Indian Journal of Ecology (2023) 50(3): 584-588
DOI: https://doi.org/10.55362/IJE/2023/3938

Manuscript Number: 3938
NAAS Rating: 5.79

Comparative Assessment of Soil Chemical Properties in Upper and Lower Forest Zones of Zanübu Mountain Range of Phek District, Nagaland, India

Pfüchüpe-ü Mero and Neizo Puro

Department of Botany, Nagaland University, Lumami-798 627, India
E-mail: pfuchupeu7@gmail.com

***Abstract*:** The present study was conducted in Zanübu mountain range of Phek district, Nagaland, India, to estimate the variability of soil chemical properties at two forest zones i.e., 2000-2426m amsl (Zone-I, the undisturbed forest) and 1600-2000m amsl (Zone-II, which is disturbed by human activities such as hunting, logging, grazing, collection of wild edible resources, jhum cultivation, and cardamom plantation). Soil samples were collected at different depths and soil chemical properties such as organic carbon, available nitrogen, available phosphorus, exchangeable potassium and pH were analysed using standard procedures. The organic carbon, available nitrogen and available phosphorus were higher in Zone-I (undisturbed forest) as compared to Zone-II (disturbed forest). The factors responsible for the variability of the soil nutrients were altitude, different land use system and anthropogenic disturbances. Exchangeable potassium had significant positive correlation with organic carbon in Zone -I and negative with phosphorus in Zone-II. A negative correlation was observed between exchangeable potassium and pH in both the two zones. If the trend of anthropogenic activities continues in zone-II, it will affect restoration process of soil.

Keywords: Soil chemical properties, Zanübu mountain range, Phek district, Undisturbed forest, Disturbed forest

Formation of soil is influenced by various factors such as parent material, relief, climate, organisms and time. Since the wide meteorological variation results in different climatic zones, soils also differ according to these variations (Poji et al 2017). Altitude plays a significant role in changing the climatic characteristics, soil properties and land use patterns (Deb et al 2019). Knowledge about the vertical distribution of soil nutrients under various forest soils help to understand the biogeochemical cycles (Yang et al 2010). The knowledge of chemical and physical properties of soils has always helped foresters to assess capacity of sites to support productive forests (Schoenholtz et al 2000). Himalayan forests play an important role in moderating the severity of the climate, in cooling and purifying the atmosphere, in protecting and conserving the soil, in holding the hill slopes in position and in cushioning up huge reserves of soil nutrients (Sharma et al 2010). Eastern Himalaya, one of the biodiversity hotspot of the world is a fragile region due to frequent land-use transformation through deforestation, land degradation, and disruption of the hydrological cycle (Tiwari 2008) and these forests, in general, are under high anthropogenic pressure due to excessive extraction of biomass in the form of fuel wood and fodder (Malik et al 2014, Singh et al 2017, Haq et al 2019a, 2019b). Himalayas have high variation in the landscape and hence, the bioclimatic conditions change rapidly within a very short distance resulting in different soil properties and types (Baumler 2015). Soil degradation process is influenced by land management, as well as by topographic factors such as altitude (Mishra and Francaviglia 2021). Zanübu mountain range is a community conserved forest conserved by seven surrounding Chakhesang villages. In the recent past, rapid land use change has occurred especially in the lower altitude caused by deforestation of natural forests for shifting agriculture, plantations and logging which has led to increase of soil erosion. Therefore, the present study aims to compare the soil chemical characteristics between the upper zone which is undisturbed forest and the lower zone forest which is disturbed by different anthropogenic forces. This will help to formulate management strategies to restore soil fertility and to maintain biodiversity.

MATERIAL AND METHODS

Experimental area and sampling site: The present study was conducted in Zanübu mountain range forests in Phek district in southern Nagaland. Mount Zanübu is the highest point at 2426 m above mean sea level, and it is the highest mountain peak in Phek district. The present study was conducted at two forest zones and designated as: zone-I (undisturbed forest) 2000-2426m amsl, which lies between

N25º40393' to N25º39800' latitude and E94º21955' to E94º21753' longitude, and zone II (disturbed forest) 1600-2000m amsl, which lies between N25º39477' to N25º38530' latitude and E94º21530' and E94º21753' longitude. Zone- I is a protected forest, hence it is free from anthropogenic disturbances. Zone II is prone to anthropogenic activities like logging, hunting, shifting cultivation, grazing, collection of wild edible resources and commercial plantations.

