

## Dynamic Variations in Soil Properties in Different Land Use Types in Doti District, Nepal

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### Abstract

Soil quality is one of the primary factors influencing how many and what kind of crops can be grown and what success ecosystems will have over the long term. Knowledge about how gradients of agroecology and land-use systems affect soil quality is essential in proposing sustainable farming practices. This study assesses the spatial variability of selected physical and chemical properties of soil across three ecological zones—lowland, midland, and highland—and three land use types: traditional agricultural practice, commercial vegetable cultivation, and barren land. The research was carried out in the Doti district of Nepal. A total of 144 soil samples were collected from four depths (0-15, 15-30, 30-60, and >60 cm intervals) for the purpose and were then tested for temperature, moisture, bulk density, pH, total nitrogen, available potassium, available phosphorus, organic carbon, and cation exchange capacity. The data collected indicated a significant variousness ( $p < 0.05$ ) of characteristics under different land uses, signifying that chemically all the land-use types were chemically variable in nature. Another low value witnessed was in the bulk density of the soils, which was  $0.88 \pm 0.04$  g/cm<sup>3</sup>. This means that the structure and nutrients will be better due to the high amount of organic matter. The highest organic carbon and cation exchange capacity were in the highland zones. In contrast, the barren land soils had a trend indicating a decline in nutrient status and increasing compaction and acidity. Nutrient concentration significantly decreased with increasing depth, pointing to the fact that the most sensitive layer to management changes is the uppermost layer. The study emphasized the need to develop zone-specific soil management strategies, through which one seeks to enhance the organic matter available in soil, protect against erosion, and achieve sustainable intensification to make the soil resilient and productive in agriculture in the case of Doti.

**Keywords:** *Soil properties; Altitude gradient; Soil depth; Soil physicochemical parameter.*

### Introduction

Soil health is of utmost importance for farm productivity and ecosystem durability. It ensures effective functioning in a natural or managed ecosystem in support of wildlife, plants, and people by maintaining or improving the quality of air and water—hence, health and living conditions. Land management affects the quality of soil. The soil quality can be

determined based on its physical, chemical and biological characteristics which includes texture, structure, pH, organic matter content, nutrient availability, and microbial activity. It is thus necessary to practice adequate tillage intensity, crop rotation, use of fertilizers and pesticides, and irrigation water on organic amendments that will enhance soil properties

and foster long term quality of the soil [1,2].

In monoculture systems, the efficiency of nutrient cycling contributes to reducing species richness and functional diversity of the soils. Diverse cropping systems or organic farming could increase microbial activities in the rhizosphere and nutrients availability to plants [3,4]. Different agroecological zones have their different farming practices that may affect the dynamics of soil fertility across both time and space. Land transformations result in significant decline of soil carbon level changes, making them a stabilizing factor of the entire ecosystem. There may be a range of effects in mountainous and hilly areas, with variation at elevations and in landscape agronomic methods [5,6]. Temperature, rainfall, and plant growth varies with elevation and can have effects on the extent to which farming methods influence soil retention of moisture, nutrient cycling and build-up of organic matter [7-9].

For instance, land transformations, which are associated with deforestation for agricultural land use or permanent grassland establishment, induce a significant reduction in changes concerning soil carbon levels and, hence, form a stabilizing factor for the entire ecosystem [10-12].

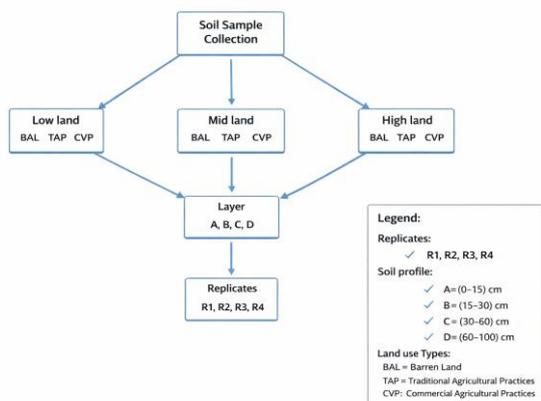
There are numerous farming practices which can influence the soil quality; therefore, it is very important to know these effects, especially in different climate and ecosystem regions. It is only through understanding the relation between people and environment that the land can be sustained. Therefore, this research is trying to find out how different farming methods that apply in land uses of different types and elevation areas participate in changes of soil quality in Doti district, Nepal. This research is intended to find such methods or practices that would help farmers to improve soil health status, which, in turn, will improve

the productivity of crop. This approach helps to examine the soil parameters of density, levels of organic carbon, nutrient contents, and pH for experimentation.

