Our Nature | January 2024 | 22 (1): 28-40

Nature Conservation & Health Care Council
Biratnagar, Nepal

Our Nature

Journal homepage: http://nepjol.info/index.php/ON

ISSN: 1991-2951 (Print)
ISSN: 2091-2781 (Online)

Assessment of Species Composition, Diversity and Carbon Stock in a Community Managed Forest of Udaypur District of Nepal

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Abstract

Species composition, diversity, and carbon sock of forests are all critical factors that affect the ability of forests to provide various important ecosystem services. However, there is a notable dearth of research regarding these factors in the community forests of Udaypur district. Therefore, this research was undertaken to assess species composition, and biodiversity and quantify the carbon stock potential of the Sringar community forest (CF) of the Udaypur district of Eastern Nepal. A total of 57 circular plots of 500m2 were inventoried using a systematic random sampling method with 0.5 % sampling intensity. In the CF, 17 tree species from 15 genera and 11 families were identified.The dominant tree species, *Shorearobusta*observed with a maximum importance value index (IVI) (176.15). According to our study, the total biomass and carbon stock in Sringar CF were 276.98 ton ha^{-1} and 138.18 ton ha^{-1}, respectively. Accurate estimation of soil carbon stocks is crucial for long-term forest management and climate change mitigation, and the integration of advanced monitoring techniques and predictive models to enhance accuracy and account for future climate projections is needed.

Keywords: *Biomass, Climate change, Carbon sequestration, Importance value index*

DOI: https://doi.org/10.3126/on.v22i1.67349
Manuscript details: Received: 21.10.2023 / Accepted:18.12.2023
Citation: Ayer S., Gautam J., Chaudhary P., Poudel S. & Ayer K., 2024, Assessment of Species Composition, Diversity and Carbon Stock in a Community Managed Forest of Udaypur District of Nepal. *Our Nature* 22 (1): 28-40. DOI: https://doi.org/10.3126/on.v22i1.67349

Introduction

Forests hold a pivotal role as essential terrestrial ecosystems, providing a multitude of advantages to both the planet and its inhabitants (Brockerhoff *et al*., 2017). These natural havens harbor a remarkable diversity of flora and fauna, including numerous species that are exclusive to specific forest types (Brockerhoff *et al*., 2017). Terrestrial ecosystems are vital for maintaining a balanced environment that encompasses key ecosystem services including regulating the climate, water and land conservation, and carbon sequestration (Bauhus *et al*., 2010; Thompson *et al*., 2011; Brockerhoff *et al*., 2013; Decocq *et al*., 2016; Liang *et al*., 2016; Mori *et al*., 2017). Forests provide many benefits, land-use changes, and the far-reaching consequences of climate change, pose formidable threats to forests worldwide (Liaison, 2013; Thapa, 2021).

Nepal has garnered recognition for its community forestry program, acclaimed as a successful model for community-based natural resource management (Ghimire and Lamichhane, 2021). Nepal boasts an impressive count of 22,519 community forests (CFs), which collectively encompass a substantial land area of 2,312,545 hectares. These invaluable forested regions are entrusted to the care and responsibility of 3,088,259 households (Pandey and Pokhrel, 2021). This makes up for 15.67% of the country's total land area, 34.98% of its forested area, and involves the active participation of 56.90% of Nepalese households and 62.68% of the country's population (Pandey and Pokhrel, 2021). Despite their vast numbers, community forests in Nepal often lack comprehensive information on vital technical aspects such as species diversity, stand structure, and carbon stocks (Anup, 2017; Poudyal *et al.*, 2019). These indicators hold crucial significance in comprehending the role of forests in delivering ecosystem services, encompassing carbon capture and storage, soil protection, and biodiversity preservation (Mandal *et al.*, 2013; Bhandari *et al.*, 2021; Baul *et al.*, 2021). Consequently, there is an escalating demand for assessment studies to furnish detailed insights into these technical facets and their implications for ecosystem services (Paudyal *et al.*, 2017).

The identification and number of plant and animal species in a particular ecosystem is referred to as species composition (Carrick and Forsythe, 2020). Assessing species composition in community forests allows for the documentation of diverse plant and animal species, including those of conservation significance (Latt and Park, 2022). Additionally, it serves as an important tool for monitoring the impacts of human activities and environmental changes on forest biodiversity, aiding in the development of effective conservation and management strategies (Thompson *et al.*, 2009). Species variability is also important for preserving ecosystem health and functionality. Variability of species promotes resiliency, and ecological balance as well as delivery of various ecosystem services including provision of clean air and water, pollination of crops, regulation of climate, and nutrient cycling (Isbell *et al.*, 2011; Mace *et al.*, 2012; Watson *et al.*, 2019; Roswell *et al.*, 2021). Similarly, carbon stock potential of forests highlights their significant role as carbon sinks absorbing and storing carbon dioxide from the atmosphere (Mukul *et al.*, 2021). Therefore, understanding the composition, variety, and carbon stock potential of tree species is critical for sustainable forest management and conservation. (Hooper *et al.*, 2005; Isbell *et al.*, 2011; Gamfeldt *et al.*, 2013).