Soil sampling and analysis: Soil samples were collected from August 2019 to March 2022 covering all the four seasons of spring, summer, autumn, and winter, by random sampling method. Soils were collected from three different depths i.e 0-10 cm, 10-20 cm and 20-30 cm, and each layer was mixed to form composite samples. pH was analysed following Jackson (1973), organic carbon, available nitrogen, phosphorus and exchangeable potassium were analysed by Walkley and Black's method (1934), Kjeldahl method (1883), Bray's No.1 extract method (1945), and photometric method as outlined by Jackson (1973) respectively. A single-tailed Pearson correlation coefficient was calculated between various chemical parameters of soil for both the forest zones using statistical software SPSS version 23.

RESULTS AND DISCUSSION

pH: The range of pH at Zone I is 4.86 (spring, 0-10cm) - 5.85 (spring, 10-20cm) and for Zone II is 5.12 (summer, 0-10cm) - 5.56(autumn, 20-30cm). The soils are acidic in both the two zones. Panda (1998) reported that about 84% soils of Nagaland are strongly acidic. Similar range of pH (4.17 to 5.74) had been reported by Poji et al (2017) in the forest soil of Phek district. The findings are also within the range of pH value (4.1 to 5.8) as reported by Singh and Munth (2013) in forest soils of Nagaland. The acidity of the soil is because of acidic nature of parent material and also because of a prolonged uptake of basic cations by tree roots (Tegenu et al 2008). The pH increase with soil depth. The lowest value of pH was found in 0-10 cm layer of undisturbed forest. This low pH can be attributed to high amount of humus in the forest soils and subsequent slow decomposition of organic matter, which releases acid. There is not so much variation in the pH values of different soil samples during different seasons from the two zones. The small variation in soil pH in the study area during different seasons shows pH stability (Zubair et al 2022).

Organic carbon: The percentage of soil organic carbon in zone-I forest was highest (2.97%) in summer at 20-30cm depth of soil and lowest (1.52%) in winter at 20-30 cm soil depth. While for zone-II, highest value of organic carbon was observed in autumn and winter (2.56%) both at soil depth of 0-10 cm, and the lowest percentage (1.30%) was observed in spring at soil depth of 10-20cm. Organic carbon was found to be high in both the forests. Similar range of organic carbon content (1.59 to 2.76%) was reported by Singh and Munth (2013) in the forest soils of Nagaland. Soil organic carbon tends to accumulate in forest ecosystem which may be due to addition of huge quantity of forest litter to the soils (Poji et al

Table 1. Seasonal variation in the soil chemical properties of zone-I (UF) and zone-II (DF)

Soil chemical properties	Soil depth	Seasons							
		Spring		Summer		Autumn		Winter	
		Zone I	Zone II	Zone I	Zone II	Zone I	Zone II	Zone I	Zone II
pH	0-10	4.86	5.38	5.26	5.12	5.27	5.35	5.59	5.39
	10-20	5.85	5.55	5.27	5.17	5.34	5.46	5.57	5.51
	20-30	5.10	5.40	5.26	5.40	5.50	5.56	5.50	5.47
Organic carbon (%)	0-10	2.72	2.30	2.38	1.99	2.44	2.56	1.94	2.56
	10-20	2.26	1.30	2.72	1.95	2.74	1.55	1.54	1.69
	20-30	1.92	1.74	2.97	1.69	2.74	1.56	1.52	1.47
Available nitrogen (Kg ha^{-1})	0-10	868.26	915.42	827.64	551.76	1065.9	877.8	1191.3	1003.2
	10-20	902.88	689.7	777.48	438.9	1040.82	727.32	852.72	777.48
	20-30	865.26	529.38	790.02	426.36	890.34	714.78	539.22	627
Available phosphorus (Kg ha^{-1})	0-10	30.52	24.08	29.4	29.904	36.288	34.608	34.94	34.72
	10-20	28.616	22.904	28.61	34.32	33.20	34.66	38.36	37.24
	20-30	22.848	28.84	34.44	33.54	34.27	33.432	39.76	37.24
Exchangeable potassium (Kg ha^{-1})	0-10	280.44	435.512	267.568	432.88	258.552	195.328	113.736	147.784
	10-20	155.68	216.104	144.48	215.32	148.064	92.736	63.112	102.928
	20-30	117.208	210.224	131.936	141.008	102.704	105.56	43.024	72.296