## **Materials and Methods**

This study was conducted in Doti district in Nepal, situated in Sudurpachim province, between latitudes 28° 54' and 29° 28' north and longitudes 80° 30' and 81° 14' east. This covers an area of 2,025 square kilometers, from an elevation of 600 meters minimum to 4,000 meters maximum above sea level. Four ecological zones are distinguished at Doti: tropical (less than 1,200 m), sub-tropical (Between 1,200–2,100 m), temperate (Between 2,100–3,300 m), and alpine (Greater than 3,300 m) in 91 area. The temperatures in this area range between 2 and 44 degrees Celsius, and the district experiences an annual average rainfall of 1,347mm [13]. Doti district has 205,683 people in total, according to the CBS report of 2021. Economic activity mainly depends on agriculture, in which rice, wheat, and maize are grown. Three types of land uses were chosen for a detailed, analytical study on land application practices Three land-use categories, viz. traditional agricultural practices (TAP), commercial vegetable cultivation (CVP), barren land (BAL), for each, the study area is characterized by three ecological or elevation zones: the lowland, midland, and highland zones. Sampling strategy involved collection of at least four replicates for each combination of ecological zone and land-use type, hence a total of 144 soil samples as shown in **Figure 1**. This stratified sampling design—focusing on 3 ecological zones, 3 land-use types, 4 depth intervals, and 4 spatial replicates per site—was particularly tailored to account for the large spatial variability and climatic heterogeneity along the altitudinal range (600 m to 4,000 m)

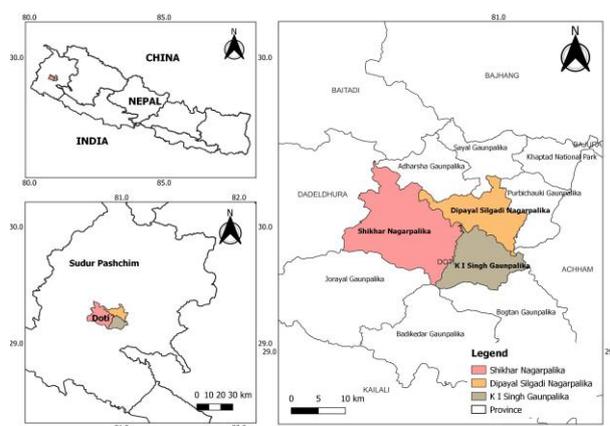
of the Doti district.



**Figure 1:** Flow diagram of sample collection

The soil collection was done in stages. Initially, locations were selected based on their elevation and land use type (**Figure 2**). At each location, four samples were collected from four different depths, and finally at different sites to check consistency. Each sample was transferred immediately into a labeled plastic bag with necessary details, including unique site ID, altitude, land-use types, and depth of sampling. The temperature of the soil was read using a soil temperature probe, whereas the moisture content was tested with the help of a moisture meter. Soil pH was measured using a digital pH meter (Walk Lab Ti 9000). Cation exchange capacity (CEC) was determined following the method described by Sumner and Miller [14]. OC was estimated by colorimetric method [15], while TN was determined by micro-Kjeldahl method [16]. Available phosphorus and available potassium were determined by Bray-1 method and flame photometer, respectively. The data were then subjected to analysis to observe differences in the characteristics with regard to land use and depth in soils. Descriptive statistics of data obtained from field and laboratory analyses related to square mean values were tested, while that of chemical soil parameters due to type of land use and depth were conducted

using a two-way ANOVA. Before the two-way ANOVA, the data were tested for normality (e.g., with the Shapiro-Wilk test) and homoscedasticity (e.g., with Levene's test). The differences between the means were then tested for significance using a post-hoc test (e.g., Tukey's HSD test) with a significance level of  $p < 0.05$ . Correlation analysis and testing for statistical significance were carried out to assess the parameters associated with different land uses and depth in relation to chemical factors.



