https://doi.org/10.3126/banko.v34i1.62716 Banko Janakari, Vol 34 No. 1, 2024 Pp 15–29

Pattern of plant biomass and carbon stock along different elevational forests in eastern Nepal

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Received: 17, March 2024 Revised: 9, May 2024 Accepted: 24, May 2024 Published: 31, May 2024

The primary aim of this investigation was to determine the biomass and carbon stock distribution pattern among different forest stands of diverse elevations in the Morang district of East Nepal. It is noteworthy to estimate carbon stock and biomass of relatively least underexplored forests in east Nepal. The data for estimating the biomass and carbon stocks of the five different forest sites, viz. Bhaunne, Raja-Rani, Murchungi, Adheri, and Sagma located between 100–1300m above the mean sea level, were acquired through the measurement of inventory plots selected randomly. Altogether, 50 sample plots were established within five forest stands located on different elevational zone; within each forest site, 10 sample plots of 20m × 20m size, were laid out for the measurement of trees. In the case of shrubs and herbs, nested plots of 5m × 5m and 1m ×1m, respectively were established. Calculation of the biomass of trees and shrubs was facilitated through the application of an allometric equation, while the biomass of herbs was determined by the harvest method. The carbon concentration in the plant materials was estimated using ash content method. The comprehensive analysis of the stand biomass in the Bhaunne, Raja-Rani, Murchungi, Adheri, and Sagma forest sites were: 815.86 Mg ha^{-1}, 414.19 Mg ha^{-1}, 606.81 Mg ha^{-1}, 519.20 Mg ha^{-1}, and 299.96 Mg ha^{-1}, respectively, with minimum at the Sagma site (high-altitude forest) and maximum at the Bhaunne site (low-altitude forest). As per the variation in stand biomass, the carbon stocks in the forest sites also showed the same trend, but the values ranged from 140.19 Mg C ha^{-1} to 333.63 Mg C ha^{-1}, with the minimum in the Sagma site and the maximum in the Bhaunne site. The application of the Friedman Test revealed statistically significant variation in the tree biomass between the Murchungi and Sagma sites and also in the shrub biomass between the Adheri and Sagma sites. Similarly, noteworthy variations were observed in the herb biomass of the Bhaunne, Raja-Rani, Murchungi, and Adheri sites as compared to that of the Sagma site. The present study contributes to the understanding of forest ecosystems in context to carbon management.

Key words: Biomass, Carbon Stocks, Morang district, Tropical forest.

Forests play a significant role in supporting human livelihoods, ensuring the provision of clean air and water, safeguarding biodiversity and mitigating the adverse effects of climate change (Aerts & Honnay, 2011). The impact of forests on the global carbon cycle is now well acknowledged since forests and their soils are significant atmospheric carbon sinks (Basu, 2009). Further, forests, as pivotal components of the global carbon cycle, play a multifaceted

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role in sequestering atmospheric carbon through accumulation of biomass and soil organic carbon. The concept of biomass in the context of forests encompasses the captured or stored carbon within trees, consisting a vital component of the terrestrial ecosystem's carbon pools. These pools comprise aboveground biomass, belowground biomass, litter, woody debris, and soil organic matter, as they are also identified by the Intergovernmental Panel on Climate Change (IPCC) as the main carbon pool (Vashum & Jayakumar, 2012; IPCC, 2013; IPCC, 2023). Forests contribute to 34% of the terrestrial gross primary production and serve as reservoir of approximately 55% of the world's forest carbon (Beer *et al.*, 2010; Pan *et al*., 2011; Hassan *et al*., 2020).

Forests located along elevational gradients exhibit variation in plant species composition, density, biomass and carbon stock which garner a significant attention in the realm of environmental research. Carbon stock in a forest is a complex process, intricately linked to various factors such as seasons, vegetation types, climate, soil structure, and nutrient availability (Chave *et al*., 2005). This complex phenomenon underscores the need for a comprehensive understanding of the dynamics of carbon sequestration in forest ecosystems, particularly in the context of elevation gradients.

Despite the importance of forests in biomass production and carbon sequestration, the works in this regard is limited, especially in the tropical forests of Nepal (Mandal, 1999; Baral *et al*., 2009). Thus, there exists a compelling need to deepen our understanding of forest composition and function, particularly in the context of elevation gradients. Hence, the present study is designed to achieve the objective of assessing the plant biomass and carbon stocks of different forests at varying elevations in east Nepal.

Materials and methods

Study area

The study was conducted across five different forest sites, viz. Bhaunne (within Belbari-Chisang Cooperative Forest, Raja-Rani (within Raja-Rani Community Forest (CF), Murchungi (within Akashe CF), Adheri (within Shat-Kanya CF), and Sagma (within Kuwapani CF) in Morang district, east Nepal (Figure 1). The sites were located between 26°39'45.69''–26°48'28.68''N latitudes and between 87°28'2.08''–87°28'45.06''E longitudes, with the terrain ranging from 100 m to 1300 m above the mean sea level (msl).

Geology and soil

The study area lies in the Churia hills composed of mostly soft limestone and the Mahabharat range made of Phyllite, Schist, Quartzite, limestone, etc. The soils of all the study sites except the Sagma site are, moreover, loamy sand; the soils of the Sagma site being sandy loam.

Climate

The district experiences a diverse types of climate, ranging from tropical to temperate. The southern part of the district exhibits tropical and subtropical types of climate while there is temperate type of climate in the northern part. There is a tropical monsoon climate with dry and warm summer, wet and warm rainy season, and dry and cool winter in areas up to 1000 m above sea level. The mean annual minimum temperature ranges from 11°C to 25°C. while mean annual maximum temperature ranges from 21°C to 35°C (DHM, 2022). Comparatively, the Bhaunne to Murchungi forest area experiences its greatest annual rainfall, which ranges from 64.4 mm to 10630.12 mm (Figure 2a). In Adheri and Sagma sites, the cold season generally begins from the beginning of December and lasts till the end of February, with temperatures dropping to around 7°C. The annual rainfall ranges from 27.9 mm to 4908.6 mm, peaking in July and reaching a minimum in November (DHM, 2022). The annual minimum temperature ranges from 7°C to 21°C while the annual maximum temperature ranges from 20°C to 30°C (Figure 2b).

