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Status of soil organic carbon and bulk density variation along the altitudinal gradient in Ngoba community forest under Paro Dzongkhag

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Abstract *-Above-ground biomass, below-ground biomass, dead mass of litter, woody debris, and soil organic matter are the five carbon pools in the terrestrial ecosystem. Each carbon pool store a substantial quantity of carbon. The study was conducted in the Ngoba Phunseum community forest in Paro Dzongkhag to determine bulk density and soil organic carbon variation along the altitudinal gradient considering different forest types.Blue pine and mix conifer forest are two main forest types in the current study area. The quadrate method was used, 10 x 10 m sample plots were placed laid covering whole study area along the altitudinal gradient. Soil samples were obtained from this plot; a total of 456 soil samples were obtained from varied depths of 0-20, 20-40, and >40 cm, as well as 60 bulk density samples from the plot's center. In present study area, bulk density of the soil was higher in a disturbed forest site than in a moderately disturbed forest site and there was a significant difference in average bulk density between the disturbed and partially disturbed areas t(48)=2.8, p=.007). Whereas the minimum bulk density was recorded in mix conifer forest (3000m -3200m) and maximum was found in blue pine forest (2700m-2900m). However, there is no significant difference among Soil organic carbon in different altitude zone f(5,51)=.333.p>.05 but significant difference was observed for average bulk density in different altitudinal ranges F (2, 57) =13.27, p =.000. There was no significant difference between soil organic carbon density in blue pine forest and mix conifer forest in the current research site t(4)=-.582, p>.05.It was also observed that organic carbon decreases with increase in depth of soil.To conclude, the current study reported that mix conifer forests have more carbon storage capacity in both soil and tree biomass carbon pool along an altitudinal gradient. Bulk density values in present study area was found between 0.3 g cm^{-3} to 0.8 g cm^{-3} which does not restrict plant growth however, management measures that minimize the bulk density are encouraged. The study also revealed that anthropogenic activities has affected the soil carbon organic, it is recommended that villagers should be aware of the importance of forest resources or soil, as well as rules and regulations for sustainable management at grass root level. This research will provide baseline line information for students and decision makers conducting research related to carbon will benefit from the outcomes of this study.*

Index Terms- Altitude,bulk-density,carbon, non-distructive,soil,undisturbed

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1 INTRODUCTION

Forests and soil serve as important carbon sources and sinks, as well as being the world's greatest carbon storehouse. As a result, it has the potential to play a substantial role in minimizing global warming and coping with climate change [51]. The five carbon pools in a terrestrial ecosystem that make up carbon pool are above-ground biomass, below-ground biomass, dead leaf litter, wood debris, and soil organic compounds [40].

Nutrient cycling, hydrologic cycles, forest productivity, and the global carbon (C) budget all benefit from organic matter in forest soils. On a worldwide basis, soils store more carbon than any other terrestrial carbon reserve [50], [24].Altitudinal gradients are strong predictors of SOC stocks in mountainous areas, because C breakdown and storage are connected to soil stabilizing activities [32].

In Bhutan, only a few scholars have studied the distribution of carbon content in forest ecosystems over various altitudinal gradients. Understanding how SOC fractions respond to changes in altitudinal gradients is crucial for forest ecosystem carbon balance [65].Environmental variables such as land management, terrain, and climatic conditions all have a significant influence on SOC potential and distribution. The lowest SOC stock potential was discovered on agricultural land with increased tillage, whereas the highest was found on natural forest land [13].

The amount of organic carbon stored in the first layer of soil is estimated to be 1500 PgC worldwide, with a variable geographical and temporal distribution [14]. Coniferous forests in the Northwest Pacific region have the highest potential for carbon storage and flow below ground of any forest ecosystem type. Because of the dominant forest types, SOC density was determined to be greatest in China's north-central area [27].