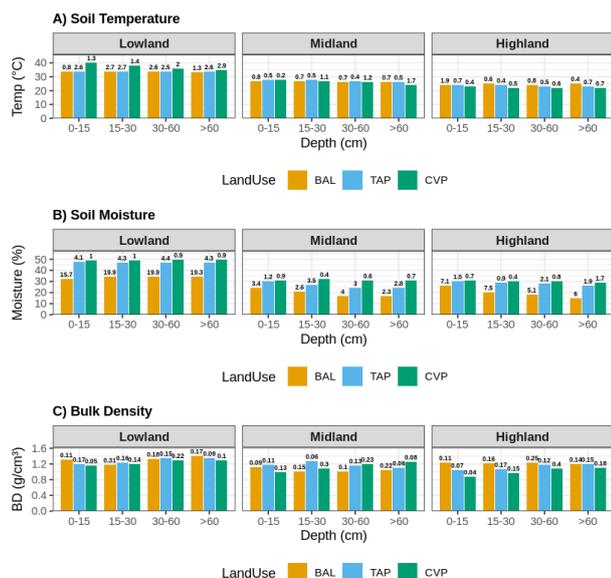
**Figure 2:** Map of study area.

## Results

### Variations in Soil Physical Properties by land use types

The study shows differences in soil physical properties among land use types as shown in **Figure 3**. In the lowland zone, BAL soils had a fairly consistent temperature ( $33 \pm 1.25$ – $34 \pm 2.71$  °C), moderate moisture ( $32 \pm 15.73$ – $34 \pm 19.88\%$ ), and a higher BD ( $1.18 \pm 0.31$ – $1.41 \pm 0.17$  g/cm<sup>3</sup>). The texture ranged from LS to SL. The temperature of TAP soils was similar ( $34 \pm 2.55$ – $34 \pm 2.66$  °C), but the moisture level was much higher ( $47 \pm 4.32$ – $48 \pm 4.14\%$ ). The BD stayed moderate ( $1.19 \pm 0.17$ – $1.35 \pm 0.09$  g/cm<sup>3</sup>), and the texture was always SL. The CVP soils had the highest temperature ( $35 \pm 2.89$ – $40 \pm 1.27$  °C), very stable moisture ( $49 \pm 1.00$ – $50 \pm 0.85\%$ ), and BD range from  $1.16 \pm 0.05$  to  $1.30 \pm 0.10$  g/cm<sup>3</sup>. The SL texture was

the same throughout the profile.



**Figure 3:** Soil Physical Properties (Mean with SD values)

In the midland zone, BAL soils had a temperature that dropped with depth ( $27 \pm 0.81$ – $26 \pm 0.67$  °C), low moisture ( $16 \pm 4.03$ – $24 \pm 3.42\%$ ), and low BD ( $1.00 \pm 0.15$ – $1.12 \pm 0.09$  g/cm<sup>3</sup>). The texture changed from SL to L. The temperature ( $26 \pm 0.45$ – $28 \pm 0.52$  °C), moisture ( $24 \pm 2.98$ – $30 \pm 1.18\%$ ), and BD values ( $1.10 \pm 0.06$ – $1.28 \pm 0.06$  g/cm<sup>3</sup>) of TAP soils were all moderately higher than those of other soils. The texture was always SL. CVP soils had a stable temperature ( $24 \pm 1.66$ – $28.03 \pm 0.21$  °C), a higher moisture level ( $31 \pm 0.86$ – $32 \pm 0.40\%$ ), and a BD that increased with depth ( $0.98 \pm 0.13$ – $1.25 \pm 0.08$  g/cm<sup>3</sup>). The texture changed from SL in the surface layers to L at deeper depths.