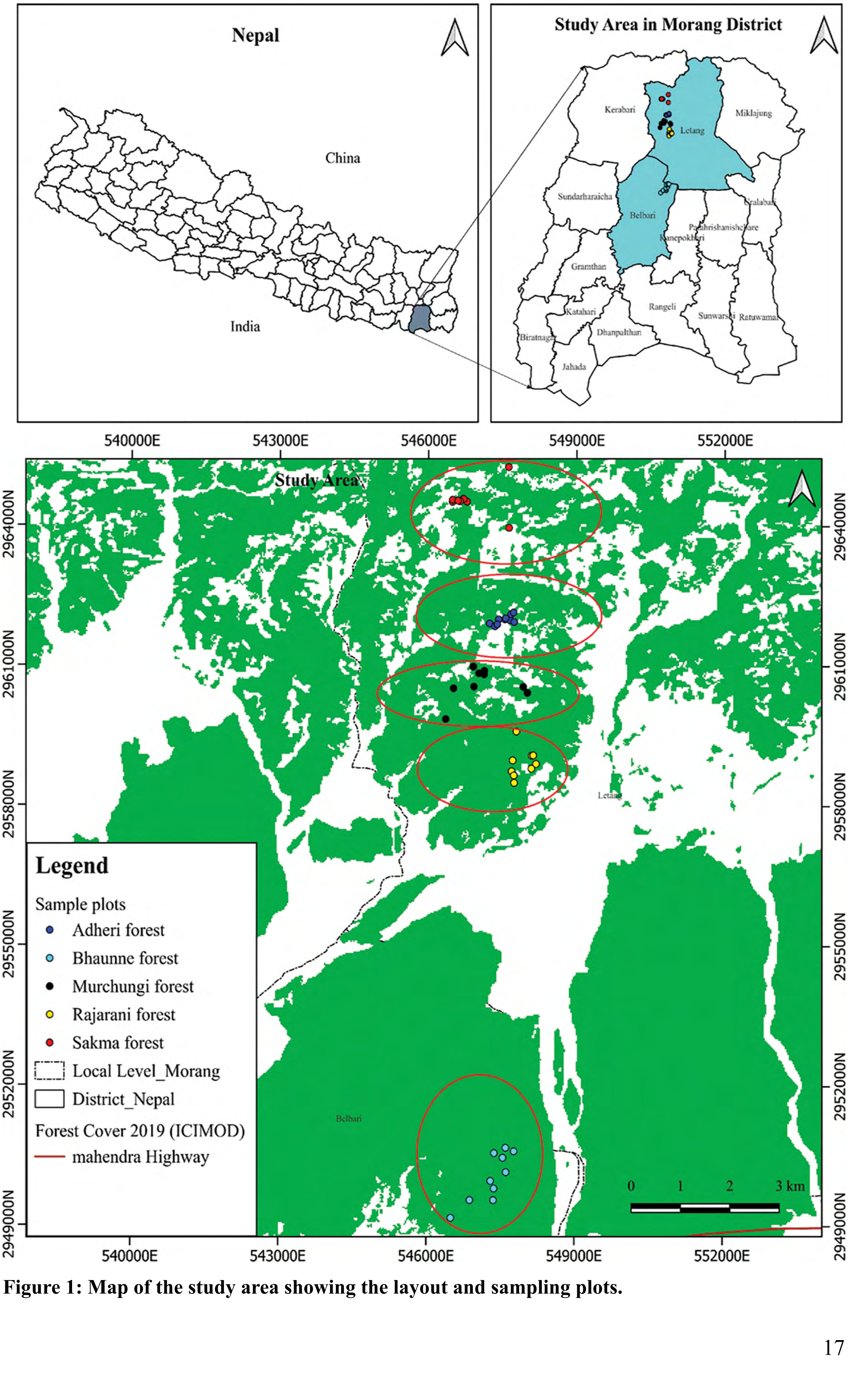

Figure 1: Map of the study area showing the layout and sampling plots.

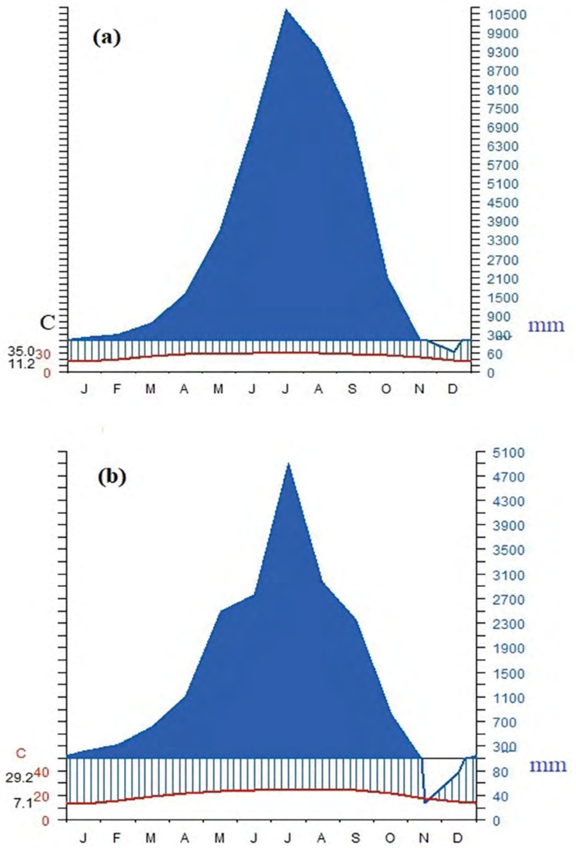

Fig. 2 (a, b): Ombrothermic representation of the climate in the study area; data belonging to the period 2000–2020 *(Source: DHM, 2022).*

Plant biomass estimation

The estimation of plant biomass involved various steps across the five forest stands. For the estimation of tree biomass, a total of 50 permanent sample plots (20m × 20m), with 10 in each stand, were established randomly. Similarly, for the estimation of shrub biomass, 5m × 5m sized nested quadrats were laid out, and for the estimation of herb biomass, 1m × 1m sized nested quadrats were established in each permanent tree plot. The girth of all standing trees with girths more than 10 cm GBH i.e. girth at breast height (1.37 m) were measured. Similarly, girth of shrubs inside the plots were measured at 10 cm above the ground. Utilizing the girth: biomass allometric equation developed by Singh & Singh (1992) for the Sal (*Shorea robusta*) forest of the Siwalik region, the biomass (aboveground biomass) of the trees with girths greater than 30 cm was determined for each plot. In this case, the major root-biomass was estimated by using the root to shoot ratio developed by Singh (1974) for Sal forest. In the case of the estimation of the aboveground and belowground biomass of Sal trees having 10–30 cm girth and also for shrubs, another set of girth: biomass regression equations developed by Mandal (1999) for the forest of eastern Siwaliks of Nepal were used. The aboveground biomass of herbs within the sampling plots was estimated using destructive sampling, i.e. by cutting and weighing all the herbs within the nested plots set aside for the measurement of herbs.

The fine-roots (<5 mm diameter, may be of herbs, shrubs and trees) in soil monoliths (10cm × 10cm × 30cm) were collected from 50 sample plots, with 10 sample plots within each site. The fine-root biomass (FRB) was estimated by washing the soil monolith with fine jet of waters. Within each sample plot, the depth ranges were separated into upper (0–15 cm) and lower (15–30 cm).