While numerous vegetation and carbon stock assessment studies have been conducted in various regions of Nepal (Aryal *et al.*, 2018; Bhatta and Devkota, 2020; Ghimire and Lamichhane, 2021; Joshi *et al.*, 2023) there is a notable dearth of research in the Udaypur district. Despite its ecological significance and the presence of community-managed forests in the district, detailed information regarding these essential aspects is lacking. The absence of studies in Udaypur district hinders our understanding of the local forest ecosystem and its potential contributions to carbon sequestration, biodiversity conservation, and ecosystem services. To address this research gap, conducting assessments and studies in the Udaypur district becomes imperative.Therefore, the objective of this study is to fill this knowledge gap by assessing the diversity, structure, and potential carbon stocks of Sringar CF in the Udaypurdistrict.

Materials and Methods

Study area

In the southeast of Nepal, in the Koshi province, Udaypur district is situated between 26.8372° N latitude and 86.3213° E longitude. The district has a moderately elevated elevation that ranges from subtropical tropical (300-2000 m above mean sea level) to lower tropical (below 300 m)(Lamichhane and Karna, 2009). The Udayapur district is bordered to the south and north by Shiwalik and the Mahabharat hills, respectively consisting of four forest types i.e., Hill sal forest, Chir Pine Forest, Chir pine Broadleaved Forest, and lower temperate oak forest (Lamichhane and Karna, 2009).

This study was carried out in the Sringar CF of Udaypur district of southeastern Nepal (Figure 1) covering an area of 280 hectare. With an annual minimum temperature of 16.8 °C, an annual maximum temperature of 28.1 °C, and an annual rainfall of roughly 1349.2 mm, this study location has a tropical and subtropical climate(DoHM, 2017). The CF under investigation had undergone degradation due to factors such as overexploitation, intense grazing, deforestation, and logging before it was handed over to community management in 1998 AD. As a result, the forest experienced a decline in tree density and diversity, with only a few scattered large trees and plants remaining. However, after the implementation of community management, strict regulations were enforced to prohibit grazing, deforestation, and logging, except for the collection of seasonal fodder and firewood by the community forest users' group.

