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Effect of changing land uses on physico-chemical and acidity properties of soils of northeast India

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Abstract : Soil samples were collected from various villages in the Tseminyu subdivision of Kohima District, representing both jhum and forest land use systems. These samples were analysed for their physicochemical properties and soil acidity parameters. The results indicated that the soils exhibited a strongly to moderately acidic reaction. The cation exchange capacity (CEC) was relatively low, ranging from 8.12 to 13.73 cmol (p^+) kg^{-1} under jhum land use and 11.01 to 16.25 cmol (p^+) kg^{-1} under forest land use. Soil organic carbon content varied from 1.51% to 2.46% in jhum soils and from 1.50% to 3.23% in forest soils. The available macronutrient status of both land use systems showed variations, with nitrogen (N) ranging from 339.35 to 450.55 kg ha^{-1} in jhum soils and 383.39 to 545.87 kg ha^{-1} in forest soils. Available phosphorus (P) content ranged from 8.78 to 17.09 kg ha^{-1} in jhum soils and 8.1 to 16.64 kg ha^{-1} in forest soils, while available potassium (K) content varied from 190.67 to 246.33 kg ha^{-1} in jhum soils and 195.92 to 272.33 kg ha^{-1} in forest soils. The lime requirement for both land use systems was found to be high. Additionally, correlation analysis was conducted to examine the interrelationships among various soil physicochemical properties. These findings highlight the influence of land use on soil fertility and acidity parameters, emphasising the need for site-specific soil management strategies to sustain agricultural productivity and ecological balance in the region.

Key words: *Forest land use, Jhum, Physicochemical properties, Soil nutrient*

Introduction

Soil is a fundamental component of terrestrial ecosystems and plays a pivotal role in sustaining agricultural productivity and environmental sustainability. The global challenge of ensuring agricultural and environmental sustainability has been exacerbated by land use practices that contribute to soil degradation and a decline in environmental quality (Singh et al., 2014). In the context of Nagaland, a region characterised by highly acidic yet inherently fertile soils, a critical gap exists in the comprehensive understanding of its soil physicochemical properties. This knowledge gap has led to suboptimal land management practices, preventing the full utilisation of soil potential for sustainable agricultural production.

The decline in soil quality is a growing concern, particularly in the absence of strategies to replenish nutrient inputs. Soil fertility depletion, if left unaddressed, can severely impact agricultural yields and long-term land productivity. A detailed examination of the physico-chemical status of Nagaland soils is essential, as the lack of such fundamental data restricts the effective application of modern agricultural technologies that could enhance soil health and crop productivity.

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One of the predominant agricultural practices in Nagaland is shifting cultivation, locally known as "jhum" cultivation. Traditionally, this practice involved rotational cycles of 15 to 20 years, allowing sufficient time for the natural regeneration of forests and soil fertility. However, with increasing population pressure and diminishing land availability, the fallow period has been significantly reduced to less than 10 years. This shortened cycle has intensified land degradation, leading to nutrient depletion, loss of organic matter, and deterioration of soil structure. The continued reliance on jhum cultivation under these altered conditions not only threatens soil productivity but also contributes to deforestation, biodiversity loss, and disruption of hydrological cycles, thereby exacerbating environmental vulnerabilities.

The persistent degradation of soil due to unregulated land use practices poses a significant risk to agricultural sustainability. If effective soil management strategies are not implemented, the consequences may include reduced agricultural yields, increased soil erosion, and irreversible land degradation. Addressing these challenges necessitates a comprehensive investigation of the physico-chemical properties of soils in Nagaland. By generating region-specific soil health information, farmers can be equipped with scientifically backed management practices that promote sustainable land use and enhance agricultural productivity. Therefore, this study aims to assess the physicochemical characteristics of Nagaland soils, providing a crucial foundation for informed decision-making in sustainable soil and crop management.

