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Spatial Analysis of Soil Characteristics Under Different Land Uses in Arun Rural Municipality and Shadananda Municipality of Bhojpur District

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Abstract— *Increased nutrient mining, soil erosion, and inadequate nutrient management have all resulted in lower soil quality and yield. In 2021, a study was conducted in the Shadananda Nagarpalika and Arun Gaunpalika in the Bhojpur district to examine the variability of chosen soil attributes from three land-use groups (agriculture, forestry, and pasture) mapping their geographical distribution. A total of 77 soil samples were collected from 0–15 cm depth and examined for soil fertility factors such as soil texture, pH, organic matter (OM), nitrogen (N), phosphorus (P), and potassium (K). The research shows that the Forests have a higher clay content (14.75%) than agricultural (10.41%) or pastureland (13.20 %). The researchers discovered that all land uses had somewhat acidic soil. Soil OM concentration was medium in agricultural land (2.85%) and low in the forest (1.99%) and pasture (2.40%) land-use types, but soil N content was low in all land-use categories (0.095%), forest (0.083%), and pasture (0.084 %). The soil K concentration was medium to high in the majority of the study area. Land-use type did not affect the concentration of K (P > 0.05). The soil K concentration was medium to high in the majority of the study area. The highest concentrations of soil K were detected in pastureland (248.98 kg/ha), followed by agricultural land (229.17 kg/ha), and woodland (196.34 kg/ha). Soil pH and available phosphorus showed a strong positive correlation, (rs=0.56, P<0.01), and the same was the case for soil organic matter and total nitrogen, (rs=0.69, P<0.01). A moderate and positive correlation was seen between available phosphorus and potassium, (rs=0.34, P<0.01). There was a weak negative correlation between available phosphorus (P< 0.01) and soil nitrogen (rs = 0.24, P< 0.05). In general, there was a moderate correlation between different soil chemical properties*.

Keywords— *Acidic soil, chemical properties, dynamic, and physical properties*.

I. Introduction

Soil is a naturally occurring self-constituting body consisting of incoherent minerals and organic matter ever-present on land surface, that occupies space, distinguished by either one or both of the following: horizons that are distinguishable from the initial parent material due to addition, loss, transfer, and transformation of energy and matter or the inherent ability of soil to support rooted plants. Soil is a complex, diverse, and dynamic system whose properties change across time and space (Cichota et al., 2006).

Soil as a resource is considered to be the most important for agricultural communities' households and thus soil fertility management is critical for their sustainable development (Pilbeam et al., 2000). Hence it is important to define soil fertility as the combination of physical, chemical, and biological variables that determine soil structure and porosity, macro and micronutrient availability, and biological organism activity in order to implement soil fertility management procedures. These are the factors that interact to influence crop growth and limit crop yield (Rowell, 1994). Main constituents of soil system are minerals, soil organic matter (SOM), water, and air (Joshi et al., 2009). Finally, soil quality can be referred to the combination of physical, chemical, and biological characteristics interconnected to each other that impact a wide range of activities in the soil that makes it suitable for agricultural and other practices (Kumar et al., 2012). Important soil physical qualities include texture, structure, and color. Similarly, key soil chemical characteristics include soil reaction (pH), organic matter, macro and micronutrients, and so on. These are the qualities that are identified during soil testing as having a key role in soil fertility (Weil .R.R. & Brady N.C., 2017).

Soil properties being dynamic alter with time due to the combined effect of biological, physical, and chemical processes, and also can vary within farmland or at the landscape scale (B., 1997; Corwin et al., 2003; Mouazen et al., 2003; Santra et al., 2008). Soil properties differ in different places due to the combination of biological, physical, and chemical processes over time (Santra et al., 2008). Land use and management changes can have a huge impact on soil physical and chemical properties (Spurgeon et al., 2013) and knowledge of the variation in soil properties within farmland use is essential in determining production constraints related to soil nutrients (Panday et al., 2019). Hence, a single study of an area could never justify the features other places possess. Detailed study of soil characteristics of all the places is crucial to enable sustainable land management to keep pace with changing human needs and to ensure long-term productivity of farmland.