Bhutan has 71 percent forest coverage, with seven different types of forest holding a significant diversity of tree species, which aids carbon sequestration and carbon stock management [45] ,[46] , [55]. The topmost horizon of Bhutan soil has around 0.9 [Gt C [13].Bhutan holds around 0.1 percent of the world's soil organic carbon stock, despite the fact that its entire land area is only 0.02 percent of the world's total land area [36]. Bhutan has almost five times the amount of soil organic carbon stock as its whole land area, indicating that Bhutan has nearly five times the amount of SOC stock as its whole land area [12]. Its enormous forest canopy and suitable environmental conditions are the key reasons for this. However, if Bhutan seeks to maintain its carbon-neutral status, boosting SOC stock through greater C sequestration and conserving the carbon resource (soil and forest) will be critical in the near future.

1.1 PROBLEM STATEMENT

Bhutan's environmental concerns include waste management, deforestation, and urbanization, but climate change is harming Bhutan's population through food security and drinking water problems [35].Bhutan's carbon emissions from industry and automobiles are also increasing at an unprecedented rate, owing to the country's rapidly growing population and economic growth [64]. Pollution, particularly carbon emissions, is particularly prevalent in Bhutan's more urbanized and industrialized areas, in addition to these issues. The most cost-effective method of carbon sequestration is through soil.

It's important to note that while the concept of biomass/carbon estimates has grown in popularity and publications in India and Nepal, it hasn't done so in Bhutan. The current study trend suggests that future carbon stock study in the eastern Himalayas should be emphasized. A full understanding of carbon dynamics is essential to promote carbon sequestration

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knowledge or awareness among the general public, which Bhutan presently lacks [39]. As a result, more study into the capability of soil-independent forest types to sequester carbon is required. Carbon is essential for climate change mitigation and adaptation, as well as promoting public awareness.

1.2 OBJECTIVE

To determine soil organic carbon and bulk density variation over an altitudinal gradient in two different forest types

2. MATETERIALS AND METHODS

2.1 STUDY AREA

The study took place in the Ngoba Community Forest in Paro Dzongkhag's Lamgong gewog. In the summer, typical temperatures in Paro Dzongkhag vary from 14 to 16 degrees Celsius, while temperatures in the winter vary from -5 to 14 degrees Celsius [46].Bhutan first introduced the concept of community forestry in year 1992 [49]. As of April 2017, Bhutan had 688 Community Forests (CFs) comprising 76,360 hectares of SRF (approximately, over 2% of the country's entire geographical area) [34].The climate of the Dzongkhag (District) is moderate, with hot and humid summers and dry, freezing winters. Every year, the village receives about 500 mm to 1500 mm of rainfall. In higher altitudes, the forest consists primarily of blue pine (*Pinus wallichiania*) and a variety of coniferous forest types [45].

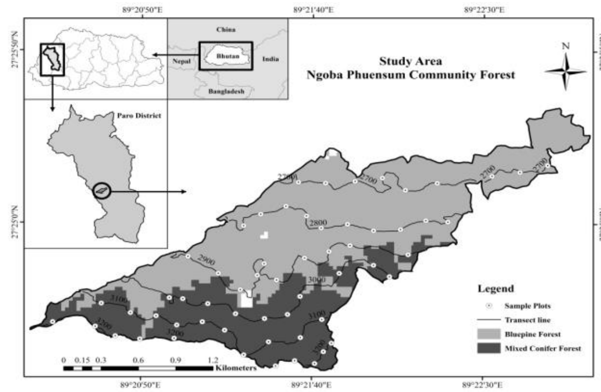

Figure 1.Study area

2.2 DATA COLLECTION

2.2.1 Sample design and sampling size

The study is based on ecological research methodologies, and the number of plots in the study region was determined at random using Arc GIS software. The research region has six altitudinal gradients ranging from 2700 to 3200 meters, and plots are assigned to each height (Fig.1). Each altitudinal gradient has 10 sample plots, for a total of 60 sample plots throughout the whole region. SW map was used to identify plots at the research location through (GIS and mobile mapping app).There are a total of 60 plots in the soil sample research region, however three of them are inaccessible owing to their location on a mountain, steep slope, and heavy forest.

For soil sampling, 10m × 10m sampling sites were set up. A standardized 300 cm^3 metal soil sampling corer was used to collect three samples of soil. In the plot, three samples were taken at 20 cm intervals (0–20 cm, 20-40 cm, and >40 cm).One composite soil sample of around 100 g was collected by blending the soils of three layers to assess the concentration of organic carbon content. The soil samples were collected and labeled before being sent to the lab to be examined for organic carbon content. Loss and ignition method was used to determine organic carbon in the soil.