Materials And Methods

Study area

The soil samples for the research were collected from 15 different villages in Tseminyu Sub-division, under Kohima District, Nagaland, namely Terogvunyu, New Terogvunyu, Phenshunyu, T. Zisunyu, Tseminyu, K. Station, Nsunyu, Chunlikha, Kandinyu, Tesophenyu, Tseminyu South, New Tesophenyu, Phenwhenyu, Kashanyu, and Sendenyu. Tseminyu is one of the oldest subdivisions of Nagaland, located 50 km from the state capital, Kohima. It is located between 25.92° N Latitude and 94.21° E longitude, with a total geographical area of 564 km². It lies at an altitude of 1062 m above sea level. Tseminyu has been classified as having a warm and temperate climate, with temperatures ranging from 16.2 to 24.6 °C. The average annual rainfall is 1885 mm.

Soil sample collection and analysis

A total of thirty composite soil samples were collected from 15 villages in the Tseminyu Sub-Division of Kohima District. Two composite samples were obtained from each village, one from Jhum fields and the other from adjacent forest areas, to facilitate a comparative assessment. The collected soil samples were air-dried, ground, and sieved through a 2 mm mesh to remove debris and coarse particles. Approximately 500–600 g of the processed soil was stored in properly labelled polyethylene bags and transported to the laboratory for further physico-chemical analysis. The soil pH was determined in a 1:2.5 water suspension (Richards, 1954). Bulk Density was determined by dividing the weight of soil by the volume of soil, particle Density by the Pycnometer method as described by Baruah and Barthakur (1997). Organic Carbon of the soil was estimated by the Walkely and Black method, and CEC of the soil by using the NH_4OAC method at pH 7.0 by Bower et al. (1952). The available Nitrogen content was determined by using the Alkaline Potassium Permanganate Method (Subbiah and Asija, 1956), available phosphorus by using Bray's No. 1 method (Bray and Kurtz, 1945) and available Potassium by neutral normal ammonium acetate (pH 7.0). Total potential acidity was determined by using BaCl3–triethanolamine extract buffered at pH 8.0-8.2. The Lime requirement of the soil was determined by using the Shoemaker et al. method (1961) by suspending soil samples in a buffer solution of para-nitrophenol (pH 7.5) in a soil: solution ratio of 1:2, and the pH value of the buffer solution was measured by using a glass electrode pH meter. Exchangeable acidity by using the method as described by Mclean (1965). Extractable acidity by aluminon reagent calorimetrically as described by

Barauh and Barthakar (1997). The exchangeable Al3+ was determined as detailed by Barauh and Barthakar (1997). Exchangeable H+ was estimated by the difference between exchange acidity and exchangeable Al3+.

Results And Discussion

Physico-chemical properties of the soils

Soil pH

The soil pH across different villages under the *jhum* land use system ranged from 4.52 to 5.25, while for the forest land use system, it varied from 4.45 to 5.23 (Table 1). This indicates that soils in both land use systems are strongly to moderately acidic in nature. Among the villages, Phenwhenyu recorded the highest pH (5.25), while New Tesophenyu had the lowest (4.52) under the jhum land use system. In the forest land use system, the highest pH (5.23) was observed in Nsunyu, whereas the lowest (4.45) was recorded in K. Station. This acidity may be attributed to heavy rainfall, which leads to the leaching of basic cations. Similar findings have been reported by Patton et al. (2005).

Soil Organic Carbon

The organic carbon content was found to be higher in forest ranging from 1.50% to 3.23 % than *jhum* land use system ranging from 1.51% to 2.46 % as shown in (Table 1). 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 which favours slow rate of organic matter decomposition might have contributed to the high organic carbon content in the soil. K. Station village showed the highest organic carbon content of 2.46% and Phenshunyu village showed the lowest organic carbon content of 1.51% in respect to jhum land use system. While the highest and lowest organic carbon content of 3.23% and 1.50 % was observed in respect to forest land use system in the soils of Nsunyu village and Terogvunyu village respectively. Correlation studies of the organic carbon content in both the land use systems had been found to have a significant and positive correlation with available N and K as shown in (Table 7&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

