^*). Available P of soils under both land use had significant positive correlation with pH ($r=0.565^{**}$, 0.565^{**}) and OC ($r=0.397^*$, 0.378^*). Available potassium of soils under both land use exhibited significant positive correlation with OC ($r=0.599^{**}$, 0.463^*) and significant negative with BD ($r= -0.556^{**}$) in case of cultivated soils. In forest soils, available sulphur manifested significant positive correlation with EC ($r=0.465^*$). Sulphur of cultivated and forest soils showed significant positive correlation with organic carbon ($r=0.386^*$, 0.501^{**}) and negative with BD ($r=-0.508^{**}$, -0.628^{**}). Positive significant correlation between organic carbon and available N, P, K, S revealed that organic matter is prominent source of available nutrients in the soils of both land use. DTPA extractable Zn, Cu, Fe and Mn of soils exhibited significant positive correlation with organic carbon. Available Zn, Cu and Mn indicated significant negative correlation with BD. All acidity components (pH-dependent acidity, exchangeable acidity, exchangeable Al^{3+}, exchangeable H^+, total potential acidity) of cultivated and forest soils indicated negative significant correlation with soil pH. Similar relationship among soil properties have also been reported by Poji *et al*, (2017); Longchari and Sharma (2022).

Table 5: Correlation coefficients among soil properties

Soil parameters	BD		PD		pH		OC		EC	
	CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU	CLU	FLU
CEC	-0.441*	-0.709**	0.187	0.442*	-0.276	-0.276	0.470*	0.385*	0.215	0.453*
N	-0.604**	-0.324	0.036	0.129	-0.091	-0.091	0.617**	0.442*	0.197	0.105
P	0.046	-0.308	0.233	-0.256	0.565**	0.565**	0.397*	0.378*	0.130	-0.363
K	-0.556**	-0.219	-0.022	0.316	-0.228	-0.228	0.599**	0.463*	0.304	0.031
S	-0.508**	-0.628**	0.254	0.291	-0.038	-0.038	0.386*	0.501**	0.202	0.465*
Zn	-0.545**	-0.397*	0.215	0.234	-0.288	-0.288	0.414*	0.713**	0.213	0.235
Cu	-0.556**	-0.471*	0.250	0.392*	-0.053	-0.053	0.534**	0.532**	0.153	0.345
Fe	-0.369	-0.429	0.361	0.067	-0.354	-0.354	0.398*	0.528**	0.098	0.308
Mn	-0.415*	-0.021	0.218	0.221	-0.199	-0.199	0.450*	0.548**	0.204	-0.063
EA	-0.265	-0.090	0.084	-0.108	-0.537**	-0.537**	0.035	-0.034	0.093	0.205
PDA	0.035	0.313	0.289	0.057	-0.465*	-0.465*	-0.014	-0.170	0.081	0.119
Ex. Al	-0.269	0.102	0.203	-0.076	-0.420*	-0.420*	0.202	0.021	0.079	0.228
Ex. H	-0.067	0.234	-0.228	-0.031	-0.406*	-0.406*	-0.344	-0.246	0.056	0.228
TPA	-0.076	0.195	0.247	0.031	-0.552**	-0.552**	0.003	-0.111	0.095	0.178

**Significance at 5% level: 0.374, ** Significance at 1% level: 0.479, PDA= pH dependent acidity, Ex. A= Exchangeable acidity, Ex.* Al^{3+}*=Exchangeable aluminium, Ex-* H^{+}*=Exchangeable hydrogen, TPA= Total potential acidity; CLU= Cultivated land use; FLU= Forest land use*

CONCLUSION

From the present study it can be concluded that both low and high altitude soils of Dimapur district of Nagaland were strongly to moderately acidic in reaction, high in organic carbon and low in CEC. High altitude and forest soils found less acidic in acidity. Overall soils observed medium in available nitrogen, potassium and zinc, low to medium in phosphorus and sulphur, high in Cu, Fe and Mn. High quantum of CEC, organic carbon and available N, P, K, S observed in high altitude (>300 m) and forest soils. However, high amount of DTPA extractable micronutrients noticed in low altitude (<200 m) and forest soils. A decreasing trend in soil acidity components and densities observed with increasing altitude and lesser values observed in high altitude soils. The soils have major problem of acidity thus lime application and growing of acidity tolerant crops with their acidity tolerant varieties is necessary for getting better crop growth and yield. Available N, P, K, S and micronutrients exhibited significant positive correlation with organic carbon. Significant negative correlation observed between acidity components and soil pH. Consequently, soils of study area need necessary attention to fertility as well as soil acidity management strategies for sustainable crop production.

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