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2.2.2 Soil organic carbon - Loss and ignition method

Calculation: SOC

$$SOM\% = ((Wcs - Wf)/(Wcs - Wc)) \times 100$$

$$SOC\% = 0.58 \times SOM\% \qquad (1)$$

$$Weight\ of\ empty\ (g)(Wc)$$

$$Wt\ of\ sample + crusible\ dried\ at\ 105°c\ (g)(Wcs)$$

$$Wt\ of\ sample\ + crusible\ dried\ at\ 500°C\ (g)(Wf)$$

2.2.3 Calculation of soil carbon density (tonnes per hectare) [43]

For example,

Depth = $0 - 10cm$ (2)

$\rho = 1.3\ g/cm3$ (3)

Soil organic carbon =1.5% (4)

10,000 m^2 in one hectare x 0.1m soil depth x1.3 g/cm3 bulk density x (1.5/100) (5)

= 19.5 tonnes carbon hectare

2.2.4 Calculation Bulk density of soil

$$\rho = Ms/Vt \qquad (6)$$

$$Weight\ of\ dry\ soil\ sample - Ms$$

$$Volume\ of soil\ (solid\ plus\ pore)$$

δ = soil bulk density [g cm^{-3}]

2.2.5 Data analysis

The data was appropriately coded and analyzed with the Statistical Packages for Social Science (SPSS) version 23 application. To assess bulk density in six distinct altitudinal ranges, a one-way ANOVA was used, followed by a post hoc analysis to find the significant pair. To assess the bulk density between the disturbed and somewhat disturbed areas, an independent t-test was used. To see if there was a significant variation in soil carbon densities along an altitudinal gradient; a one-way ANOVA was used (6 variables). Arc Gis was used to assign plots and examine maps, while Microsoft Excel 2007 was utilized to make graphs and standardize raw data

3. RESULTS AND DISCUSSION

3.1 Background information about study area

There are three types of disturbance zones, somewhat disturbed zones, and natural forest zones in the current research region (Table 1). The disturbance zones include human populations, agricultural regions with a few fallow areas, and road construction. Between towns, farm zones, and natural forest zones lies the semi-disturbed zone. The rural dwellings in the area benefit from the timber and other natural products provided by these woodlands.

Since the semi-disturbed and disturbed areas are adjacent to or within human settlements in the elevation range of 2700m to 2800m, these two areas are strongly influenced by anthropogenic management. As a result, there is a greater emphasis on appraising timber, firewood, non-timber forest products, and animal grazing. These two zones are also near a development site with a dense road network. The natural forest zone joins the semi-disturbed zone at elevations of 2800m and 2900m. In the natural forest zone, there are also minor anthropogenic disturbances such as tree harvesting for prayer flags, water channel construction, and restricted forest grazing.The natural forest zone, which is between 2900 and 3200 meters above sea level and is located further away from human populations, is difficult to access. In the top half of the natural forest zone, higher slopes with abundant undulating vegetation may be found.

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Table 1. Geographical condition of present study area

Area	Forest type	Status	Altitude	Major species
Site 1	Blue pine forest	Disturbed	2700	Pw
Site 2	Blue pine forest	Partially disturbed	2800	Pw ,QO,
Site 3	Blue pine forest	Undisturbed	2900	PW ,QO and LG
Site 4	Mix conifer forest	Undisturbed	3000	PS,QO ,RA
Site 5	Mix conifer forest	Undisturbed	3100	PS,RA
Site 6	Mix conifer forest	Undisturbed	3200	SP, AD,BU ,RA

PW- Pinus wallichiana, QO-Quercus oxyodon LG-Larix griffithii RA- Rhododendron arboreum PS- Picea spinulosa AD-Abies densa, BU-Betula utilis