Estimation of carbon in vegetation

The samples of trees, shrubs and herbs (aboveground) components were collected within each sampling plot for carbon estimation. Additionally, fine-root samples (<2mm and 2–5mm diameter) were collected and weighed. Composite samples of all components were subjected to oven drying at 80 °C until a constant weight was achieved, followed by powdering of each component for carbon (C) analyses. The ash-free weight method was used to estimate the carbon concentration (McBrayer & Cromack, 1980).

With this technique, each oven-dried plant part (stem, branch, twig, root, and leaf) was burned separately at 400 °C in an electric furnace. After burning, resulting ash content; the inorganic elements in the form of oxides, was weighed. The carbon concentration was then calculated using the following equation:

Carbon % = (Initial weight – Ash weight) × 100/2

Carbon stock in vegetation was calculated by multiplying the dry weight biomass by the C-concentration.

Statistical analysis

Initially, the observed data underwent testing for normality distribution. The carbon stock and biomass data were identified as quantitative variables while forest types were used as categorical variables. An equal number of samples were collected from each forest. However, the data exhibited unequal variance and non-normal distribution. Consequently, a non-parametric alternative to one-way analysis of variance (ANOVA), specifically the Friedman Test was used to assess the distribution of medians among the forest stands. After statistically significant results obtained by using the Dunn Test (Dunn, 1964), multiple pairwise comparisons were conducted through the Friedman Test; it was also referred to as the 'Sign Test' when p-adjustments were made through the Bonferroni test. In this test, fixed errors caused by sampling biases among the sample plots were corrected after partialling out from random errors caused by forests.

The Friedman Test was used by using the formula:
friedman_test(data, a ~ b|c)

In this formula, 'data' refers to data.frame containing variables such as 'fine.root.biomass', as well as 'Forests', 'Plots' etc. The variable 'a' represents the response variable, for instance, 'fine.root.biomass'. 'b' denotes the predictor variable, which is 'Forest' in this context. 'c' stands for the fixed variable, represented here by 'Plots'.

All the analyses were conducted using the R Software (R Core Team, 2023).

Results

Plant biomass and carbon stock

The total biomass estimation revealed that the Bhaunne forest possessed the highest stock of biomass (815.86 Mg·ha^{-1}) and carbon (333.63 Mg C·ha^{-1}) while the Sagma forest had the lowest biomass stock of 299.96 Mg·ha^{-1} and carbon stock of 140.19 Mg C·ha^{-1} (Table 1). The total biomass and carbon stocks of tree layer were found to be the highest in the Bhaunne forest, with 796.46 Mg·ha^{-1} and 326.91 Mg C·ha^{-1}, respectively while the lowest was in the Sagma forest, with 265.23 Mg·ha^{-1} and 124.88 Mg C·ha^{-1}, respectively (Table 2 and Annex-I).

Across all the forest stands, it was observed that 79% of the total tree biomass belonged to aboveground while the remaining 21% being belowground (excluding fine-roots). The boles (main trunks) of the trees contributed the highest proportion to the total stand biomass in in all the study sites; however, the proportions of their contribution decreased with the increase in elevation, with the maximum (514.29 Mg·ha^{-1}) at Bhaunne site and the minimum (154.33 Mg C·ha^{-1}) at Sagma site. Additionally, the Sagma site possessed the highest shrub biomass of 16.38 Mg·ha^{-1} which decreased with the increase in elevation. Likewise, the aboveground herb biomass was maximum (8.65 Mg·ha^{-1}) in the Sagma site. The aboveground biomass and carbon stock showed almost decreasing pattern with the increase in elevation (Figure 3).

Table 1: Oven dry stand biomass (Mg ha^{-1} ± SE) of forests located at different elevation in Morang district

Forest stands / Components		**Bhaunne**	**Raja-Rani**	**Murchungi**	**Adheri**	**Sagma**
Tree	Bole	514.29 ± 167.50	230.02 ± 38.15	336.93 ± 44.27	286.04 ± 36.69	154.33 ± 42.15
	Branch	70.16 ± 7.35	46.69 ± 7.01	73.44 ± 7.51	66.10 ± 6.60	38.37 ± 8.14
	Twig	30.67 ± 6.30	17.89 ± 2.78	28.06 ± 3.16	26.27 ± 2.71	10.51 ± 1.57
	Leaf	16.99 ± 1.74	11.41 ± 1.59	17.37 ± 1.86	17.92 ± 1.47	7.29 ± 1.16
	Course root	164.35 ± 45.13	79.56 ± 12.84	118.51 ± 14.7	103.05 ± 12.31	54.73 ± 13.35
	Total	**796.46 ± 218.72**	**385.57 ± 62.23**	**574.31 ± 71.23**	**499.38 ± 59.64**	**265.23 ± 64.72**
Shrub	Stem	3.79 ± 0.60	7.17 ± 1.05	7.29 ± 1.90	4.15 ± 0.70	8.58 ± 1.10
	Leaf	1.50 ± 0.18	2.07 ± 0.25	2.01 ± 0.30	1.70 ± 0.18	3.01 ± 0.18
	Root	3.24 ± 0.6	4.61 ± 0.50	5.11 ± 1.33	2.63 ± 0.33	4.79 ± 0.55
	Total	**8.53 ± 1.21**	**13.85 ± 1.79**	**14.41 ± 3.5**	**8.48 ± 1.14**	**16.38 ± 1.76**
Herbs*		3.73±3.35	2.04±1.85	2.09 ±1.89	1.80 ± 1.52	8.65 ±7.73
Fine-root		7.14± 0.84	12.73 ± 1.43	16.00 ± 2.69	9.54 ± 0.83	9.70 ± 1.42
Total stand vegetation		**815.86**	**414.19**	**606.81**	**519.20**	**299.96**

*Aboveground part

Table 2: Component wise Carbon stock (Mg C·ha^{-1}) estimates in different growth forms in different forests of Morang district

GROWTH - FORM	COMPONENT	FOREST STANDS				
		BHAUNNE	RAJA-RANI	MURCHUNGI	ADHERI	SAGMA
TREE	BOLE	207.39	103.89	157.80	82.00	72.54
	BRANCH	30.63	22.72	34.15	26.55	18.35
	TWIG	14.77	7.93	13.28	11.04	5.06
	LEAF	6.66	5.27	8.08	7.53	3.16
	COURSE ROOT	67.46	36.35	55.46	33.05	25.77
	TOTAL	**326.91**	**176.16**	**268.77**	**160.17**	**124.88**
SHRUB	STEM	1.74	3.31	3.50	1.73	4.08
	LEAF	0.66	0.96	0.95	0.76	1.40
	ROOT	0.24	1.36	2.33	1.03	2.23
	TOTAL	**2.64**	**5.63**	**6.78**	**3.52**	**7.71**
HERB		1.18	0.60	0.57	0.77	3.70
FINE-ROOT		2.90	4.10	7.00	4.20	3.90
TOTAL		**333.63**	**186.49**	**283.12**	**168.66**	**140.19**