CEC of soils of different villages under the jhum land use system varied from 8.12 to 14.25 cmol (p+) kg^{-1}, while for the forest land use system, it varied from 11.01 to 16.25 cmol (p+) kg^{-1}, as shown in Table 1. The latter showed the higher CEC values due to a higher amount of organic carbon in the soils under the forest land system (Rudramurthy et al., 2007). K. Station village showed the highest of 14.25 cmol (p+) kg^{-1}, and Kandinyu village showed the lowest CEC of 8.12 cmol (p+) kg^{-1} with respect to the *jhum* land use system. While the highest and lowest CEC of 16.25 and 11.01 cmol (p+) kg^{-1} with respect to forest land use systems were observed in the soils of New Terogvunyu and T. South village. The CEC in both the land use systems had a significant and positive correlation with available N and K (Tables 7 and 8). A similar finding was also reported by Kundu et al. (2014)

Total Potential Acidity

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

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

Sl.no	Name of the village	pH		Organic carbon (%)		CEC (cmol (p+) kg^{-1})	
		jhum	forest	*jhum*	forest	*jhum*	forest
1	Terogvunyu	5.03	4.75	2.40	1.50	12.12	11.63
2	New Terogvunyu	4.91	4.51	1.80	2.1	8.65	16.25
3	Phenwhenyu	5.25	4.79	2.17	2.54	9.09	16.11
4	Kashanyu	4.75	4.77	2.34	1.87	13.21	14.80
5	Phenshunyu	4.82	5.02	1.51	3.08	8.61	16.03
6	Sendenyu	4.85	4.92	1.95	2.78	8.32	12.79
7	T. South	4.71	4.67	2.21	1.88	13.73	11.01
8	T. Zisunyu	4.99	4.78	2.32	1.52	12.46	12.32
9	Tseminyu	4.61	4.82	2.40	2.26	12.21	11.29
10	Tesophenyu	4.86	4.49	2.12	2.12	13.23	15.61
11	New Tesophenyu	4.52	4.72	2.01	2.78	10.51	14.33
12	Nsunyu	4.65	5.23	2.23	3.23	13.61	16.02
13	Chunlikha	4.87	4.65	1.76	3.16	13.01	15.79
14	K. Station	4.77	4.45	2.46	2.29	14.25	16.01
15	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

pH-dependent Acidity

The data relating to pH-dependent acidity of different villages of Kohima district under both *jhum* and forest land use systems are presented in Table 2. The data shows that pH-dependent acidity of the *jhum* land use system varied from 8.4 to 11.42 cmol (p^+) kg^{-1}, while for the forest land use system, it varied from 7.31 to 12.15 cmol (p^+) kg^{-1}. Among the soils of the *jhum* land use system, the highest pH-dependent acidity of 11.42 cmol (p^+) kg^{-1} was recorded in soils of Tseminyu and Chunlikha village, while in the forest land use system the highest pH-dependent acidity of 12.15 cmol (p^+) kg^{-1} was recorded in soils of Tseminyu village (Table 2). From the above findings, it implies that pH-dependent acidity made the major contribution 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, presented in Tables 7 and 8, indicated that pH-dependent acidity had a significant and negative correlation with soil pH and a significant and positive correlation with all other forms of acidity in both the land use systems. A similar result was also reported by Bandyopadhyay and Chattopadhyay (1997).