Nepal's land is classified into forestry, grassland, agricultural land, residential, commercial, archeological, and water bodies as per the land use categories outlined by the National Land Use Policy (MoLRM, 2015). The most vital types of land for farmers' livelihood are forest, grassland and agricultural lands. Forest covers about 29% of Nepal's land, 21% is under cultivated agricultural land and 12% is under

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grassland (MOALD, 2020). Nepal's land has been in degrading trend over the course of past few years due to which average annual crop production is decreasing at an alarming rate. It is necessary to modify land use and management practices with soil quality which could both restore the degraded soil physiochemical quality and guarantee steady and sustainable productivity.

Bhojpur is a hilly district with very rough topography and rocky terrain with soil texture ranging from sandy loam to silt. Lack of proper research and reliable data has made it difficult to evaluate the soil quality of Bhojpur and suggest proper management practices to the farmers. Thus, the study is aimed to analyze the variations in soil characteristics under various land uses and map their spatial distribution using ArcGIS. The study will benefit the local farmers and planners in implementing effective soil management practices for sustainable land use.

II. Materials and Methods

A. Study Area

Bhojpur District was selected for our study based on the feasibility and availability of the funds. Bhojpur District lies in Province 1 in the eastern region of Nepal. Bhojpur is surrounded by Dhankuta and Sankhuwasabha in the east, Khotang in the west, Solukhumbu in the north and Udayapur in the south.

The study was carried out in the eastern part of Bhojpur district and includes Arun Rural Municipality (21.21° N 87.16° E) and Shadananda Municipality (27°21' N 87°7' E) covering an area of 396 km^2. The study area experiences the climate varying from tropical to temperate with altitude ranging 223-3,200m from mean sea level.

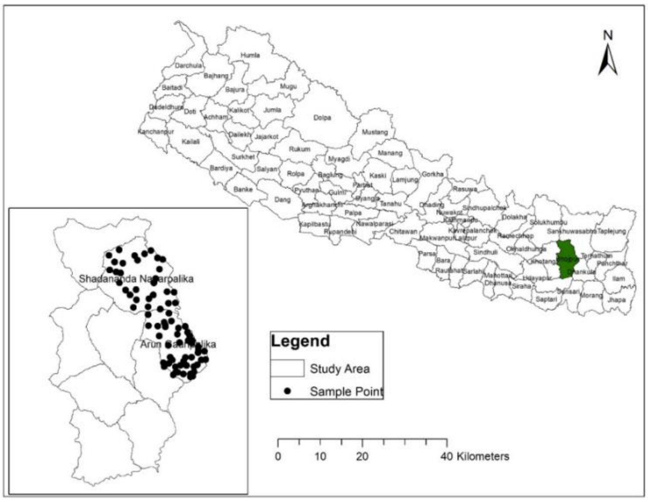

Figure 1. Map showing study area and soil sampling locations

B. Soil Sampling Method

A total of 77 samples were collected from the study area. The samples were collected from different land use types viz. agricultural (64), forest (8) and pastureland (5) at the depth of 0-15 cm. About half kg of soil samples were collected and packed in plastic bags for analysis in laboratory.

C. Laboratory Analysis

Laboratory analysis was started on 25 August, 2021 A.D. Analysis was done for soil texture, soil pH, soil organic matter (OM), total nitrogen (N), available Phosphorus (P) and available Potassium (K).

1) Chemical analysis

Each soil sample was grinded and passed through 2mm sieve and tested using suitable procedure. Analysis was done for soil texture, soil pH, soil organic matter (OM), total nitrogen (N), available Phosphorus (P) and available Potassium (K) at Soil Water and Air Testing Laboratories Pvt. Ltd., Babarmahal, Kathmandu.

2) Determination of available nutrient

TABLE 1. Soil chemical analysis methods followed for testing soil properties.

S.N.	Parameters	Analysis Methods
1.	Texture	Bouyoucos hydrometer method (Bouyoucos, 1962)
2.	Soil pH	Digital pH meter (McLean, 1983)
3.	Organic Matter (OM)	Walkley and Black method (Houba et al., 1989)
4.	Total Nitrogen (N)	Kjeldahl distillation (Bremner & Mulvaney, 1983)
5.	Available Phosphorus (P)	Olsen's and Somers method (Olsen et al., 1982)
6.	Available Potassium (K)	Flame photometer method (Thomas, 1983)

3) Determination of soil fertility status

The soil fertility was determined by using the rating chart.