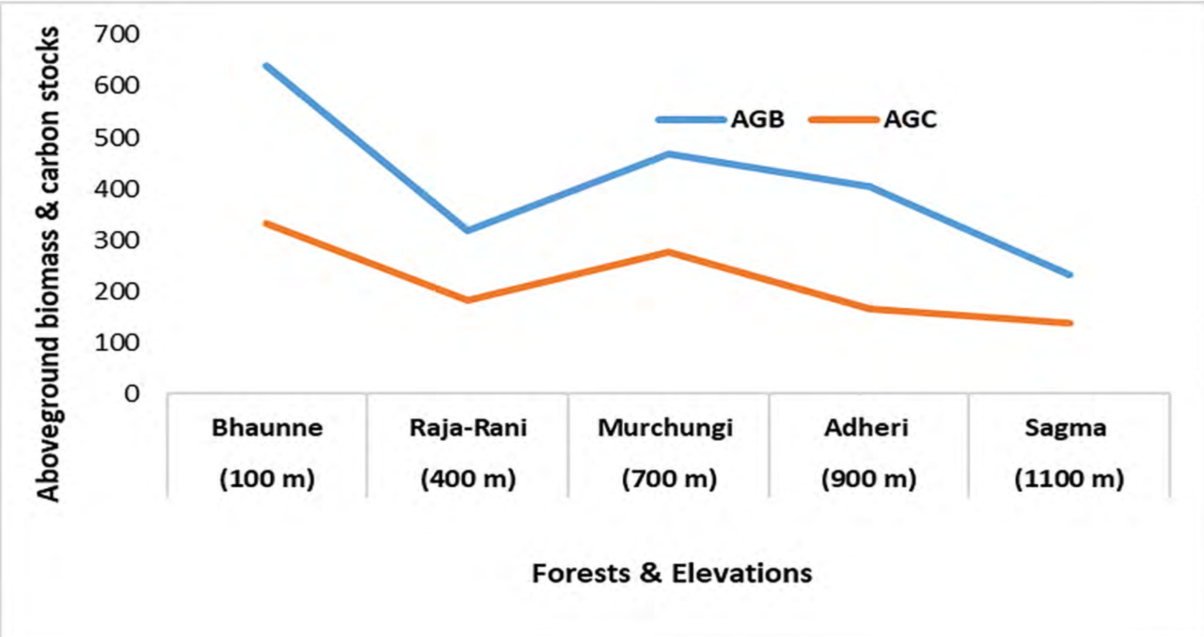

Fig. 3: Trend of aboveground biomass (Mg ha^{-1}) and carbon stock (MgCha^{-1}) in the forests located at different elevations of Morang district.

Fine-root biomass and carbon stock

The total fine-root biomass and carbon stock exhibited the maximum values of 16 Mg ha^{-1} and 7 Mg C ha^{-1}, respectively in the Murchungi site located in the mid-mountain region and the minimum values of 7.14 Mg ha^{-1} and 2.90 Mg C ha^{-1}, respectively in the Bhaunne site (low-elevation site, Figure 4).

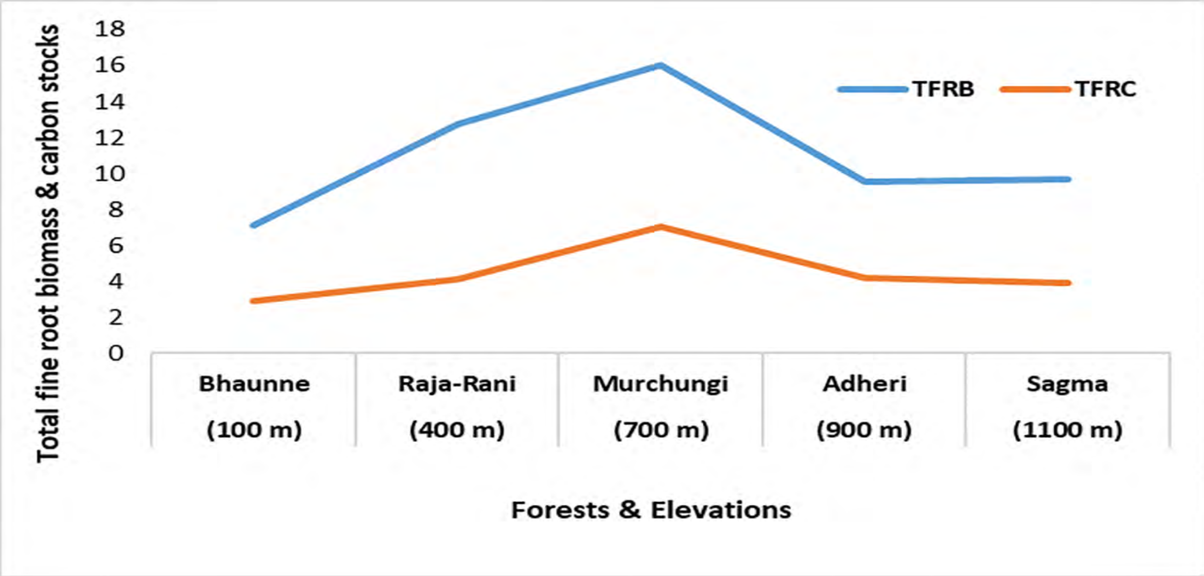

Figure 4: Trend of total fine-root biomass (Mgha^{-1}) in the forests located at different elevations of Morang district.

The maximum fine-root biomass value was recorded in the Murchungi site in terms of both soil depths and fine-root size classes (<2mm and 2–5mm), where the total maximum fine-root biomass was 9.63 Mg ha^{-1} within the 0–15cm soil depth and reaching up to 6.37 Mg ha^{-1} within the 15–30cm soil depth (Figure 5).