3.2 Comparison of bulk density in blue pine and mix conifer forest

Bulk density decreases with altitude from 2700 to 3200 meters, with totals of 5.14 g cm^{-3}, 6.31 g cm^{-3}, 4.51 g cm^{-3}, 3.24 g cm^{-3}, 4.14 g cm^{-3}, and 3.96 g cm^{-3}, respectively (Fig 2). [8] ,[53] found an inverse relationship between elevation and soil bulk density in their studies. Lower bulk density is indicated by increased organic matter in the soil, as well as improved granulation, aeration, and infiltration [8]. Similar findings were obtained by [41],[48]revealing a negative relationship between bulk density and C density. At each site, the total bulk density is displayed, with blue pine woods having a greater bulk density than mixed conifer forests (Fig.2) More tree species have been discovered as key players in soil microbial communities, and litter combinations in mixed forests help soil microorganisms thrive and expedite litter breakdown [58],[6].

The diversity of species can influence how soil microbial communities are formed. Although the identity and variety of tree species, whether coniferous or deciduous, or mixed species forest, are yet unknown, all forest types have an effect on soil microbes and bulk density[62],[6].

It is further backed up by the presence of tree diversity in mixed coniferous forests, as well as a large amount of biomass covering the forest floor in the present research area.The total bulk density of (blue pine forest) was 6.31 g cm^{-3} in all places; whereas the minimum was 3.24 g cm^{-3} in (mix conifer forest) (Fig 2).This is corroborated by the findings of

[63], who discovered that bulk density was highest in the cold coniferous forest, owing to low decomposition rates of soil organic matter in the cold-temperate climate. Conifer forest can be found between 2700 and 2900 meters above sea level, where there is more settlement, logging, and soil compaction, whereas mix conifer forest can be found between 3000 and 3200 meters, which matches the current statistical results. Similar findings were reported by [32] who found that increased organic content causes lesser bulk space accessible within specific soil layers, which is inversely related to pore space.A research done in a Nepalese community forest found a similar finding, with bulk density being greater in forests dominated by pine species [25].

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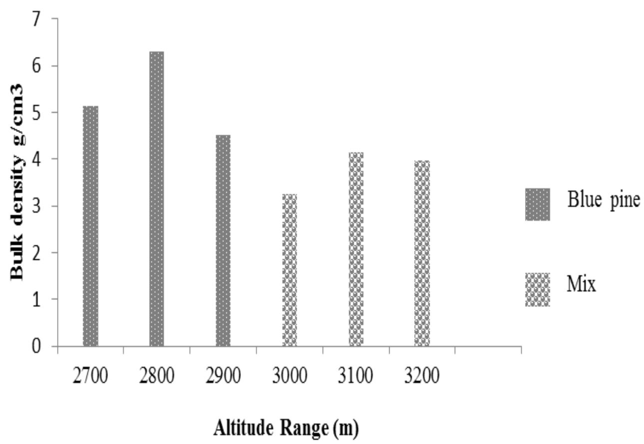

Figure 2. Bulk densities in different forest type along altitudinal gradient

3.3 Variation of bulk density along altitudinal gradient

Bulk density is influenced by soil texture and density. Furthermore, soil bulk density is affected by elevation. In the current investigation, significant variations in average bulk density were detected in different altitudinal ranges, F (2, 57) =13.27, p =.000. This suggests that bulk density varies greatly between altitudes. To establish the important pairings, the LSD post hoc test was used, and it revealed a significant difference in bulk density along the altitude. The bulk density contents of the following groups differed considerably, according to the LSD post hoc test (Table 2).

The light-colored, usually acidic soils of coniferous woodlands known as podzols are the types of soil found at the current research area, since bulk density varies substantially depending on soil type. The vegetation changes from dry conifer to mixed conifer forest as one rises higher in elevation, from 3000 to 3200 meters, with a larger diversity of species and more organic content in the soil. Higher organic carbon decomposition rates and rising temperatures [9] have resulted in an increase in bulk density, making soil more vulnerable to land management activities, climate change pressures, environmental variables, and high-intensity rainfall, all of which promote soil degradation in lower altitudes [4]. The current finding shows a considerable difference between higher and lower altitudes, implying that temperature has an impact on bulk density.