TABLE 2. Rating chart for soil fertility status of soil.

Nutrient status	Soil organic matter (%)	Total N (%)	Available P (kg/ha)	Available K (kg/ha)
Very low	<1	<0.03	<10	<55
Low	1-2.5	0.03-0.1	10-30	55-110
Medium	2.5-5	0.1-0.15	30-55	110-280
High	5-10	0.15-0.3	55-110	280-500
Very high	>10	>3	>110	>500

Source: Soil Science Division, NARC Nepal.

TABLE 3. Rating chart for soil pH

Soil pH	Soil reaction
<5	Strongly acidic
5-6.5	Moderately acidic
7	Neutral
>7	Alkaline

Source: (Brady, 1995)

D. Data Analysis

The data obtained from the field survey and laboratory analysis were entered into MS-Excel 2019 and then imported to Statistical Packages for Social Sciences (SPSS) version 25.0. SPSS was used for descriptive analysis and graphs. Kruskal-Wallis test evaluated differences among the land use types. When a significant effect was found, pairwise comparisons were conducted using Mann-Whitney U test. The pairwise Spearman's correlation between the soil chemical properties was also calculated in SPSS. ArcMap 10.5 was used for geostatistics and preparation of the location map.

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III. Results and Discussion

A. Soil Physical Properties

1) Soil Texture

Our findings highlight that land use had no effect on the texture of the soil in the study area. It is interesting that silt loam (Figure 2) was the predominant soil textural class in the study area. In our view the most compelling explanation for such finding might be attributed to identical source materials and consistent soil formation processes. Furthermore, forests had a greater clay content (14.75 percent) than agricultural (10.41 percent) or pastureland (13.20 percent). The slopy land comprising pasture and agricultural land with sparser vegetation might have led to removal of clay fractions sparser vegetation due to selective water erosion processes (Bewket & Stroosnijder, 2003). Pastureland had the highest silt and sand fraction, followed by agricultural land and forest. Silt and clay concentration was found to be the best predictors of soil carbon and nitrogen (Whisler et al., 2016).

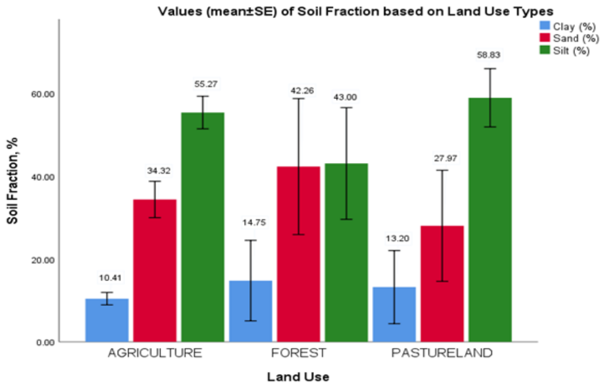

Figure 2. Values (mean ± SE) of soil fractions based on land use types of the study area.

B. Soil Chemical Properties

TABLE 4. Spatial variability of soil chemical properties among land use using Kruskal-Wallis test

Test Statistics[a,b]

Soil Properties	Kruskal-Wallis H	Df	F-Value
Soil pH	.395	2	.821 NS
OM, %	3.616	2	.164 NS
N, %	.445	2	.800 NS
P, kg/ha	6.022	2	.049*
K, kg/ha	1.578	2	.454 NS

a. Kruskal Wallis Test
b. Grouping Variable: Land Use Code
*Significantly different among different land uses at $P < 0.05$, NS: Non-Significant

TABLE 5. Mann-Whitney U test for pairwise comparison of available P content in forest and pastureland.

Ranks				
	Land Use	N	Mean Rank	Sum of Ranks
P (kg/ha)	Forest	8	5.00	40.00
	Pastureland	5	10.20	51.00
	Total	13		

	P2O5 (kg/ha)
Mann-Whitney U	4.000
Wilcoxon W	40.000
Z	-2.342
Asymp. Sig. (2-tailed)	.019*

* Significantly different at $P < 0.05$

1) Soil Organic Matter (OM)

The results highlighted that amount of soil organic matter (OM) differed slightly based on land use, with agricultural land having the most and forest regions having the least. The majority of the research area had low and medium soil OM (Figure 3). The best explanation could be that farmers' frequent use of organic manures may have led to higher OM on agricultural land. Also, the growth of extensive root systems in natural grasslands may lead to higher soil OM (Fu, 2007). Furthermore, in grasslands, plants and plant litter form a covering layer that protects the soil from erosion when combined with minimal disturbance (Chalise et al., 2018).