In the highland zone, BAL soils had a cooler temperature ( $24 \pm 1.91$ – $25 \pm 0.62$  °C), a sharp drop in moisture ( $15 \pm 5.98$ – $26 \pm 7.09\%$ ), and a stable BD ( $1.20 \pm 0.14$ – $1.24 \pm 0.11$  g/cm<sup>3</sup>). The texture was always SL. The temperature of TAP soils was similar ( $23 \pm 0.71$ – $24 \pm 0.66$  °C), but the moisture was higher ( $26 \pm 1.93$ – $30 \pm 1.53\%$ ), and the BD was between  $1.04 \pm 0.07$  and  $1.19 \pm 0.15$  g/cm<sup>3</sup>. The texture changed between L, CL, and L. The temperature of CVP soils was

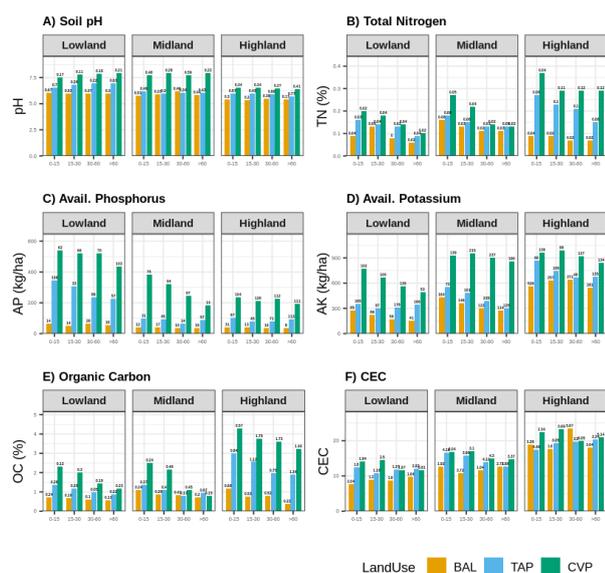
the lowest ( $22 \pm 0.70$ – $23 \pm 0.39$  °C), but the moisture content was relatively high ( $29 \pm 1.74$ – $31 \pm 0.68\%$ ). The BD increased with depth ( $0.88 \pm 0.04$ – $1.10 \pm 0.18$  g/cm<sup>3</sup>), and the texture changed from SL at the surface to L in deeper layers.

### Variation in Soil Chemical Properties by land use types

Soil chemical parameters exhibited significant variation within types of land use and depth of soil as shown in **Figure 4**. The BAL soils in the lowland were moderately acidic, with a pH of  $5.95 \pm 0.30$  to  $6.01 \pm 0.67$ . The TN was low ( $0.06 \pm 0.00\%$  to  $0.13 \pm 0.05\%$ ), the AP was moderate ( $49 \pm 14$  to  $64 \pm 28$  kg/ha), and the AK was decreasing with depth ( $151 \pm 41$  to  $273 \pm 86$  kg/ha). OC went down from  $0.73 \pm 0.24\%$  at the surface to  $0.58 \pm 0.13\%$  below 60 cm. CEC, on the other hand, ranged from  $7.77 \pm 1.20$  to  $9.77 \pm 2.04$  meq/100g. TAP soils in the same area were more fertile, with a pH that was close to neutral ( $6.54 \pm 0.22$  to  $6.96 \pm 0.70$ ), a higher TN ( $0.09 \pm 0.02\%$  to  $0.16 \pm 0.04\%$ ), and a lot more AP ( $226 \pm 33$  to  $347 \pm 106$  kg/ha) and AK ( $297 \pm 97$  to  $349 \pm 165$  kg/ha). The CVP soils had the most chemicals in them. They had an alkaline pH ( $7.54 \pm 0.11$  to  $7.95 \pm 0.21$ ), a high TN ( $0.10 \pm 0.02\%$  to  $0.20 \pm 0.04\%$ ), and an exceptionally high AP ( $434 \pm 62$  to  $539 \pm 103$  kg/ha) and AK ( $493 \pm 53$  to  $772 \pm 102$  kg/ha). They also had the highest OC ( $1.16 \pm 0.12\%$  to  $2.32 \pm 0.30\%$ ) and CEC ( $11.55 \pm 0.81$  to  $14.44 \pm 2.50$  meq/100g).