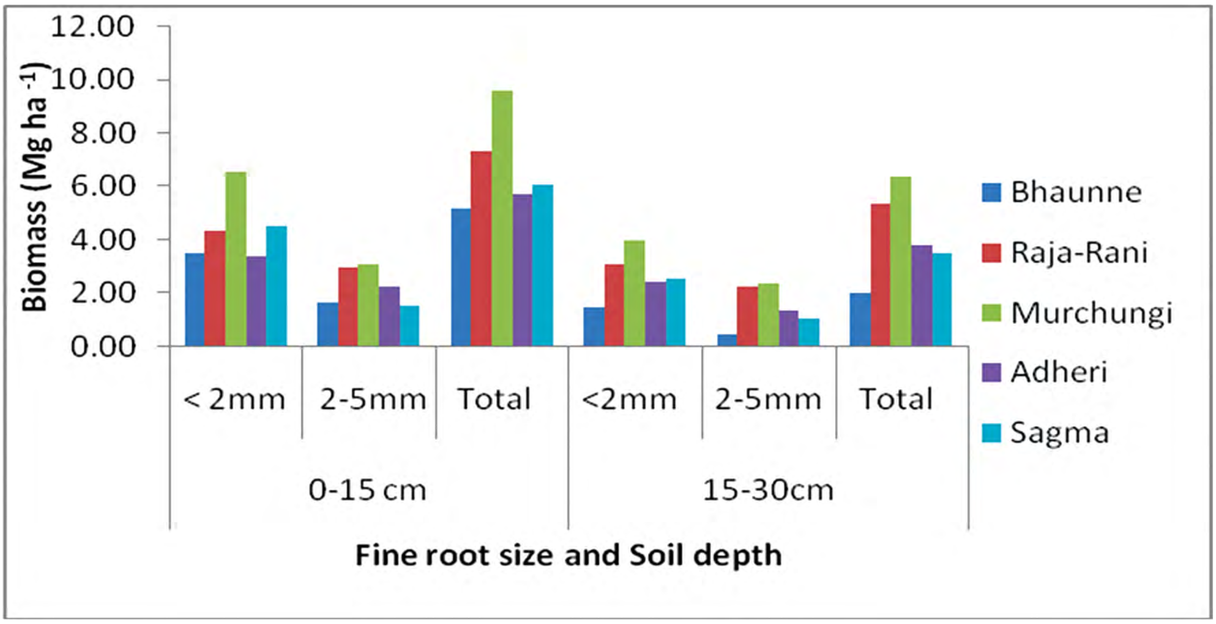

Figure 5: Fine-root biomass at 0–15 cm and 15–30 cm soil depth of different sites.

The carbon stock value was also maximum (5.44 Mg ha^{-1}) for both <2mm and 2–5mm diameter classes in 0-30 cm soil depth (Figure 6). The fine-root biomass was not found to be statistically significant among the studied forest sites even in the case of both diameter classes (<2mm and 2–5mm).

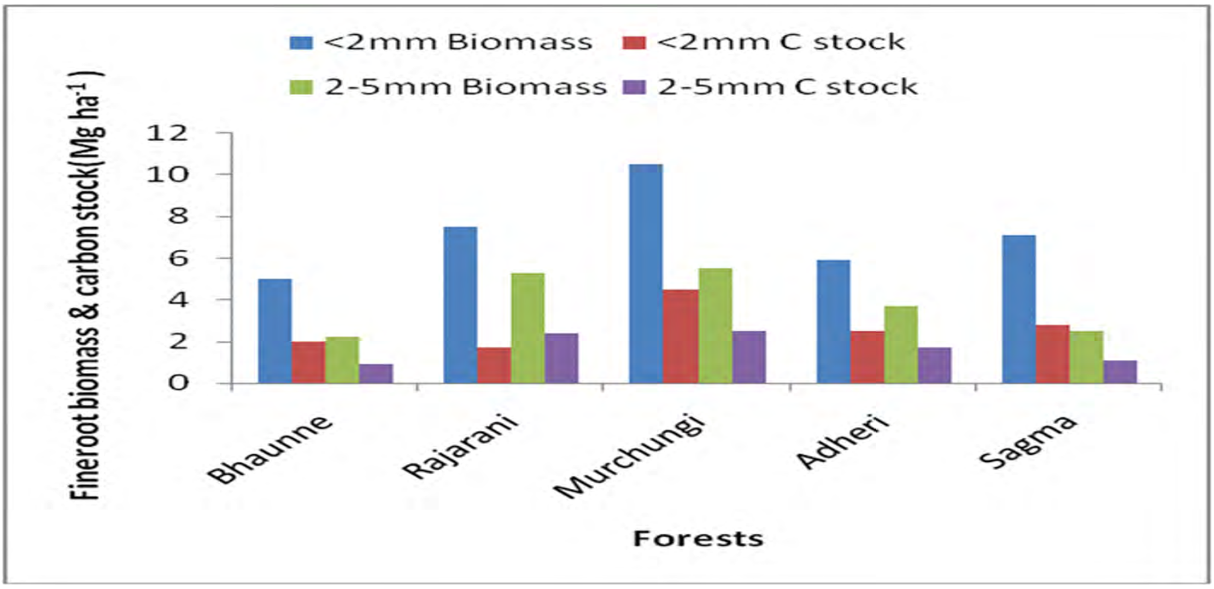

Figure 6: Fine-root biomass and carbon stocks (Mg C·ha^{-1}) of <2mm and 2–5mm diameter classes within 0–30cm soil depth.

Friedman Test

The Friedman Test conducted on three variables (trees, shrubs, and herbs biomass) revealed distinctive differences in the distribution of tree biomass among the five different forests. Statistical significant disparities were noted in the tree biomass between the Murchungi and Sagma sites (*p*=0.021, Figure 7). Regarding the shrub biomass, statistical significant differences were observed between the Adheri and Sagma sites (*p*=0.017, Figure 8). Moreover, statistical significant differences in the herb biomass were observed among the Bhaunne and Sagma, Raja-Rani and Sagma, Murchungi and Sagma, and Adheri and Sagma sites (*p*=0.0001, Figure 9).

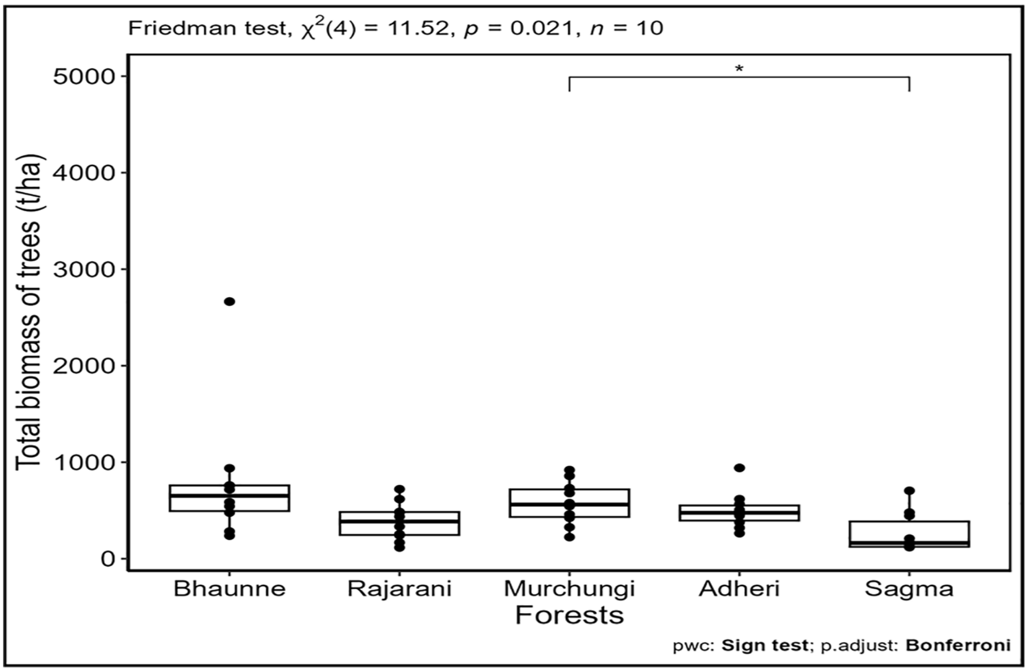

Figure 7: Relationship of total tree biomass (t/ha) among five forests located at different elevations of Morang District. Line covered forests inside figure with asterisk sign (*) indicated statistical significance pair after Friedman test (p < 0.05).