Exchangeable Acidity

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

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

Sl.no	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
1	Terogvunyu	10.89	12.03	9.01	9.76	1.88	2.27
2	New Terogvunyu	12.48	14.63	10.22	12.07	2.26	2.56
3	Phenwhenyu	10.82	10.16	9.18	8.4	1.64	1.76
4	Kashanyu	13.8	12.31	11.27	9.81	2.53	2.5
5	Phenshunyu	12.22	11.12	9.8	8.22	2.42	1.9
6	Sendenyu	11.21	10.56	9.2	8.88	2.01	1.68
7	T. South	11.37	14.04	8.86	11.48	2.51	2.56
8	T. Zisunyu	10.39	13.36	8.46	11.01	1.93	2.35
9	Tseminyu	14.02	14.23	11.42	12.15	2.6	2.08
10	Tesophenyu	13.16	13.3	9.01	10.7	2.61	2.7
11	New Tesophenyu	11.25	14.06	10.55	11.49	1.67	2.57
12	Nsunyu	14.18	9.09	9.58	7.31	2.76	1.78
13	Chunlikha	11.08	12.66	11.42	10.04	2.1	2.62
14	K. Station	13.09	10.93	8.98	10.28	2.61	2.65
15	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 the *jhum* land use system varied from 2.61 to 4.59 cmol (p^+) kg^{-1}, while for the 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 the *jhum* land use system, the highest extractable acidity of 4.59 cmol (p^+) kg^{-1} was recorded in soils of Tsemiynu village, while in the forest land use system, the highest extractable acidity of 4.47 cmol (p^+) kg^{-1} was recorded in soils of New Terogvunyu village. The % contribution of extractable acidity towards total potential acidity was 30.91% and 29.83% in *jhum* and forest, respectively. Correlation studies, presented in Tables 7 and 8, indicated that extractable acidity had a significant and negative correlation with soil pH and a significant and positive correlation with all other forms of acidity in both the land use systems. A similar result has also been reported by Bandyopadhyay and Chattopadhyay (1997).

Exchangeable Al^{3+}

Exchangeable Al^{3+} of the *jhum* land use system varied from 1.43 cmol (p^+) kg^{-1} to 2.34 cmol (p^+) kg^{-1}, while for the forest land use system, it varied from 1.54 to 2.34 cmol (p^+) kg^{-1} (Table 3). Among the soils of the *jhum* land use system, the highest exchangeable Al^{3+} of 2.34 cmol (p^+) kg^{-1} was recorded in soils of Kashanyu village. In contrast, in the forest land use system, the 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 was 88.2% and 16.3% in the *jhum* land use system, while in forest land use systems, the contribution towards exchangeable acidity and total potential acidity was 81.33%. Exchangeable Al^{3+} made the major contribution towards exchangeable acidity. The exchangeable Al^{3+} had a significant and negative correlation with soil pH and a significant and positive correlation with lime requirement of soils for both land use systems (Tables 7 and 8). Also, exchangeable Al^{3+} showed a positive and significant correlation with pH-dependent acidity in both land use systems. These similar observations were also reported by Talashilkar *et al*. (2006). Positive and significant correlation with total potential acidity was also observed in the *jhum* land use system.

Exchangeable H^+

Exchangeable H^+ of the *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}, while for the forest land use system, it varied from 0.11 to 0.97 cmol (p^+) kg^{-1} with a mean value of 0.42 cmol (p^+) kg^{-1} (Table 3). Among the soils of the *jhum* land use system, the highest exchangeable H^+ of 0.71 cmol (p^+) kg^{-1} was recorded in soils of New Tesophenyu village, and the lowest exchangeable H^+ of 0.13 cmol (p^+) kg^{-1} was recorded in soils of Terogvunyu village, while in the forest land use system, the highest exchangeable H^+ of 0.97 cmol (p^+) kg^{-1} was recorded in soils of Tesophenyu village. The contribution of exchangeable H^+ towards exchangeable acidity and total potential acidity was 14.02% and 2.58 % in the *jhum* land use system, while in the forest land use system, the contribution was 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 land use systems.