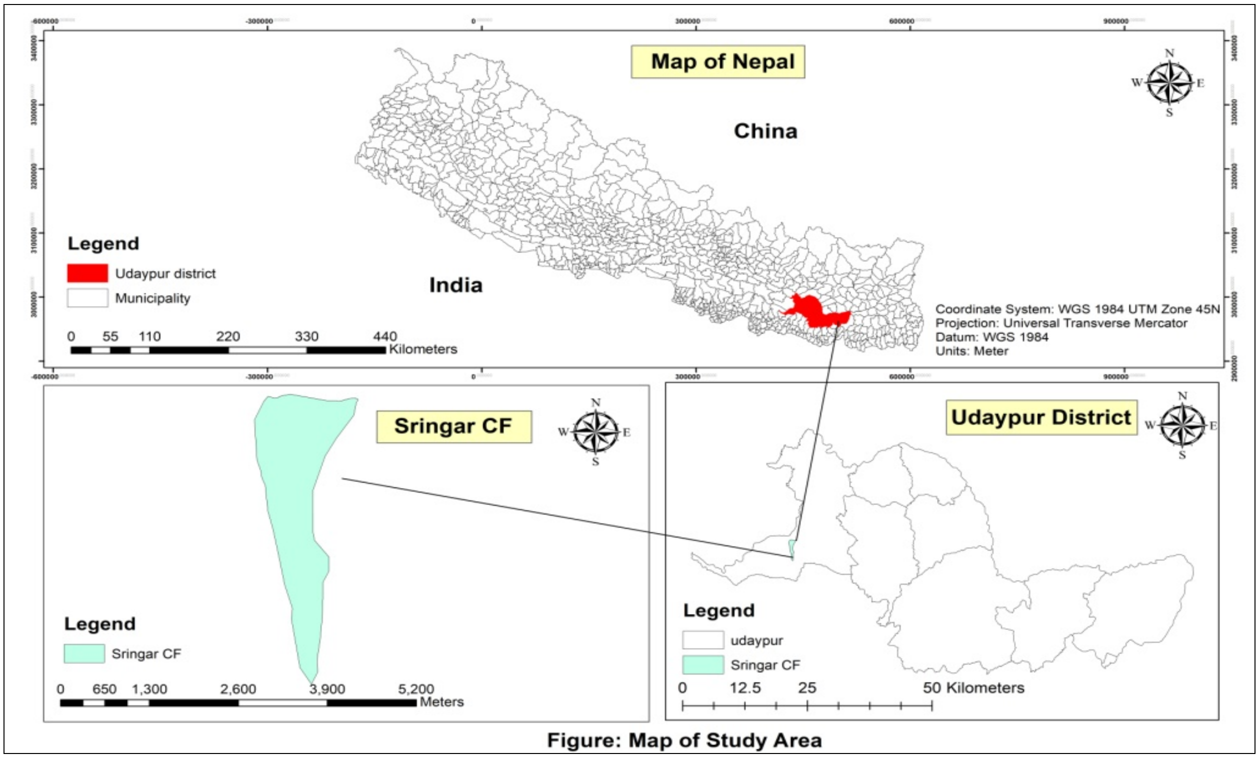

Figure 1: Map of Study Area

Data collection

The Sringar CF was delineated using GPS and Arc Map 10.4. For this study, a 0.5% sampling intensity systemic random sampling was adopted (DoF, 2004). A total of 57 concentric circular plots having 250 m^2 area were established for assessment of species composition, diversity, and carbon stock in Sringar CF. Trees (DBH ≥ 5cm) and Saplings (1cm < DBH < 5cm) in each sample plot were measured within a radius of 8.92 m and 5.64 m respectively (Subedi *et al.*, 2011). Diameter tape was used for DBH measurement at 1.3m height from the ground and a clinometer was used for tree height measurement. To gain a better understanding, evaluation, and analysis of the research, several scientific studies, articles, and other important and relevant literature linked to carbon and biomass estimation were explored.

Species composition and diversity

The data from the forest inventory were used to compute the species composition and diversity. The term "species composition" describes the particular kinds or categories of species that are found in the research region (Aye *et al.*, 2022). The species composition was evaluated in terms of density (D), frequency (F), basal area (m2), relative density (RD), relative frequency (RF), relative basal area (RBA), and important value index (IVI) using the Curtis and Mcintosh (1950) technique.

Following Whittaker (1972), the number of woody species in each plot was tabulated to determine species richness 'S'.The research area's species diversity was also assessed using the Simpson's index (D) (Simpson, 1949), the Shannon-diversity

Weiner's index (H) (Shannon and Weaver, 1949), and the species evenness (D/S) (Wilsey et al., 2005). A crucial aspect of the dynamics, structural variability, and operation of many forest ecosystems is the diameter class-wise distribution(Lutz *et al.*, 2013).The total plant population of every species present in every plot was divided into different size classes based on DBH at intervals of 10 cm in order to analyze community structure. The distribution pattern of people in DBH classes was then examined using the plant d-d curve.

Estimation of biomass and carbon Stock

Chave et al. (2005),allometric equation was used to compute the aboveground tree biomass (AGTB).

$AGTB = 0.0509 \times D^2 \times \rho \times H$ …………………………… eq (1)

Where, AGTB= Aboveground tree biomass (Kg), ▫= specific gravity of wood (g cm^{-3}) (Sharma, and Pukkala, 1990), D= tree DBH in cm and H= Height of tree (m).

In the case of saplings ($1\ cm < DBH < 5cm$) the application of the allometric equation commonly used for estimating AGTB does not provide accurate results. Therefore, an alternative approach was employed to calculate aboveground sapling biomass (AGSB) using the national allometric biomass tables developed by Tamrakar (2000).

$Log\ (AGSB) = a + b\ log\ (D)$…… …..………. eq (2)

Where AGSB=Aboveground sapling biomass (Kg), Log=natural log (dimensionless), a=intercept of allometric relationship for saplings (dimensionless), b=slope allometric relationship for saplings (dimensionless), and D=over bark diameter at breast height measured at 1.3 m above ground (cm).

Below-ground biomass (BGB) was computed by multiplying the value of AGTB by the constant factor 0.26 (IPCC, 2006; Mandal and Joshi, 2015). Total biomass (Kg) wascalculated by summing up above and below ground biomass (Djomo and Chimi, 2017; Sheikh *et al.*, 2011).