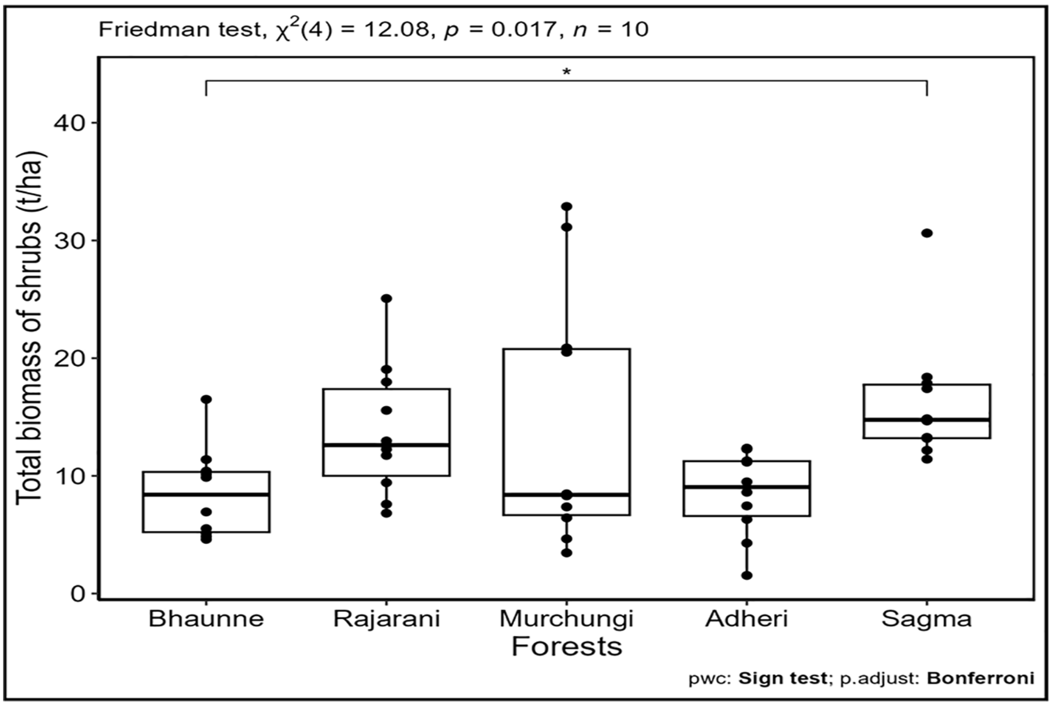

Figure 8: Relationship of total shrub biomass (t/ha) among five forests located at different elevations of Morang District. Line covered forests inside figure with asterisk sign (*) indicated statistical significance pair after Friedman test (p < 0.05).

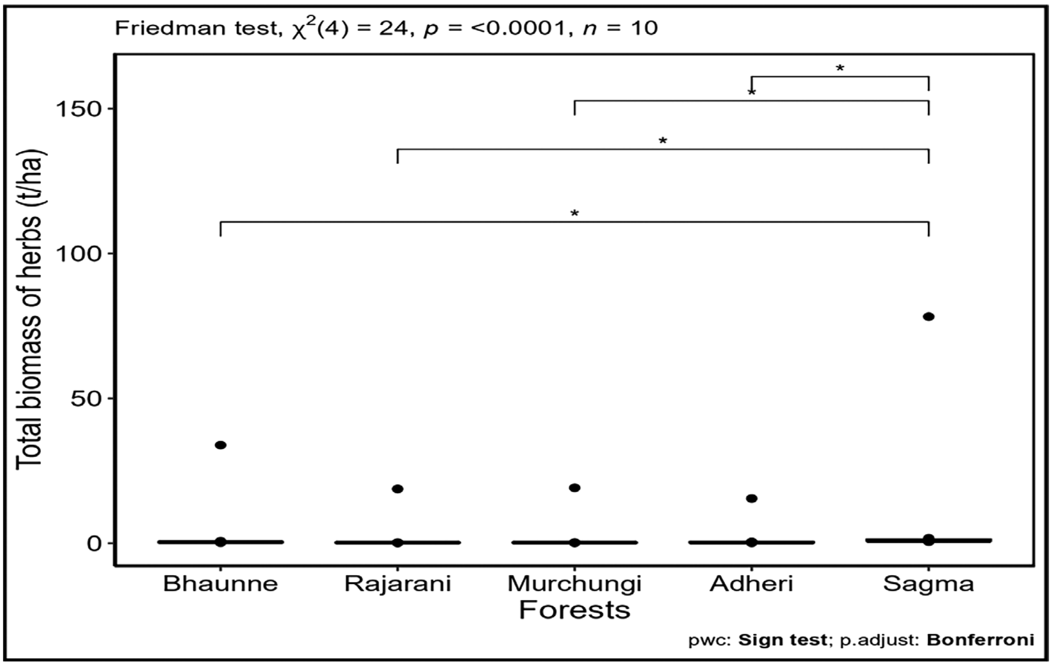

Figure 9: Relationship of herb biomass (t/ha) among five forests located at different elevations of Morang District. Line covered forest inside figure with asterisk sign (*) indicated statistical significance pair after Friedman test (p < 0.05).

Fine-root biomass and carbon stocks

The study revealed a higher fine-root biomass in the upper soil depth (0–15 cm), indicative of an efficient utilization of soil nutrients. Notably, fine-roots with <2 mm diameter exhibited greater dynamism in nutrient supply due to their high turnover rate as compared to those with 2–5 mm diameter (Gautam & Mandal, 2016). The maximum fine-root biomass observed in the Murchungi site (see Figure 5 above) could be attributed to a potentially lower turnover rate, possibly associated with specific species characteristics (Pandey *et al*., 2023; Raich *et al*., 2009). The fine-root biomass displayed an increasing trend up to the Murchungi site, followed by a decrease with increase in elevation beyond this point.

The present study highlighted an extensive carbon stock in fine-root biomass with <2 mm diameter, likely influenced by various external factors such as soil nutrients and altitude in addition to internal factors (Bhattarai *et al*., 2020; Vogt *et al*., 1986; Wendy & Gordon, 2000).