BAL soils in the midland were moderately acidic (pH  $5.74 \pm 0.31$  to  $6.21 \pm 0.51$ ), had low TN ( $0.11 \pm 0.02\%$  to  $0.16 \pm 0.08\%$ ), and high AP ( $38 \pm 10$  to  $40 \pm 19$  kg/ha). AK went down with depth ( $278 \pm 114$  to  $431 \pm 164$  kg/ha), OC went down slowly ( $0.73 \pm 0.20\%$  to  $1.09 \pm 0.41\%$ ), and CEC went up and down between  $10.87 \pm 1.04$  to  $12.65 \pm 3.72$  meq/100g. TAP soils had a little more fertility, with a pH range of  $6.00 \pm 0.30$  to  $6.20 \pm 0.49$ , a TN range of  $0.13 \pm 0.03\%$

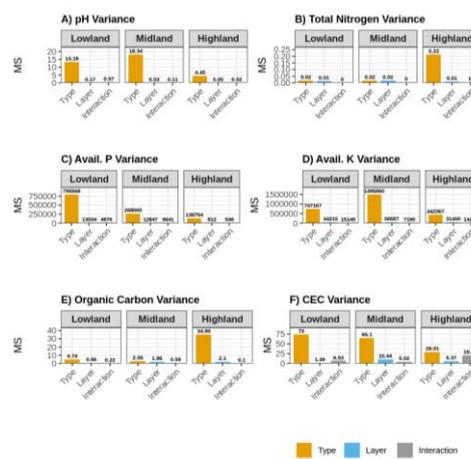
to  $0.18 \pm 0.08\%$ , and an AP range of  $62 \pm 14$  to  $98 \pm 57$  kg/ha. The CVP soils in midland had a lot more nutrients. They had an alkaline pH ( $7.75 \pm 0.22$  to  $7.95 \pm 0.59$ ), a high TN ( $0.13 \pm 0.02\%$  to  $0.27 \pm 0.05\%$ ), a very high AP ( $182 \pm 14$  to  $385 \pm 97$  kg/ha), and the highest AK across all zones ( $861 \pm 139$  to  $956 \pm 237$  kg/ha). OC was also high ( $0.80 \pm 0.15\%$  to  $2.52 \pm 0.46\%$ ), and CEC stayed high ( $14.72 \pm 2.04$  to  $16.98 \pm 3.37$  meq/100g).



**Figure 4:** Soil Chemical Properties (Mean with SD values)

In the highland, BAL soils stayed acidic ( $\text{pH } 5.36 \pm 0.17$  to  $5.49 \pm 0.38$ ), and they had low TN ( $0.07 \pm 0.02\%$  to  $0.09 \pm 0.04\%$ ) and AP ( $36 \pm 8$  to  $40 \pm 31$  kg/ha). AK was very different ( $547 \pm 257$  to  $641 \pm 526$  kg/ha), OC dropped off quickly with depth ( $0.36 \pm 0.22\%$  to  $1.16 \pm 0.69\%$ ), and CEC was very different ( $17.60 \pm 1.26$  to  $23.52 \pm 5.67$  meq/100g). TAP soils had higher nutrient levels, with TN levels ranging from  $0.15 \pm 0.06\%$  to  $0.27 \pm 1.12\%$  and AP levels ranging from  $77 \pm 45$  to  $102 \pm 113$  kg/ha. AK levels stayed high at  $667 \pm 48$  to  $864 \pm 166$  kg/ha. The CVP soils in the highland had the most fertile soil overall. They had a moderately acidic pH ( $6.37 \pm 0.34$  to  $6.50 \pm 0.41$ ), the most TN in the area ( $0.29 \pm 0.04\%$  to  $0.37 \pm 0.12\%$ ), and high AP ( $195 \pm 104$  to  $235 \pm 120$  kg/ha)

and AK ( $837 \pm 98$  to  $987 \pm 138$  kg/ha). OC was significantly higher ( $3.21 \pm 0.57\%$  to  $4.30 \pm 1.78\%$ ), and CEC was highest at  $22.42 \pm 0.69$  to  $23.24 \pm 2.34$  meq/100g.