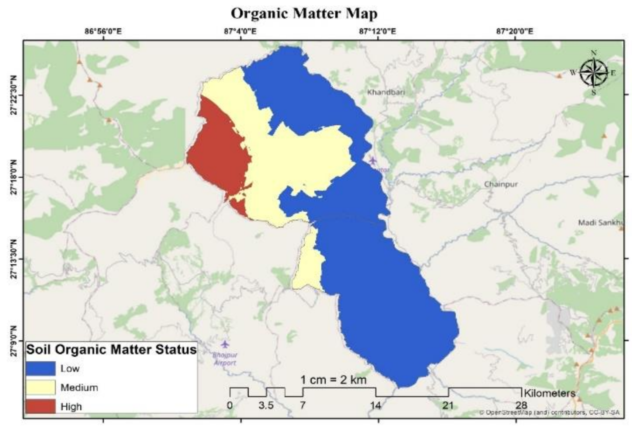

Figure 3. Soil OM spatial variability map in the study area. The study area was dominated by low (54.37%) and medium (33.29%) OM content

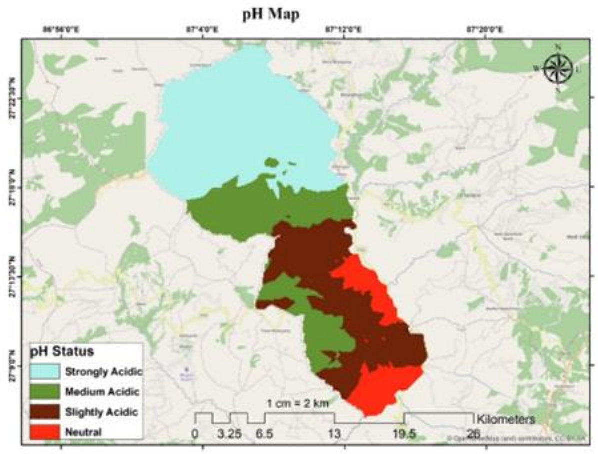

Figure 4. Soil pH water spatial variability map in the study area. Most area had strongly acidic (44.22%) followed by slightly acidic (24.15%) and medium acidic (22.53%).

2) Soil PH

The results imply no apparent change in pH levels between land use types. Forest soil (6.31) had the highest pH, followed by pastureland (6.29) and agricultural land (6.16) that might be due to the fact that Nepalese soils are mainly made of Himalayan residuum and alluvium formed from shale, sandstone, and siltstone, and have a limited buffering ability

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(Ojha & Panday, 2021). The influence of parent materials on imparted acidity was also observed by Panday et al., (2019). According to Carson, (1992), increased soil acidity in hilly areas is caused by the increased use of nitrogenous fertilizer and the government reforestation program's focusing mainly on pine tree plantings.

3) Total Nitrogen (N)

Nitrogen has a considerable impact on crop development, quality, and yield when compared to other nutrients (Panday et al., 2019). The results show that total nitrogen content ranged from low to medium throughout the research area. Agricultural land had the highest nitrogen level (0.095%), followed by pasture (0.084%), and forestland (0.083%). The possible reason maybe the farmers' use of nitrogenous fertilizers and integration of organic manures that could contribute to higher nitrogen content in agricultural land, but it was still below the acceptable range whereas past researchers have found higher nitrogen levels in grassland than in agricultural land (Panday et al., 2019).

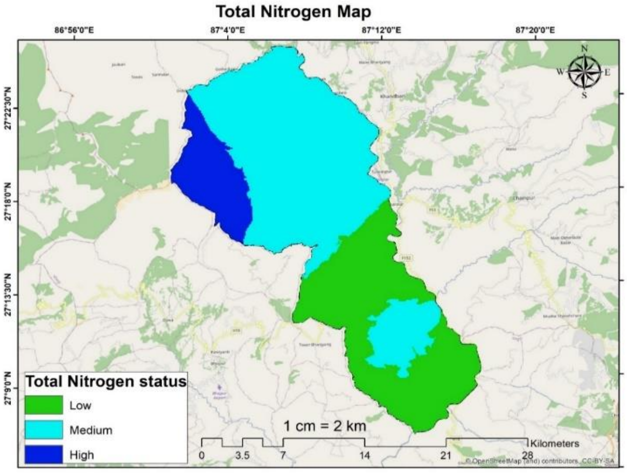

Figure 5: Soil N spatial variability map in the study area. Most of the study area had medium (55.94%) total N content.