Table 3: Soil fertility under *jhum* and forest land use systems

Sl.no	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
1	Terogvunyu	2.61	4.03	1.75	1.96	0.13	0.31
2	New Terogvunyu	4.53	4.47	2.08	2.02	0.18	0.54
3	Phenwhenyu	2.81	3.04	1.43	1.54	0.21	0.22
4	Kashanyu	3.71	4.2	2.34	2.08	0.19	0.42
5	Phenshunyu	3.83	2.71	1.95	1.66	0.47	0.24
6	Sendenyu	3.52	3.15	1.82	1.56	0.19	0.12
7	T. South	3.62	4.32	2.26	2.34	0.25	0.22
8	T. Zisunyu	3.51	4.02	1.78	1.81	0.15	0.54
9	Tseminyu	4.59	2.51	1.99	1.79	0.61	0.29
10	Tesophenyu	4.02	4.15	2.13	1.73	0.18	0.97
11	New Tesophenyu	4.51	4.11	1.96	1.79	0.71	0.78
12	Nsunyu	4.01	2.81	2.08	1.67	0.68	0.11
13	Chunlikha	3.61	3.6	1.92	1.73	0.18	0.89
14	K. Station	4.1	3.8	2.26	2.18	0.35	0.47
15	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 details of the values of the LR at pH 6.0 and pH 6.4 for various soil samples of *jhum* and forest soils are given in Table 4. From the table, 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}, whereas in respect to 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 the lowest was observed in the soils of Phenwhenyu village (7.53 t ha^{-1} and 8.99 t ha^{-1}). For the 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}), and the lowest LR at pH 6.0 and 6.4 was recorded in the soils of Nsunyu village (7.53 t ha^{-1} and 8.99 t ha^{-1}). It is evident from the above data that the lime requirement under both the land use systems of Kohima district was high. The high value of lime requirement for both *jhum* and forest soil may be attributed to the highly acidic nature of the soils. Similarly, Tsanglao (2012) reported a high lime requirement in the soils of the Wokha district under various land use systems. Correlation studies, presented in Tables 7 and 8, indicated that lime requirement in both the land use systems had a significant and negative correlation with soil pH and a 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

Sl. No	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
1	Terogvunyu	9.48	11.42	12.64	15.07
2	New Terogvunyu	10.69	12.64	14.58	17.5
3	Phenwhenyu	7.53	8.99	12.64	15.07
4	Kashanyu	12.64	15.07	2.64	15.07
5	Phenshunyu	11.66	13.58	9.48	11.42
6	Sendenyu	11.66	13.58	10.69	12.64
7	T. South	12.64	15.07	13.61	16.28
8	T. Zisunyu	10.69	12.64	12.64	15.07
9	Tseminyu	13.61	16.28	11.66	13.85
10	Tesophenyu	11.66	13.85	15.79	18.71
11	New Tesophenyu	14.58	17.5	12.64	15.07
12	Nsunyu	13.61	16.28	7.53	8.99
13	Chunlikha	11.66	13.85	13.61	16.28
14	K. Station	12.64	15.07	15.79	18.71
15	Kandinyu	9.48	11.42	9.48	11.42
Mean		11.61	13.81	12.36	14.74

Bulk Density and Particle Density

The lower bulk and particle densities were recorded in the *jhum* land use system, whereas in the forest land use system, higher bulk densities were observed. Tesophenyu village showed the highest BD with respect to the *jhum* land use system. In the forest land use system, the highest BD was observed in Tseminyu village (Table 5). Low bulk densities might be due to high organic matter in the soil. Chaudhari *et al.* (2013) and Chaudhary *et al.* (2005) also reported similar findings.

The particle density of soils of different villages under the *jhum* land use system varied from 2.60 to 2.69 g cm^{-3}, while for the forest land use system, it varied from 2.51 to 2.64 g cm^{-3}. K. Station village showed the highest PD with respect to the *jhum* land use system. The highest

PD was observed in Tseminyu village for the forest land use system, as shown in Table 5. The particle density of the forest land use system was comparatively lower than *the jhum land use system, which may be attributed* to less compaction and high content of organic matter in the soil.

Porosity

The porosity percentage of soils in different villages under the jhum land use system varied from 43.46% to 52.59%, while for the forest land use system, it varied from 49.80% to 57.58%. Forest land use system exhibited higher porosity (53.26%) than the *jhum* (48.42%) land use system (Table 5).