**Figure 5:** Analysis of Variance (Mean Square Values)

Mean Square (MS) values indicated that land use types were the primary source of variability in soil chemical properties, as illustrated in **Figure 5**. In the lowland, soil pH, TN, AP, AK, OC, and CEC varied significantly across different land use types ( $p < 0.05$ ). The soil layer had a big effect on TN ( $p < 0.05$ ), but the type and layer interaction did not ( $p > 0.05$ ). In the midland, the type of land use had a big effect on pH, TN, AP, AK, and CEC ( $p < 0.05$ ). There were significant layer effects for TN and AK ( $p < 0.05$ ), and there was a significant interaction between land use type and layer for AP and OC ( $p < 0.05$ ). In the highland, land use type had a big effect on pH, TN, AP, AK, and OC ( $p < 0.05$ ). Layer significantly influenced OC ( $p < 0.05$ ), while interactions between type and layer were not significant ( $p > 0.05$ ).

### Correlation between Soil physicochemical parameter

Pearson's correlation analysis revealed significant relationships among soil properties that varied by land use types (**Figure 6**). Similar correlation patterns were found for the same types of land use in both highland and midland. Under BAL, AP and AK exhibited substantial positive correlations with soil pH ( $p < 0.01$ ).

There was also a strong positive link between TN and OC ( $p < 0.01$ ). Also, soil temperature had strong negative correlations with AP ( $p < 0.05$ ), AK ( $p < 0.05$ ), and OC ( $p < 0.05$ ). There was a positive correlation between Soil Moisture and TN ( $p < 0.05$ ) and OC ( $p < 0.05$ ).

For TAP in high and midlands, pH have a strong positive relationship with TN, AP, AK, and OC ( $p < 0.05$ ). There were also strong positive correlations between OC and TN ( $p < 0.01$ ), AP ( $p < 0.01$ ), and AK ( $p < 0.01$ ). On the other hand, Cation Exchange Capacity (CEC) had a strong negative relationship with pH ( $p < 0.05$ ), AP ( $p < 0.01$ ), AK ( $p < 0.01$ ), and OC ( $p < 0.05$ ).

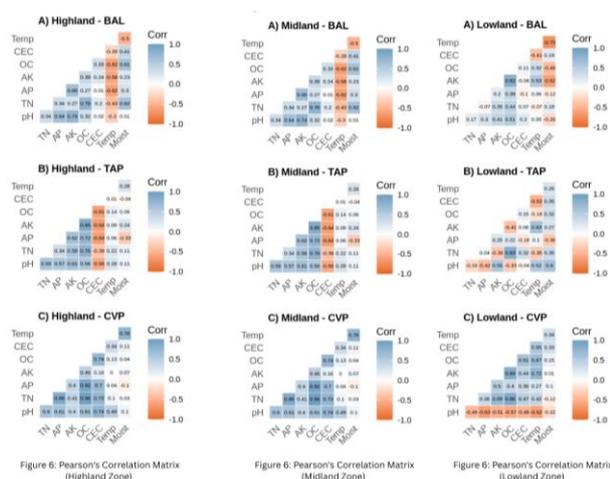
In CVP for high and midlands, pH had a strong relationship with TN ( $p < 0.05$ ), AP ( $p < 0.05$ ), OC ( $p < 0.05$ ), and CEC ( $p < 0.01$ ). There were very strong positive correlations between TN and OC ( $p < 0.01$ ) and between AP and OC ( $p < 0.01$ ). CEC was positively correlated with TN ( $p < 0.01$ ), AP ( $p < 0.01$ ), and OC ( $p < 0.01$ ).

and pH ( $p < 0.05$ ), OC and TN ( $p < 0.01$ ), and Temperature and pH ( $p < 0.05$ ) and AK ( $p < 0.01$ ). For CVP in the lowland, the most important correlations were negative. For example, pH was inversely related to AP ( $p < 0.01$ ), AK ( $p < 0.05$ ), and OC ( $p < 0.05$ ). There were strong positive correlations between TN and OC ( $p < 0.01$ ) and between AK and OC ( $p < 0.01$ ).