The wet mix conifer forest zone maintains more moisture soil, and the soil is black with a loose texture, as shown in this study. It was revealed that the two variables had a negative relationship, meaning that the soil bulk density decreases as elevation rises. Similar findings were reported by [54] who observed an inverse relationship between altitude and soil bulk density. This result backs up the current findings.[56] found that independent of forest type or height, the soil bulk density of the top soil horizon of the forest in the research region was 1.25 (ton m^{-1}). This might be due to a change in vegetation from dry to mixed conifer forest, which has more species variety and organic content in the soil. The wet mix conifer forest zone, on the whole, contains a lot of water, and the soil texture is black and loose.

Table 2. Comparison of bulk density along different altitudinal gradient (Post hoc test)

Altitude	N	Bulk density(g cm^3)
2700	10	$0.54±0.16^{a}$
2800	10	$0.63±0.11^{a}$
2900	10	$0.45±0.16^{a}$
3000	10	$0.32±0.11^{b}$
3100	10	$0.41±0.13^{b}$
3200	10	$0.40±0.13^{b}$

Bulk densities with different superscript are significantly different at p≤0.05

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3.4 Comparison of bulk density in disturbed and partially disturbed area

Bulk density was somewhat higher in a disturbed site and moderately disturbed forest site in the current research region ($\bar{X}$=0.58, SD=0.14) and ($\bar{X}$ =.39, SD=0.14), respectively; t (48) =2.8 p=.007 (Table 3). [31] Confirmed this result, indicating that anthropogenic activities had a substantial influence on soil compaction and composition. Soil compaction and bulk density have increased in the village area or along the road, according to the data.Bulk density was somewhat higher in a disturbed site and moderately disturbed forest site in the current research region ($\bar{X}$ =0.58, SD=0.14) and ($\bar{X}$ =.39, SD=0.14), respectively; t (48) =2.8 p=.007 (Table 3). [31] Confirmed these results, indicating that anthropogenic activities had a substantial influence on soil compaction and composition. Soil compaction and bulk density have increased in the village area or along the road, according to the data.

Plant covering, soil compaction, and leaf litter may have contributed to the increased organic matter in urban land uses, resulting in low bulk density values. In comparison to disturbed areas, partly disturbed areas in the buffer zone between forest and disturbed sites had a lower bulk density (0.39 ±0.14) g cm^{-3} (Table 3) than disturbed areas because disturbed area falls in the lowest altitude range of 2700 m, which is located in village, and some plots were located in fallow land, road construction site, which has higher bulk density in present result.

Fallow land has a higher bulk density than wooded land, according to [1]. Furthermore, by lowering natural soil erosion rates, plant development in wooded regions has decreased the rate of mineral surface soil loss. As a result, soils in woody regions contain more organic matter and have lower bulk densities. The findings are similar to those of [37] who discovered that well-protected forest without fragmentation stores the most carbon stock but has the lowest bulk density, and the current study was conducted in one of the well-protected community forests where the mixed conifer forest zone falls entirely within the protected area.

[1], In general, soils that are loose, porous, and rich in organic matter have a lower bulk density. Bulk density was measured to be between 1.2 g cm^{-3} and 0.5 g cm^{-3} in this investigation. The bulk densities of the research sites (both partially disturbed and undisturbed regions) were, on the other hand, lower below the essential root limiting range (1.75 – 1.85 g cm^{-3}) measured by soil survey personnel in 1996.However, in order to retain the land's productivity, management techniques are recommended to reduce the bulk density of the sites (partially disturbed area) and keep it from reaching critical root limitation levels.

Table 3. Bulk density in disturbed and undisturbed site (Independent t test)

	Bulk density (g cm^{-3})	***t* value**	***P***
Disturbed	0.58 ± 0.14	2.8	.007
Partially disturbed	0.39 ± 0.14		

3.5 Soil organic carbon density content along the altitudinal gradient

Rather than being a variable that directly influences the ecosystem, altitude is an index for a variety of climatic functions that affect the character of plants and the process of soil formation [21],[5]. Because the plant species are the same over the altitudinal gradient, the rise in SOC content with altitude was mostly due to a shift in flora and increased soil microbial activity.The highest and lowest SOC stock values were found at 3200 m and 3100 m, respectively, with ($\bar{X}$=11.19,