$TB = AGTB + AGSB + BGB$………………..eq (3)

For each plot, sum of all individual biomass in kgwas divided by the sampling plot area (250 m^2) to calculate biomass stock density in kg m^{-2} and then simply multiplied by 10 to get biomass stock density in ton ha^{-1}. Similarly, the IPCC (2006) standard carbon proportion of 0.47 was applied to translate the biomass stock density of a sampling plot into carbon stock density. Lastly, the carbon stock densities of various carbon pools were added up to estimate the carbon stock density of the overall CF. (Subedi*et al.*, 2011).

$TC = C(AGTB) + C(AGSB) + C(BGB)$……… eq (4)

Where,

TC = total density of carbon stocks for a type of land use (ton ha^{-1}), *C(AGTB)* = carbon in above-ground tree biomass (ton ha^{-1}), *C(AGSB)* = carbon in above-ground sapling biomass (ton ha^{-1}), *C(BGB)* = carbon in below-ground biomass (ton ha^{-1}).

Shorearobusta has the highest importance value index (176.15) (Table 1). The frequency of *Shorearobusta* was 100 %. *Buchananialatifolia* was co-dominant species in this forest and other larger trees such as *Terminalia tomentosa, Largerstroemiaparviflora, Terminalia bellirica*, *Schimawallichii*, *Pinusroxburghii*, *Cassia fistula*, *Syzygiumcumini,Semicarpusanacardium, etc* were the common tree species found in the study area (Table 1). Total tree density in the forest ranged from 1.40 trees/ha to 431.58 trees/ha (Table 1). The total basal area of all tree species was 29.52 m^2ha^{-1}.

Statistical analysis

SPSS software was used to combine and analyze the data. To design a map, Arc GIS 10.4 was utilized. MS-Excel 2010 was used to create the graphs and tables.

Results

Species composition

Shorearobusta was the dominant tree species in the study site. Altogether 848 tree individuals, representing 17 species, 15 genera, and 11 families, were identified within the study area.

Table 1: Information on the Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF) and Relative Basal Area (RBA), and Importance Value Index (IVI) of trees in the whole forest.

SN	**Species**	**Family**	**D (Tree ha^{-1})**	**F (%)**	**BA (m^2 ha^{-1})**	**RD (%)**	**RF (%)**	**RBA**	**IVI**
a	*Shorearobusta*	Dipterocarpaceae	431.58	100.00	21.58	72.52	30.65	72.98	176.15
b	*Buchananialatifolia*	Anacardiaceae	32.28	33.33	1.03	5.42	10.22	3.48	19.12
c	*Lagerstroemia parviflora*	Lythraceae	30.18	31.58	0.68	5.07	9.68	2.30	17.05
d	*Semicarpusanacardum*	Anacardiaceae	22.46	33.33	0.81	3.77	10.22	2.74	16.73
e	*Anogeissuslatifolia*	Combretaceae	9.82	14.04	1.95	1.65	4.30	6.59	12.54
f	*Symplocossps*	Symplocaceae	16.84	29.82	0.03	2.83	9.14	0.09	12.06
g	*Terminalia tomentosa*	Combretaceae	5.61	14.04	1.13	0.94	4.30	3.82	9.06
h	*Mallotusphilippensis*	Euphorbiaceae	12.63	14.04	0.13	2.12	4.30	0.44	6.86
i	*Other*	Other	7.72	12.28	0.13	1.30	3.76	0.44	5.50
j	*Syzygiumpaniculatum*	Myrtaceae	4.21	7.02	0.47	0.71	2.15	1.58	4.44
k	*Pinusroxburghi*	Pinaceae	3.51	5.26	0.65	0.59	1.61	2.21	4.41
l	*Syzygiumcumini*	Myrtaceae	3.51	5.26	0.62	0.59	1.61	2.10	4.30
m	*Werndlandiaheynei*	Rubiaceae	4.21	8.77	0.02	0.71	2.69	0.07	3.47
n	*Cassia fistula*	Fabaceae	3.51	5.26	0.03	0.59	1.61	0.10	2.31
o	*Schimawallichii*	Theaceae	1.40	3.51	0.00	0.24	1.08	0.01	1.32
p	*Terminalia bellirica*	Combretaceae	1.40	1.75	0.14	0.24	0.54	0.49	1.26
q	*Acacia katechu*	Fabaceae	1.40	1.75	0.11	0.24	0.54	0.36	1.13
	Total		**595.09**	**326.32**	**29.52**	**100.00**	**100.00**	**99.80**	**299.80**

Size class distribution

The tree density of the 0–10 cm diameter class was the highest and very few trees were found with a diameter size greater than 50 cm which followed a reverse "J" shape curve (Figure 2).