2017). Organic carbon was higher in zone-I as compared to zone-II. The higher soil organic carbon stock in zone-I (undisturbed forest) could be because, at higher altitude, the lower mean temperature and increasing rainfall decreases soil organic matter decomposition (Du et al 2014). Similar result was obtained by Mishra and Francaviglia in Mon and Zunheboto districts of Nagaland (2021) where soil organic carbon showed an increasing trend with altitude. Andrew et al (2020) observed higher organic carbon content in undisturbed sites as compared to disturbed sites from Takamanda rainforest, Cameroon. Soil organic carbon decreased with soil depth in both the two zones with maximum content in topsoil, which is due to the availability of more organic matter from trees. The presence of trees continuously adds litter in the upper layer (Kimmins 2004) which further enhanced soil organic carbon due to positive priming (Wu et al 1993). The percentage of soil organic carbon in the disturbed forest was lower as compared to the undisturbed forest, which might be due to deforestation which has reduced the amount of organic matter on the forest floor.

Exchangeable potassium: The concentration of potassium in zone-I is highest (280.448 Kg ha^{-1}) in spring at 0-10 cm soil depth and lowest (43.024 Kg ha^{-1}) in winter at soil depth of 20-30 cm. in zone II, highest value (435.512 Kg ha^{-1}) was observed in spring at 0-10 cm soil depth and lowest value (72.296 Kg ha^{-1}) was observed in winter at 20-30 cm soil depth. Potassium content varied from high to low, but majority of the soil samples showed low to medium potassium content, which is in conformity with the results of Motsara (2002) in soils of Nagaland. Poji et al (2017) also reported medium class exchangeable potassium content in the soils of Phek district, Nagaland. Available potassium in both the zones generally decreases with increase in soil depths. Maximum value of potassium was recorded at zone-II i.e., lower elevation zone, which is in conformity with the results obtained by Mishra and Francaviglia (2021) in lower elevation of Zunheboto district in Nagaland. The lower elevation zone is subjected to disturbances like deforestation, forest fire and jhum cultivation which may be the reason for higher contents in available potassium, derived from the ash left on the field after burning.

Available phosphorus: Highest available phosphorus (39.76 Kg ha^{-1}) in zone -I was observed in winter and lowest (22.848 Kg ha^{-1}) in spring, both at 20-30 cm soil depth. In zone-II, highest value (37.46 Kg ha^{-1}) was observed in winter and lowest value (22.904 Kg ha^{-1}) in spring, both at 10-20 cm soil depth. Available phosphorus in both the zones varied from low to medium. Over 60% of the soils in Nagaland were reported to be deficient in available phosphorus (Sharma et al 2001). The low content of available phosphorus in these soils might be due to higher formation of phosphorus by Fe2+, Mn2+ and Al3+ (Medhi et al 2002). Available phosphorus was higher in zone-I as compared to zone-II. The lower concentration of available phosphorus in the disturbed site could be due to anthropogenic activities which might increase the rate of soil erosion and thereby influence leaching of these nutrients. In most cases, phosphorus content was found to be higher in lower depths than upper and middle ones (Table 1) which may be due to leaching process of nutrients. This result is in conformity with the findings of Zubair et al (2022) in the forest soils of Western Himalaya, India.

Available nitrogen: Highest available nitrogen (1191.3 Kg

Table 2. Correlation matrix between the soil chemical properties

Soil parameters	Nitrogen	Phosphorus	Potassium	OC	pH
Zone I (Undisturbed forest)					
Nitrogen	1				
Phosphorus	-0.190	1			
Potassium	0.335	-0.484	1		
OC	0.245	-0.458	0.633*	1	
pH	0.096	0.420	-0.587	-0.474	1
Zone II (Disturbed forest)					
Soil parameters	Nitrogen	Phosphorus	Potassium	OC	pH
Nitrogen	1				
Phosphorus	-0.036	1			
Potassium	0.028	-0.686*	1		
OC	0.547	0.053	0.399	1	
pH	0.329	0.007	-0.614*	-0.487	1

ha^{-1}) in zone-I and highest (1003.2 Kg ha^{-1}) in zone-II was observed both in winter at 0-10 cm, while lowest (539.22 Kg ha^{-1}) in zone-I was observed in winter at 20-30 cm and lowest (426.36 Kg ha^{-1}) in zone-II was observed in summer at 20-30 cm. Available nitrogen is found to be high in both the two zones. But it was higher in zone-I than in zone-II. This may be due to the fact that organic carbon is higher in the undisturbed forest which contributes to the available nitrogen content in the soil. The available nitrogen decreases with soil depth in both the two zones. This could be attributed to the presence of heavy litter and humus contents in the upper layers of the forests leading to the richness of nitrogen in the upper layers as compared to lower layers. Similar result was obtained by Semy et al (2021) in the coal-mining affected and non-affected forest soil at Changki, Nagaland.