The total fine root biomass for both below 2mm as well as 2-5 mm diameter did not show statistical significant results in the pairwise comparison among studied forests of varying elevations (Figures 10 and 11) though chi-square value of Friedman Test for fine root biomass below 2 mm was statistically significant (Figure 10).

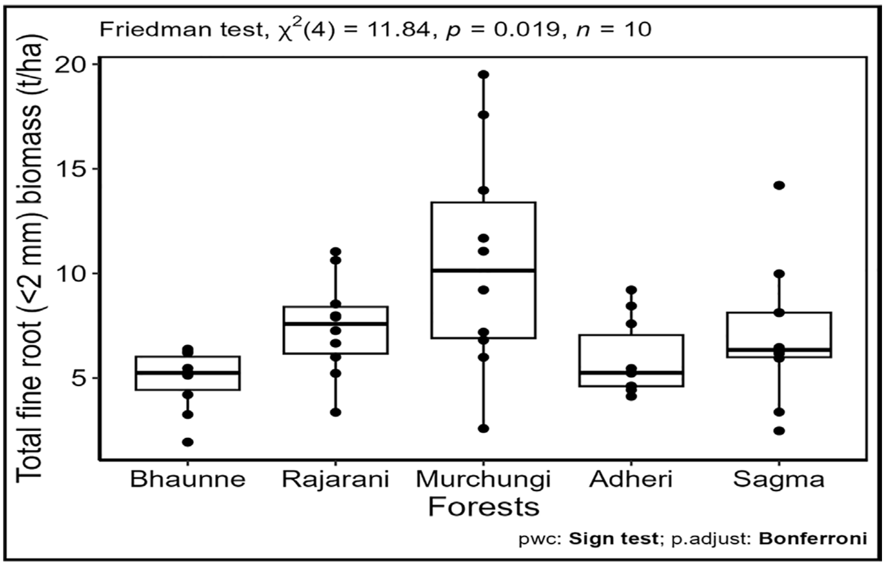

Figure 10: Relationship of fine root (<2 mm) biomass (t/ha) among five forests located at different elevations of Morang District. The pairwise comparison result plotted after Friedman test.

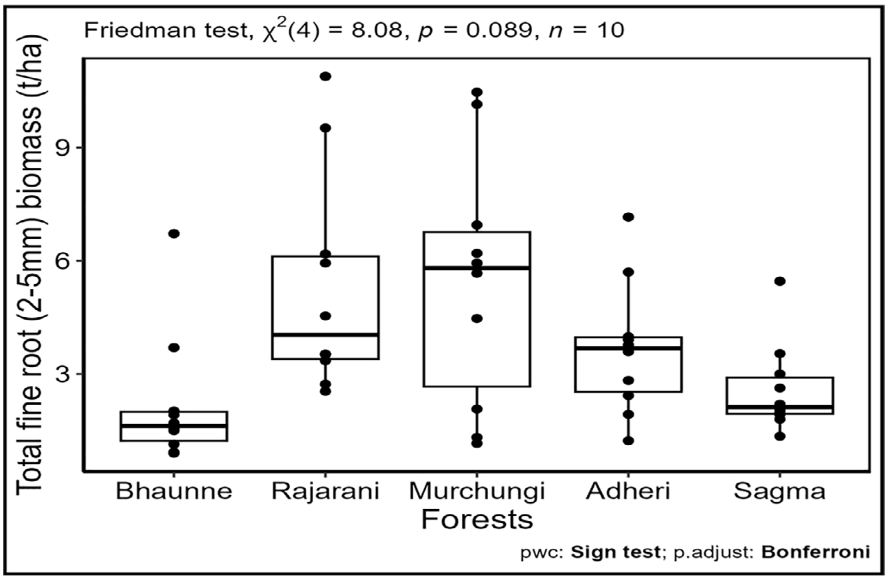

Figure 11: Relationship of fine root (2-5 mm) biomass (t/ha) among five forests located at different elevations of Morang District. The pairwise comparison result plotted after Friedman test.

Discussion

Plant biomass and carbon stock

The distribution of plant biomass and carbon stocks in the forest are known to affect by various factors, including the presence of different tree species, nutrient availability in the soil, and climate (Bhatta *et al*., 2018; Dani & Baniya, 2019; Gurung *et al*., 2022; Malla & Neupane, 2024). The current study suggests that total biomass and carbon stocks vary across sites in relation to different elevations. A higher biomass of 815.86 Mg ha^{-1} was observed in Bhaunne site, possibly due to the presence of various species with greater girth, such as *S. robusta* (Baral *et al*., 2009) while a lower carbon pool in Sagma forest may be due to the composition of different species, dominated by *Schima castanopsis*, which is similar to the findings of Khanal *et al*. (2008). Several other researchers (Shrestha & Singh, 2008; Mwakisunga & Majule, 2012; Gautam & Mandal, 2016; Bohara *et al*., 2021) have claimed that higher plant biomass is due to increase in tree density, which is in contrast with the findings of our study. We found that the aboveground biomass varied among the sites due to differences in plant species and community structure. In present study, the decline in carbon stocks in high-elevation forests might be due to steep slopes (Bohara *et al*., 2021; Pandey *et al*., 2020). However, an increase in the forest carbon stock in tropical lowlands may be due to the accumulation of more organic matter and other minerals in the less sloping areas as a result of heavy rainfall. This result is comparable to the findings of Leuschner et al. (2007), Moser et al. (2011), Sanquetta et al. (2013), Bhattarai & Mandal (2020) and Bohara et al. (2021).

Aboveground biomass and carbon exhibit wide variations in tropical forests, influenced by stem size distribution, soil fertility (Gautam & Mandal, 2013) and topography (KC *et al*., 2024; Castilho *et al*., 2006; Malhi *et al*., 2006). Baral *et al*. (2009) estimated 97.86 Mg C ha^{-1} in Hill *Shorea* forest, with a maximum stand height of 30 m and the mean height of 12.75 m, and the maximum DBH of 89 cm and the mean DBH of 19.56 cm.

A decline in aboveground biomass with the increase in elevation as reported by a number of researchers (Rana *et al*., 2023; Leuschner *et al*., 2007; Moser *et al*., 2011) are in line with the findings of this study while some others (Pokhrel & Sherpa, 2020; Thakur *et al*., 2024; Kumar *et al*., 2019; Thokchom & Yadava, 2017) have reported an increase in aboveground biomass with the increase in elevation. The range of aboveground biomass (230.74–641.13 Mg ha^{-1}) of the trees, shrubs, and herbs in the present study supports well with other studies in the tropical forests of Nepal. Ramachandran *et al*. (2007) reported a range of aboveground biomass (36.85 to 196.98 Mg ha^{-1}) in Kolli Hills of eastern Ghats, 7.92–307 Mg ha^{-1} in Chitteri Hills of eastern Ghats, 64.81–624.96 Mg ha^{-1} in Sathanur Reserve Forest, and 118–260 Mg ha^{-1} in Javadi Hills (Pragasan, 2014) of India.