Table 5: Nature of soil acidity under *jhum* and forest land use systems

Sl.no	Name of the Village	Bulk Density (g cm^{-3})		Particle Density (g cm^{-3})		Porosity (%)	
		jhum	forest	*jhum*	forest	*Jhum*	forest
1	Terogvunyu	1.12	1.41	2.62	2.63	46.18	57.58
2	New Terogvunyu	1.23	1.35	2.62	2.58	48.47	52.33
3	Phenwhenyu	1.12	1.36	2.67	2.59	49.06	56.76
4	Kashanyu	1.23	1.36	2.63	2.59	48.29	52.51
5	Phenshunyu	1.17	1.37	2.60	2.60	47.31	55.00
6	Sendenyu	1.21	1.32	2.68	2.55	50.75	52.55
7	T. South	1.14	1.47	2.60	2.60	43.46	56.15
8	T. Zisunyu	1.26	1.28	2.60	2.51	52.59	49.80
9	Tseminyu	1.25	1.51	2.63	2.64	42.59	52.65
10	Tesophenyu	1.28	1.47	2.65	2.60	44.53	50.77
11	New Tesophen yu	1.15	1.32	2.67	2.55	50.56	54.90
12	Nsunyu	1.18	1.28	2.62	2.51	51.15	52.99
13	Chunlikha	1.21	1.36	2.65	2.59	48.68	53.28
14	K. Station	1.25	1.33	2.69	2.56	50.56	51.17
15	Kandinyu	1.24	1.27	2.65	2.50	52.08	50.40
Mean		1.20	1.36	2.64	2.57	48.42	53.26

Nutrient Status of the Soil

The soil fertility status of the jhum and forest land use system is shown in Table 6. The available N of soils of different villages under the *jhum* land use system varied from 339.35 to 450.55 kg ha^{-1}, while for the forest land use system, it varied from 383.39 to 545.87 kg ha^{-1}. T. South village showed the highest available N of 450.55 kg ha^{-1} with respect to the *jhum* land use system. The highest available N of 545.87 kg ha^{-1} with respect to forest land use system was observed in the soils of Phenshunyu and T. Zisunyu village, respectively.

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

The available P of soils of different villages under the *jhum* land use system varied from 8.78 to 17.09 kg $ha^{-1,}$ while for the 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 showed the highest available P of 17.09 kg ha^{-1}, compared to the *jhum* land use system. While the highest available P of 16.64 kg ha^{-1} with respect to forest land use system were observed in the soils of Nsunyu and K. Station. The available phosphorus (P) was found to be higher in jhum than in forest land use systems, which can be attributed to the fact that slash and burn is commonly followed, leading to the addition of ash in the soil, which in turn increases the pH, thereby increasing phosphorus availability (Butler *et al*., 2018). The available phosphorus in both the land use systems had a significant and positive correlation with soil pH (Tables 7 and 8). A similar finding was also reported by Verma *et al*. (2021).

The available K of soils from different villages under the jhum land use system varied from 190.67 to 246.33 kg ha^{-1}, whereas for the forest land use system, it ranged from 195.92 to 272.33 kg ha^{-1}. The highest available K value of 246.33 kg ha-1 was observed in the soils of Terogvunyu and Phenshunyu villages, specifically in the jhum land use system. In contrast, the highest available K of 272.33 kg ha^{-1} for the forest land use system was observed in the soils of Chunlikha and T. South villages, respectively. The available K was higher in the forest land use system, which may be attributed to the increased organic carbon content that promotes the availability of potassium in forest soil (Singh et al., 1999). Correlation studies, presented in Tables 7 and 8, indicated that the available K in both land use systems had a significant and positive correlation with organic carbon. This result aligns with those of Meena et al. (2006).