CORRELATION

Available potassium had significant positive correlation with organic carbon under zone-I i.e., undisturbed forest zone. Similar correlations were reported by Gairola et al (2012), Kumar et al (2013) and Pandey et al (2018). This might be due to creation of favourable soil environment with presence of high organic carbon (Meena et al 2006). A negative correlation was observed between available potassium and pH of the soil in both the two forest zones. These correlations indicate that soil pH and organic carbon govern nutrient availability in these soils. These results are in agreement with those of Somasundaram et al (2009), Tsanglao et al (2014), and Poji et al (2017). A negative correlation was also observed between potassium and phosphorus in zone-II.

CONCLUSION

The results of the present study revealed that the soils of both the forest zones were acidic. Soil chemical parameters such as organic carbon, available phosphorus and available nitrogen were higher in the undisturbed forest. Soil organic carbon, available nitrogen and exchangeable potassium were generally higher at the surface soil (0-10 cm) than the deeper layers (10-20 cm and 20-30 cm). Organic matter from forest litter increase soil organic carbon thereby restoring soil fertility and ensures proper functioning of the forest ecosystem. Lower content of soil nutrients in the disturbed forest zone may be due to the complex interactions of forest disturbances, such as, slash and burn agriculture, landslides, selective logging, grazing and commercial plantations. If the trend of anthropogenic activities continues, it will lead to harmful environmental changes and affect restoration process of soil. The results from this study indicates that there is a need for proper land use planning and adoption of sustainable farming systems in order to prevent further deterioration of soils in the lower elevation forest zone of Zanübu mountain range.

REFERENCES

Andrew EE, Ndah NR, Bechem E and Lucha CFB 2020. Soil physico-chemical properties at different habitat types in disturbed and undisturbed sites of the Takamanda Rainforest, Cameroon. *International Journal of Plant & Soil Science* **32**(11): 1-17.

Baumler R 2015. Soils, pp. 126–134. In: Miehe G, Pendry CA, Chaudhary RP (eds.). *Nepal: An introduction to the natural history, ecology and human environment in the Himalayas - a companion to the flora of Nepal*. The Royal Botanical Garden Edinburgh, Edinburgh.

Bray RH and Kurtz LT 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil sciences* **59:** 39-45.

Deb P, Debnath P, Denis AF and Lepcha OT 2019. Variability of soil physicochemical properties at different agro ecological zones of Himalayan region: Sikkim, India. *Environment, Development and Sustainability* **21**: 2321-2339.

Du B, Kang H, Pumpanen J, Zhu P, Yin S, Zou Q, Wang Z, Kong F and Liu C 2014. Soil organic carbon stock and chemical composition along an altitude gradient in the Lushan Mountain, subtropical China. *Ecological Research* **29**: 433-439.

Gairola S, Sharma CM, Ghildiyal SK and Suyal S 2012. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. *Environmentalist* **32:** 512-523.

Haq SM, Malik ZA and Rahman IU 2019a. Quantification and characterization of vegetation and functional trait diversity of the riparian zones in protected forest of Kashmir Himalaya, India. *Nordic Journal of Botany* **37:** 1-11.

Haq SM, Rashid I, Khuroo AA, Malik ZA and Malik AH 2019b. Anthropogenic disturbances alter community structure in the forests of Kashmir Himalaya. *Tropical Ecology* **60:** 6-15.

Jackson ML 1973. Prentice hall of India Pvt. Ltd., New Delhi, 498.

Kimmins JP 2004. *Forest ecology: A foundation for sustainable forest management and environment ethics in forestry, 3rd ed.* Prentice Hall, Upper Saddle River, NJ, p 611.

Kjeldahl J 1883. Neue Methodezu rBestimmung des Stickstoffs in organischen Körpern (New method for the determination of nitrogen in organic substances). *Zeitschriftfüranalytische Chemie* **22**(1): 366-383.

Kumar M, Singh H, Bhat JA and Rajwar GS 2013. Altitudinal variation in species composition and soil properties of Banj Oak and Chir Pine Dominated Forests. *Journal of Forensic Sciences* **29:** 29-37.

Malik ZA, Bhat JA and Bhatt AB 2014. Forest resource use pattern in Kedarnath wildlife sanctuary and its fringe areas: A case study from Western Himalaya, India. *Energy Policy* **67:** 138-145.