4) Available Phosphorus (AP)

Hill and mountain soils have a higher phosphorus content than Terai soils (Ojha & Panday, 2021). According to various studies conducted by the Nepal Agricultural Research Council (NARC), soil phosphorus levels are rising in Nepal since most farmers use Diammonium Phosphate fertilizer to enhance their crop yield. Phosphorus (P) availability in agricultural (300.15 kg/ha), forest (216.91 kg/ha), and grasslands (464.48 kg/ha) soils varied significantly. In compared to agricultural and forest land, pastureland had the highest available P, which contradicts findings of Panday et al., (2019) that forest land had higher available phosphorous. The predominance of pine trees, which cause soil acidity and thus phosphate fixation with iron and aluminum, could be one reason for the low phosphorus level in forest lands. Also, because Nepal lacks phosphate rocks, low levels of AP in the forest may have resulted as a result of this. Agricultural management that involves disturbing the soil surface with plowing frequently increases the quantity of phosphorus taken away on eroded sediment (i.e., particulate P). On the other hand, unincorporated fertilizer, manure, or even high-phosphorus crop waste on the surface of crops or pastures usually results in higher phosphorus losses dissolved in runoff water (i.e., dissolved P). Phosphorus may be washed away from manure-laden animal holding areas, or from nearby fields where regular manure treatments are convenient, resulting in extraordinarily high phosphorus concentrations near the soil surface (Weil .R.R. & Brady N.C., 2017). In terms of phosphorus, however, agricultural land did not vary significantly from forest or pastureland at $P<0.05$. Mann-Whitney U test for pairwise comparison of available phosphorus content in forest and pastureland revealed significant difference in available phosphorus between the two land use types at $P=0.019$.

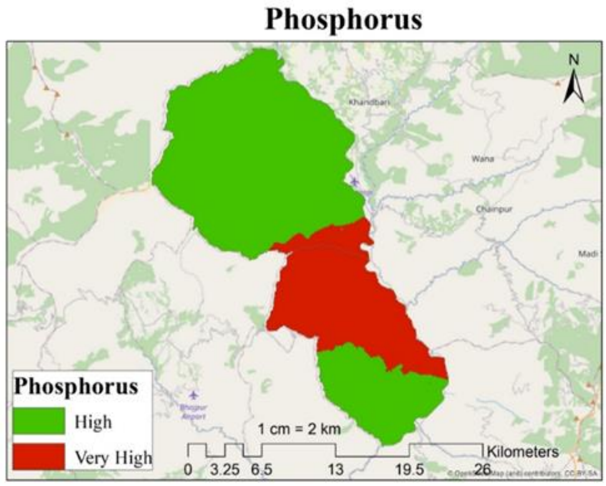

Figure 6: Soil P spatial variability map in the study area.

5) Available Potassium (AK)

The soil K concentration was medium to high in the majority of the study area. Land use type had no effect on the concentration of K ($P > 0.05$). The availability and distribution of K content in soils is determined by the nature of parent materials, weathering, land use regimes, fertilizer types and leaching rates, and crop residue (Mbah, 2008; Uzoho & Ekeh, 2014). The highest concentrations of soil K were detected in pastureland (248.98 kg/ha), followed by agricultural land (229.17 kg/ha) and woodland (196.34 kg/ha). The predominance of the slash and burn farming practice may account for the high soil K level (Fachin et al., 2021). Increased soil K content can be linked to the addition of OM in soil utilizing organic manures, however, weak nutritional content, soil pH, and bulky volume demand special maintenance (Mikkelsen, 2007). Increased OM input increases cationic exchange capacity in the soil, which reduces the rate of leaching of positively charged nutrients like Ca^{2+}, potassium (K^+), and magnesium (Mg^{2+}) (Mbah, 2008). However, when compared to grasslands, soil K leaching through irrigation water, restricted crop residue recycling, continuous cropping, and soil erosion have all contributed to the depletion of basic cations on agricultural fields (Akbas et al., 2017; Lechisa et al., 2014; Srivastava et al., 2004). Lower potassium availability in forest soil may be owing to greater pH, which causes potassium fixation. Lower potassium availability in forest soil may be due

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to a higher pH, which enables potassium to be attached to soil colloids (Weil .R.R. & Brady N.C., 2017).