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SEM=2.59) and ($\bar{X}$=10.96, SEM=2.55), whereas the lowest SOC stock was found at 2800 m with ($\bar{X}$=7.62, SEM=1.63); f (5, 51) =.333 p>0.05 (Table 4). SOC does not differ much between altitude zones (Table 4.) When comparing the soil organic carbon stock values of different sites in both forests, the carbon stock content rises with altitude ($\bar{X}$=28.02, SEM=7.26) at three lower altitude sites, but carbon density rose with altitude ($\bar{X}$=30.31, SEM=8.17) at higher sites in the research region (Table 4).A soil carbon study in Nepal's Kathmandu valley in a Pinus roxburghii forest spanning an altitudinal gradient at elevations ranging from 1,200 to 2000m found that the higher altitude soil had considerably less carbon than the lower altitude soil [47].However, because of the lower population density at higher altitudes, human disruption would be negligible [29],[55].The current result is identical to that of the previous one. The current study region, the elevation range of 3000–3200 m has a greater carbon density level in all land use patterns. As a result, this height range necessitates extra caution from an environmental aspect. Less human activity, leaf litter, and root death are major mechanisms that contribute to soil carbon content input ascribed to increased carbon accumulation at higher altitude ranges, which might explain the increasing trend of SOC with altitude.According to [2] agroforestry's carbon sequestration potential ranged from 12 to 228 tons of carbon per hectare, with a typical value of 95 tons of carbon per hectare. This entire study backed up the current findings (Table 4), which may be attributed to higher carbon stock in leaf biomass and a slower decomposition rate at higher altitudes than at lower altitude zone (Table 4)

Table 4. Soil organic carbon density content along altitudinal-gradient (Mean ± SD)

Altitude	N	SOC (t ha^{-1})	*P*
2700	9	9.88 ± 2.54	
2800	10	7.62 ± 1.63	
2900	10	10.52 ± 3.09	>0.05
3000	9	8.16 ± 3.03	
3100	9	10.96 ± 2.55	
3200	10	11.19 ± 2.59	

3.6 Average Organic carbon (%) in vertical distribution of soil horizon

Forest types, climate, precipitation, temperature, soil organic matter, and soil types all impact the amount of soil organic carbon in the soil. Organic carbon concentration is highest in the top layer (0-20 cm) of the soil and gradually decreases to 3.19 percent at depths greater than 40 cm. The top layers of the soil had a higher organic carbon content, which gradually decreased as the depth of the soil decreased. Increased leaf litter Integration on the surface leads to a larger deposit of soil organic carbon. The findings of [47], [42] for the Himalayan area back up the conclusions.

Other research [20],[30], [3] indicates that soil organic matter is concentrated in the top 25 cm and progressively reduces with increasing soil depth, and the current findings demonstrates a similar pattern of decreasing carbon content with depth. [26] Discovered a decrease in soil organic carbon as depth increased. In addition, [16] identified depth-dependent decomposition rates as a viable mechanism for deciphering vertical patterns of soil organic carbon. Because SOC content is predominantly influenced by root system dispersion in deep soil, this variation occurred at depths less than 40 cm [24],[62].SOC decomposition rates decrease with depth in soils

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from the Great Plains of North America [38] and boreal, temperate, and tropical forests [59],[57].