## Discussion

The study indicates that the soil physicochemical characteristics in the Doti region are indicative of order subject to type of land use and depth. This implies quite a common interaction between environmental gradients that mountainous regions usually have and management strategies applied by people.

Changes in the area have been consistent with reported literature existing on prevalent farming practices in the Himalayas. Climatic regimes, together with the features of land and human activity, distinctly influence the formation of the soil, movement of nutrients, and structural stability. Soil temperature, moisture, bulk density, and texture showed marked variability based on land use. Soil temperature mostly displayed highly varying values among land-use types, within each ecological zone, with CVP consistently recording higher temperatures. Very insignificant fluctuation levels below a threshold level were observed for BAL and TAP, while tuff plants with minimal disturbance degree already established can affect the soil microclimate. A similar trend of this pattern was observed across low, middle, and highland zones, thus indicating the significant impacts of land use intensities on soil temperature. The moisture status of the soil is another major factor that governed the land use system. CVP systems showed higher levels of moisture



**Figure 6:** Pearson's Correlation Matrix

The correlation structure was different in the lowland. Under BAL, the only important correlations were a positive one between OC and pH ( $p < 0.05$ ), a strong positive one between OC and AK ( $p < 0.01$ ), and a negative one between Moisture and AK ( $p < 0.05$ ). For TAP, significant correlations were found between AK

within the soil, which clearly shows better retention characteristics of this land-use type. BAL showed weak structure stability and less moisture content compared to all other land-use types. At higher elevations, the rate of decline of the moisture content was steep. Soils that had been degraded possess very poor moisture-retentive capacity and allow water to pass through with ease. This makes them more susceptible to drought stress [17].

Bulk density in CVP was found to be drastically lower compared to TAP and BAN, which can be attributed to the large masses of incorporated organic matter. Such amendments improve soil structure, aid in aggregation, and enhance other variables of porosity by reducing their density [3]. The highland CVP had the most significant effect. In addition, lower temperatures significantly interacted with organic amendments that could work better for maintaining material stability.

The chemical data made it clear that the most important factor that would determine soil fertility is the way the land has been used. In this respect, it showed that soils under Commercial Vegetable Cultivation (CVP) would have pre-eminent chemical properties compared to the other categories of land uses. This is based on the fact that the pH of these soils was mostly neutral to slightly alkaline against significantly high levels of TN, AP, AK, OC, and CEC. High AP and AK levels in CVP, along with increased levels of OC and CEC, probably suggested an essential role of organic matter in nutrient retention. Soils from the BAL land-use category were generally acidic, and most nutrients were found to be in deficient ranges. Inadequate organic inputs lead to loss of base cations; coupled with high risk of nutrient loss and erosion, it further reduces fertility [18].

Variations in the OC and CEC values

are expressed with the altitude factor. The best level for both OC and CEC values is in the highland zones. Colder weather brings low microbial activity, therefore, reducing the pace of decomposition and enhancing the accumulation of more stable organic matter more. Upon the pH of the soil of commercial farming being higher than that of traditional farming and barren land, this disaggregated evidence supports the fact that lime, chemical fertilizers, manure, and water for irrigation containing bicarbonates lead to soil acidification, the cause of increased base saturation, as proposed by Kharal & Khanal [19] Chauhan, Pande, & Thakur [20]. On the contrary, the traditional farmers use organic manuring accompanied by low external inputs. Consequently, in general, the soil is acid because of low cationic presence used for the neutralization of acid. The barren lands, poorest in supplement, experience the loss of nutrients by leaching and erosion, and their parent materials are acidic; many times, solutions to show the lowest pH values. Furthermore, commercial fields usually exhibit higher OC levels and total nitrogen than barren fields. This would most likely be the result of crop residues, manures, and added plants lying on the soil that assist in nutrient cycling. Consequently, intensity of land management practices is more likely to affect soil pH and nutrient availability based on land use than just the type of land use.