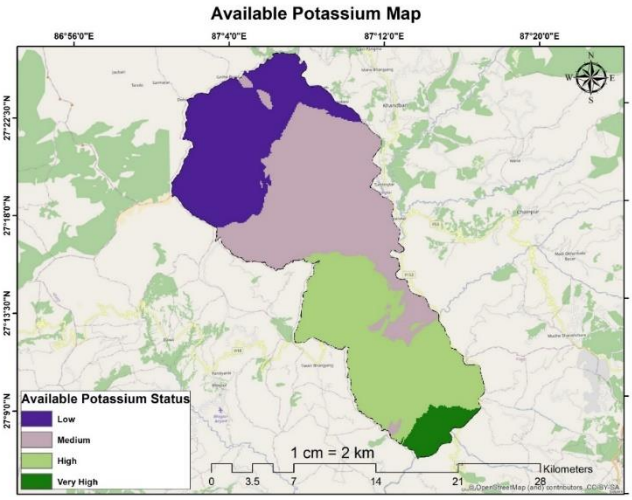

Figure 7: Soil K spatial variability map in the study area. The study area was dominated by medium (34.26%), followed by high (28.75%).

C. Correlations between soil chemical properties

Soil pH and available phosphorus showed a strong positive correlation, rs= .56, p<0.01, and the same was the case for soil organic matter and total nitrogen, rs= .69, p<0.01. A moderate and positive correlation was seen between available phosphorus and potassium, rs= .34, p<0.01. Soil nitrogen and pH showed a weak and negative correlation, rs= -.24, p<0.05 which was consistent with the findings of Panday et al., (2019). In general, there was a moderate correlation between different soil chemical properties.

TABLE 6. Spearman's Correlation Coefficients between the soil chemical properties.

	pH	OM	P2O5 (kg/ha)	K2O (kg/ha)	N (%)
pH					
OM	**-.007**				
P2O5 (kg/ha)	**.123**	**-.057**			
K2O (kg/ha)	**.563****	**-.016**	**.337****		
N (%)	**-.236***	**.685****	**-.018**	**-.161**	

* Correlation is significant at the 0.05 level (2-tailed).
******Correlation is significant at the 0.01 level (2-tailed).

The major limitation of the study is small sample size from forest and pastureland. This study was the first attempt to explore the soil qualities of different regions of the district. We feel that further research in the area could either establish our findings as facts or our findings could be corrected. Despite the limitations our study provides foundation for other interested people to improve where we lacked upon. These data could prove helpful to determine or categorize different places for future projects. Our several findings didn't comply with the results of similar studies conducted by other researchers which opens a door for future researchers to explore the numerous possibilities. Much work needs to be done in order to develop the full understanding of the actual affect that land use pattern exerts on soil properties.

IV. Summary and Conclusion

The study on "Spatial Analysis of Soil Characteristics Under Different Land Uses in Arun Rural Municipality and Shadananda Municipality of Bhojpur District" was carried out in the Bhojpur district of eastern Nepal. Our study included Arun Rural Municipality and Shadananda Municipality of the Bhojpur district. A total of 77 soil samples were collected from different land-use types viz. agricultural land, forest, and pastureland in the study area. Soil samples from the upper 0-15cm layer of soil were taken and used for laboratory analysis.

The study assessed soil properties to determine the effect of different land use on individual soil parameters. The study area was dominated by silt loam soil textural class. The result showed that soil pH, OM, N, and K did not vary with the land use types. However, a statistically significant difference in available P content was seen between forest and pastureland.

The soil of the study site was particularly low in organic matter and nitrogen content hence needing additional manure and nitrogenous fertilizer application. The study showed that available K was present in medium amounts while available P was present in high concentrations. Results reveal that soil chemical properties were in poor status demanding remedial measures and appropriate soil management techniques.

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