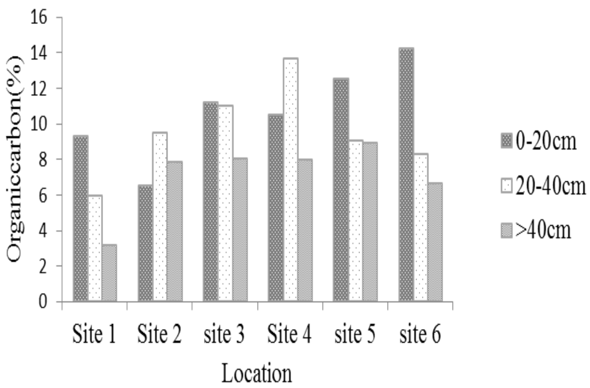

Figure 3. Organic carbon concentration in different depth

Nonetheless, in the present research; decrease in organic concentration is lesser humus and mineralization taking place in sub horizon. As a result of leaching, organic carbon flows through the soil, and soil organisms may mix huge volumes of dirt [11]. C enrichment below the surface and C dilution in shallow strata are the results of both processes. Leaching and mixing tend to increase with precipitation along climate gradients [22]. More comprehensive descriptions of soil carbon pools and the environmental variables that influence them at depth may benefit models that include several soil layers and examine carbon dynamics below the top 30 cm of soil [28] whereas Changes in forest type may also have a significant impact. Incorporating relatively deeply rooted plant into shallow-rooted systems can store carbon deep in the soil, perhaps functioning as a long-term carbon sink. Shrub encroachment on grasslands or afforestation of areas allocated to annual crops or grazing are two possible instances which has altered the present findings.

3.7 Comparison of carbon stock in blue pine forest and mix conifer forest

Changes in forest types, species richness, and landscape affect soil carbon. In mixed conifer forests, soil organic carbon concentrations are higher than in conifer forests. There is no significant difference between carbon stock in blue pine forest and mix conifer forest in the current research site ($\bar{X}$=9.34, SD=1.52) and ($\bar{X}$=10.1, SD=0.97); t(4)=-.582, p>.05. (Table 5.). The carbon density of a mixed conifer and blue pine forest is nearly same. The dryness, lack of species diversity, and lower altitude of the blue pine forest all contribute to inadequate carbon storage.

[15] Discovered an average total carbon stock density of 18.1 t C ha^{-1} in a Pinus roxburghii forest in Nepal's Makawanpur forest. These findings are comparable to the current market price. Cool and damp biomes have the highest soil carbon reserves, whereas hot and dry biomes have the lowest [10]. The majority of organic input into the soil happens on the surface horizon, and it declines substantially as you go deeper [10]. The results of this study (Table 5) are similar to those of [7],[17] ,[18] in a temperate forest study in India.

The current results are lower than those obtained by [17] in coniferous forests of the Garhwal Himalaya, India; this discrepancy might be due to the larger number of plots and other environmental variables that impact carbon content [68] has an impact on the carbon content and [65] found minimal variation in values (Table 5) from the current finding of SOC density in temperate forests on Mt. Changbai, China, which might be due to a smaller altitudinal range taken than the current research. [61] On the other hand, revealed comparable results or value ranges to the current report.

Table 5. Comparison of carbon stock in blue pine forest and mix conifer forest

	Blue pine		Mix conifer			
	Mean	**SD**	**Mean**	**SD**	***t* value**	***P***
Carbon stock	9.34	1.52	10.1	0.97	-0.582	>0.05

4.1 Conclusions

Forest soil carbon stock is impacted by environmental variables such as altitude, forest type, and bulk density, anthropogenic activities, according to this study. Along this environmental gradient, each carbon pool displays variance.The current study additionally examines the associations between soil organic carbons (SOC), elevation, and bulk density (BD). The findings suggest that blue pine forests have higher bulk densities, implying that anthropogenic activities, soil compaction, and fewer plants are present. Bulk density was slightly higher in a disturbed and less in partially disturbed forest site in present study area and it was mainly due to anthropogenic activities largely influenced the soil compaction and the composition of soil. In addition, there is significant difference in bulk density among altitudinal ranges, where bulk density was lower in higher altitude (3000 to 3200 m) which indicates that lower altitude ranges are prone to soil erosion and has lesser organic compound. Soil organic carbon has an inverse relationship with soil depth, with SOC decreasing as depth increases, implying that deeper soils contain more minerals and less organic matter. Organic content decreases with depth, according to the current study. However, statistically, there were no significant differences in carbon stocks between blue pine forest and mix conifer, although there was minimal variance in carbon density between mix conifer and blue pine forest when comparing means (Mean of carbon density). Along the altitudinal gradient, soil carbon density was found to be greater in the mixed conifer forest and lower in the blue pine forest.

4.2 Recommendation

Meteorological data should be considered in future research on terrestrial carbon stocks, and soil texture determinations are also encouraged. This will make research out come more comprehensive and informative on understanding basic of terrestrial carbon stock potential. However, the goal of this study was to establish a baseline for terrestrial carbon stock throughout the altitudinal gradient in various forest types.

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