The findings of the present study contradict with those of Behera *et al*. (2017), and Borah *et al*. (2013), Padmakumar *et al*. (2018) regarding the relationship between species diversity and biomass. The present study suggests that higher biomass is not always associated with higher diversity, which may be attributed to the tree density and girth size of individual species. A positive relationship between tree density and carbon stock was found by Pragasan (2014) which is similar to the present study. Thus, tropical forests of east Nepal act as C-accumulating systems, serving as significant global carbon sinks (Gautam & Mandal, 2016), similar to other wet tropical forests (Pan *et al*., 2011).

Conclusion

In conclusion, this study highlights the considerable variation in biomass and carbon stocks across the forests situated at different elevations in the Morang district of Nepal. The intricate relationship between fine-root biomass, carbon stocks and elevation, together with variations in fine-root diameter classes, unveiled a distinct ecological pattern. Notably, thinner-diameter fine-roots exhibited higher biomass compared to their thicker fine-root. The observed high fine-root biomass and carbon stocks in the upper layers of soil (0–15 cm) emphasized the importance of this region for nutrient cycling and storage. The fine-root biomass of <2 mm and 2–5mm diameters across the forests were insignificant. This highlights a potential uniformity in fine-root dynamics despite variations in forest types and elevations, contributing valuable insights to our understanding of below-ground ecological processes.

The implications of these findings are expected to be useful in preparing practical guidelines for forest ecosystem management. Recognizing the intricate relationships between plant biomass and carbon stocks, fine-root biomass and carbon stocks with elevation can enhance strategies aimed at optimizing carbon storage and promoting sustainable forestry practices. This study contributes to the broader understanding of forest ecosystems and provides a foundation for decision-making in the realm of carbon management.

Acknowledgments

We acknowledge the Koshi Province's Ministry of Forests, Tourism, and Soil Conservation for providing us a partial financial support to conduct this study. Similarly, we are thankful to the District Forest Office, Morang for providing us permission to conduct this study in the aforementioned community forests. Last but not least, we would like to express our sincere thanks to Mr. Madan Bhattarai and all the other individuals for their support during our fieldwork and laboratory work.

Authors contribution:

Conceptual framework, data collection, and manuscript written by P. K. Gachhadar, Conceptual frame and manuscript written, statistical analysis, editing, reviewed, and correspondence by C. B. Baniya and Conceptual frame and manuscript written, editing and review T. N. Mandal.

Data availability:

The data used in this study are accessible upon request to the corresponding author.

Declaration

We have no conflict of interest in the publication of this research manuscript.

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Annex-I

Plotwise total biomass among five studied forests of Morang, East Nepal.

Forests	Plot	Tree_biomass(t/ha)	Shrub_biomass (t/ha)	Herb_biomass (t/ha)	Fine_root_less_than_2mm (t/ha)	Fine_root_two_five mm(t/ha)
Bhaunne	1	716.97	6.936	0.215	4.7	0.7
Bhaunne	2	937.48	10.4	0.423	3.9	1.26
Bhaunne	3	2664.76	9.872	33.86	2.42	0.75
Bhaunne	4	238.04	10.14	0.1975	4.99	6.42
Bhaunne	5	543.52	11.388	0.1902	3.88	2.97
Bhaunne	6	282.67	4.852	0.443	3.94	0.81
Bhaunne	7	477.18	4.608	0.3294	3.29	0.99
Bhaunne	8	757.3	16.5	0.35	1.66	0.93
Bhaunne	9	760.19	5.12	0.7589	2.89	1.11
Bhaunne	10	586.38	5.516	0.5266	2.9	1.03
Rajarani	1	721.18	7.592	0.2304	4.49	3.71
Rajarani	2	242.78	9.424	0.2011	5.11	3.79
Rajarani	3	167.77	11.736	18.73	5.15	8.95
Rajarani	4	334.07	12.964	0.1923	3.94	1.62
Rajarani	5	479.75	17.98	0.2011	3.06	0.17
Rajarani	6	115.38	12.26	0.11	4.56	1.16
Rajarani	7	485.23	25.072	0.1532	6.59	3.25
Rajarani	8	436.69	19.048	0.1955	3.36	4.12
Rajarani	9	617.87	15.568	0.1675	2.56	1.14
Rajarani	10	254.97	6.828	0.1987	4.98	1.85
Murchungi	1	576.54	20.868	0.2246	2.58	0
Murchungi	2	858.21	31.132	0.1456	11.62	3.81
Murchungi	3	731.31	6.432	19.12	9.91	4.16
Murchungi	4	545.19	7.368	0.256	5.77	3.7
Murchungi	5	459.07	20.508	0.209	0.55	0.05
Murchungi	6	919.01	4.652	0.1377	13.2	6.85
Murchungi	7	680.33	32.888	0.178	2.56	0.83

Forests	Plot	Tree_ biomass(t/ ha)	Shrub_ biomass (t/ha)	Herb_ biomass (t/ha)	Fine_root_less_ than_2mm (t/ha)	Fine_root_two_ five mm(t/ha)
Murchungi	8	223.56	3.46	0.1543	5.87	2.69
Murchungi	9	423.84	8.472	0.2021	7.56	4.78
Murchungi	10	326.16	8.304	0.2257	5.87	3.89
Adheri	1	566.56	12.272	0.4955	5.49	1.99
Adheri	2	320.14	6.304	0.1956	3.24	2.73
Adheri	3	263.7	11.276	15.44	3.27	0.48
Adheri	4	447.01	4.288	0.2013	2.69	1.32
Adheri	5	377.93	11.164	0.1249	5.9	2.83
Adheri	6	464.78	7.452	0.4605	2.48	1.07
Adheri	7	940.95	1.54	0.1867	2.7	3.11
Adheri	8	617.81	12.352	0.201	3.36	4.37
Adheri	9	487.27	9.492	0.4377	2.45	3.67
Adheri	10	507.67	8.608	0.2211	2.61	1.37
Sagma	1	444.89	14.852	0.5	2.35	1.5
Sagma	2	122.54	11.42	0.511	5.35	1.5
Sagma	3	208.71	13.272	78.2	4.49	0.71
Sagma	4	479.04	30.624	0.7512	4.18	2.42
Sagma	5	169.71	12.176	1.5013	11.02	4.6
Sagma	6	704.57	17.412	0.9001	1.53	0.34
Sagma	7	120.58	18.388	0.7511	3.34	1.65
Sagma	8	127.07	13.184	0.822	4.07	1.26
Sagma	9	119.37	14.668	0.8005	3.32	0.23
Sagma	10	155.73	17.868	1.7501	5.76	1.23