Very high significance was determined from the Mean Square-type analysis for the source of variation "Type" (land use) at least at a 0.05 level of probability in nearly all the cases of the chemical soil parameters. These differences in soil characteristics within the CVP, TAP, and BAL are attributed to the changing chemical nature. The TN and OC concentrations were unexpectedly high at

greater depths of the soil layer in CVP systems. This vertical transport of nutrients is presumably fueled by the intensive application and deep incorporation of large masses of organic matter, as well as the deep root systems of commercial vegetables and tillage practices that mix organic layers downward.

Correlation analysis of the Pearson link tends to reveal how different land uses impact the relationship of soils with particular properties. However, the high positive  $r$  values of pH with AP and AK in the BAL systems might be suggestive of a commonality—a relationship with the loss of base cations through leaching and erosion—at least in the sense of these systems having some management. A very strong positive trend between TOC and TN in unmanaged systems might, in fact, point to a very strong coherence of nitrogen to organic matter in the soil.

Positive relationships were found between TAN and pH, TN, AP, AK, and OC. These could possibly be indicating a tendency of increased nutrient management cohesion. The strong negative relationship of CEC with nutrients might indicate very different underlining mineralogy or the setting up of very stable organs with mineral complexes at the development state. Correlation structure of CVP suggests strong input into systems particularly energized by organic matter. Strong positive correlations of TN, AP, and OC largely infer that nutrient availability is mainly controlled by the organic matter cycle. Finally, it can be established from the correlation analysis of CEC, pH with TN, AP, and OC that in these managed systems, the CEC is predominantly regulated by the availability of organic carbon. While interpreting the Pearson correlation analysis, it is critical to acknowledge that environmental gradients inherent to mountainous regions act as

confounding factors. Variations in altitude and climatic regimes directly influence soil temperature and moisture, which dictate microbial decomposition rates. Therefore, the strong correlations observed between CEC, pH, and nutrient availability are simultaneously mediated by these altitudinal baselines.

## **Conclusions**

The study demonstrated significant variations in soil characteristics across various land use types in the Doti district. The way land is used and the way farming is done have a big effect on the physicochemical properties of soil. Farms, especially those that use a lot of commercial methods, usually have more moisture in the soil, lower bulk density, a higher CEC, and more nutrients. On the other hand, the quality of the soil on BAL usually gets worse. To counter these differences, zone-specific management practices need to be adopted. For BAL, which are prone to compaction, acidity, and base cation depletion, initial management practices should focus on erosion control and the addition of organic amendments to counteract base cation depletion and improve water holding capacity. For TAP, the addition of nitrogen-fixing legumes and enhanced organic manuring will raise fertility levels safely. For CVP, although nutrient and organic carbon status are optimal, management practices should concentrate on accurate monitoring to avoid nutrient leaching and maintain soil structure.

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## Author's contribution statement

**J.B. Shahi:** Conceptualization, Methodology, Formal analysis, Data curation. Writing-original draft, Writing-review & editing, **B. M. Dahal:** Conceptualization, Methodology, Software, Supervision, Writing- review & editing, **N. Raut:** Methodology, supervision, Writing-review & editing **D. Giri:** supervision, Writing-review & editing

**Dahal:** Conceptualization, Methodology, Software, Supervision, Writing- review & editing, **N. Raut:** Methodology, supervision, Writing-review & editing **D. Giri:** supervision, Writing-review & editing

## Conflict of interest

The authors do not have any conflict of interest pertinent to this work

## Data availability statement

The data that supports the findings of this study can be made available from the corresponding author, upon reasonable request.

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