Medhi BK, Deka CR, Hazarika S, Hussain M and Barman B 2002. Morpho-electrochemical characterisation and nature of soil acidity as influenced by topography and vegetation in some acid soils of Kamrup district, Assam. *Annals of Agri Bio Research* **7:** 1-8.

Meena HB, Sharma PR and Rawat US 2006. Status of macromicronutrients in some soils of Tonk district of Rajasthan. *Journal of the Indian Society of Soil Science* **54:** 508-512

Mishra G and Francaviglia R 2021. Land uses, altitude and texture effects on soil parameters: A comparative study in two districts of Nagaland, Northeast India. *Agriculture* **11:** 171.

Motsara MR 2002. Available N, P and K status of Indian soils as depicted by soil fertility maps. *Fert. News* **47**(8): 15-21.

Panda N 1998. *Soil of North-Eastern Region and arrangement for sustainable production*. Paper presented at the symp. on ICAR Research Complex for NEH region.

Pandey NC, Tewari LM, Joshi GC and Upreti BM 2018. Physico-chemical characterization of Oak, Pine and Sal forest soil profiles of Betalghat Region of Kumaun Himalaya. Eurasian *Journal of Soil Science* **7:** 261-272.

Poji I, Sharma YK and Sharma SK 2017. Fertility status and forms of acidity in soils of Phek district of Nagaland in relation to land use systems. *Annals of Plant and Soil Research* **19**(3): 260-265.

Schoenholtz SH, Van Miegroet H and Burger JA 2000. A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. *Forest Ecology and Management* **138:** 335-356.

Semy K and Singh MR 2021. Comparative assessment on the physico-chemical properties of coal mining affected and non-affected forest soil at Changki, Nagaland. *Indian Journal of Ecology* **48**(1): 36-42.

Sharma CM, Gairola S, Ghildiyal SK and Suyal S 2010. Physical properties of soils in relation to forest composition in moist temperate Valley Slopes of the Central Western Himalaya. *Journal of Forest Science* **26:** 117-129.

Sharma SK, Singh PK. Sharma, Anamika and Sharma A 2001. Status of available nitrogen, phosphorus, potassium and physicochemical characteristics of acidic soils of North East Region with special reference to Nagaland state. *Journal of Interacademicia* **7:** 123-126.

Singh H, Malik ZA and Baluni P 2017. Forest resource use pattern in relation to socioeconomic status: A case study from two altitudinal zones of Western Himalaya, India. *Indian Forest* **143**: 334-343

Singh PK and Munth Hage 2013. Fertility status of soil under forest and cultivated land use system of Nagaland: A comparative study. *Asian Journal of Soil Science* **8**(2): 470-475.

Received 04 December, 2022; Accepted 05 April, 2023

Somasundaram J, Singh RK, Parandiyal AK and Prasad SN 2009. Micronutrient status of soils under land use systems in Chambal ravines. *Journal of the Indian Society of Soil Science* **57**: 307-312.

Tegenu AE, Kassahun HT, Collick AS, Adissu T, Ashagrie BB, Tessema ZK, Derebe A, Solomon D and Steenhus TS 2008. Soil properties and fertility status dynamics of north western Ethiopia as influenced by land use changes: Case of Dibanke watershed, Ethiopia. https://www.researchgate.net/publication/258993430

Tiwari PC 2008. Land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India. *Advances in Atmospheric Sciences* **25**(6): 1029-1042.

Tsanglao, Chenithung, Sharma YK and Sharma SK 2014. Fertility status and soil acidity under different land use systems in Wokha district of Nagaland. *Journal of the Indian Society of Soil Science* **62**: 414-418.

Walkley AJ and Black IA 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Sciences* **37**: 29-38.

Wu J, Brookes PC, and Jenkinson DS 1993. Formation and destruction of microbial biomass during the decomposition of glucose and rye grass in soil. *Soil Biology and Biochemistry* **25**: 1435-1441.

Yang YH, Fang JY, Guo DL, Ji CJ and Ma WH 2010. Vertical patterns of soil carbon, nitrogen and carbon: nitrogen stoichiometry in Tibetan grasslands. *Biogeo Discuss* **7**: 1-24.

Zubair A, Malik and Shiekh Marifatul Haq 2022. Soil Chemical properties - variation with altitude and forest composition: A case study of Kedarnath Wildlife Sanctuary, Western Himalaya (India). *Journal of Forest and Environmental Science* **38**(1): 21-37.