Table 6: Nature of soil acidity under *jhum* and forest land use systems

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 of the physico-chemical properties of soils in Kohima district, under jhum and forest land use systems, indicated that the soils are strongly to moderately acidic in reaction, with low bulk density and sufficient pore space. The findings further indicated a high level of organic carbon in both land use systems, which exhibited a significant positive correlation with available nitrogen. The major plant nutrients were found to be at a medium level in both systems, while phosphorus (P) ranged from low to medium, and potassium (K) was medium in both jhum and forest land use systems. Overall, the nutrient status of forest soils was significantly superior compared to that of jhum soils. Additionally, both land use systems contained a reasonable quantity of various components of soil acidity. The soils in this region are inherently organic and are utilised for cultivating valuable cash crops.

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	-0.391	1														
PD	-0.125	0.174	1													
BD	-0.192	0.312	-0.032	1												
Porosity	-0.010	0.033	-0.823**	0.593*	1											
OC	-0.078	0.638**	0.087	0.200	0.034	1										
N	-0.231	0.622**	-0.029	0.197	0.124	0.842**	1									
P	0.698**	-.298	-0.120	0.114	0.156	0.008	0.033	1								
K	-0.039	0.669**	-0.216	-0.011	0.161	0.831**	0.652*	-0.064	1							
TPA	-0.576	0.452	0.334	0.327	-0.073	0.270	0.195	-0.322	0.170	1						
PDA	-0.552*	0.370	0.297	0.276	-0.069	0.277	0.148	-0.313	0.182	0.982**	1					
Ex-A	-0.534*	0.591*	0.372	0.405	-0.068	0.203	0.286	-0.288	0.106	0.865**	0.757**	1				
Extra-A	-0.770*	0.203	0.389	0.207	-0.187	-0.075	-0.046	-0.391	-0.235	0.645*	0.631**	0.540*	1			
AB+	-0.720**	0.629**	0.292	0.316	-0.053	0.192	0.412	-0.275	0.112	0.703**	0.616*	0.812**	0.648*	1		
H+	-0.741**	0.105	-0.164	0.006	0.143	0.014	-0.055	-0.712**	0.113	0.474	0.516*	0.276	0.604*	0.219	1	
LR	-0.988**	0.461	0.195	0.146	-0.70	0.107	0.264	-0.724**	0.062	0.588*	0.559*	0.562*	0.778*	0.730**	0.708**	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	-0.042	1														
PD	0.222	0.104	1													
BD	0.046	-0.332	0.293	1												
Porosity	-0.195	-0.318	-0.781**	0.367	1											
OC	0.541	0.542*	-0.318	0.063	-0.272	1										
N	0.215	0.661**	0.524*	-0.060	-0.443	0.808**	1									
P	0.655**	-0.219	0.661**	-0.189	-0.105	0.388	0.194	1								
K	0.178	0.670**	-0.219	-0.321	-0.377	0.612*	0.579*	0.057	1							
TPA	-0.542*	-0.383	0.670**	0.271	0.331	-0.454	-0.135	-0.055	-0.606*	1						
PDA	-0.720**	-0.402	-0.383	0.120	0.381	-0.579*	-0.302	-0.143	-0.460	0.903**	1					
Ex-A	-0.827**	0.025	-0.402	0.104	0.091	-0.458	-0.207	-0.470	-0.348	0.657**	0.712**	1				
Extra-A	-0.727**	-0.079	0.025	-0.037	-0.057	-0.648**	-0.320	-0.534	-0.396	0.538*	0.585*	0.818**	1			
AB+	-0.546*	-0.280	-0.079	0.209	-0.158	-0.603*	-0.411	-0.457	-0.277	0.427	0.549*	0.678**	0.666**	1		
H+	-0.655*	0.274	-0.280	-0.037	0.260	-0.105	0.069	-0.248	-0.235	0.526*	0.497	0.777**	0.540	0.065	1	
LR	-0.991**	0.035	0.224	0.274	0.012	0.237	-0.565*	-0.257	-0.709**	-0.229	0.513*	0.680**	0.728**	0.532*	0.656*	1

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