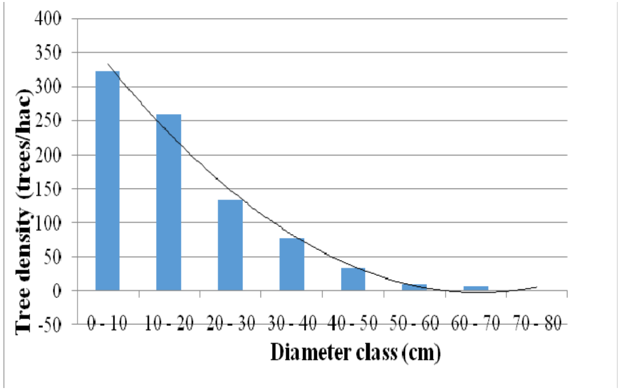

Figure 2: Diameter Class distribution Curve

Species Diversity

Tree species richness that simply shows the total number of species in the community was found to be 17 (Table 2). The calculated values of the Shannon and Simpson indices were 0.54 and 0.47, respectively, which indicate medium levels of tree diversity. The evenness index was found to be 0.03, indicating that each species is not very abundant.

Table 2: Diversity indices of trees of Sringar CF

Diversity Indices	**Sringar CF**
Species Richness 'S'	17
Simpson’s index ‘D’	0.47
Shannon-Weiner’s diversity index ‘H’	0.54
Species Evenness 'E'	0.03

Biomass and carbon stock

It was found that Sringar CF had a mean AGTB and carbon stock of 182.15 tons ha^{-1} and 85.61 tons ha^{-1}, respectively. Similarly, it was estimated that Sringar CF's mean AGSB and carbon stock were 0.05 and 0.026 tons ha^{-1}, respectively. The Sringar CF yielded mean BGB and carbon stock values of 47.36 ton ha^{-1} and 22.26 ton ha^{-1}, respectively. The overall biomass and carbon stock quantities in this study were calculated to be 276.98 tons ha^{-1} and 138.18 tons ha^{-1}, respectively. (Figure 3).

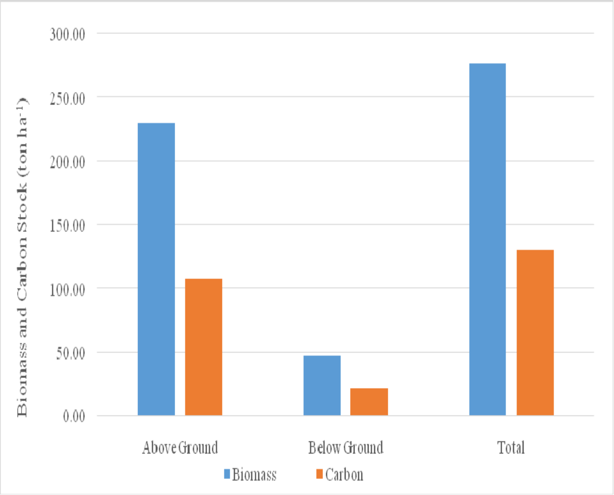

Figure 3: Biomass and Carbon stock of different pools

Contribution of tree species in carbon stock

In our study, *Shorearobusta* contributed the most carbon to the CF (61.22 ton ha^{-1}) (Table 3). The estimated carbon stock was followed by *Anogeissuslatifolia* (8.02 ton ha^{-1}) and *Terminalia tomentosa* (4.63 ton ha^{-1}) respectively. Similarly, *Cassia fistula* (0.03 ton ha^{1}), *Wendlandiaheynei* (0.01 ton ha^{1}), *Symplocossps* (0.01 ton ha^{-1}), and *Schimawallichii* (0.01 ton ha^{-1}), these plants have the lowest carbon stocks. Other tree species contributed significantly to the community forest's carbon supply as well (Table 3).

Table 3: Species wise carbon stocks

SN	Species	Carbon (ton ha^{-1})	Carbon (%)
a	*Shorearobusta*	61.22	71.57
b	*Anogeissuslatifolia*	8.04	9.40
c	*Terminalia tomentosa*	4.63	5.41
d	*Buchananialatifolia*	2.09	2.44
e	*lagerstroemia parviflora*	1.95	2.27
f	*Syzygiumcumini*	1.87	2.18
g	*Pinusroxburghi*	1.81	2.12
h	*Semicarpusanacardum*	1.57	1.83
i	*Syzygiumpaniculatum*	1.26	1.47
j	*Others*	0.32	0.37
k	*Terminalia bellirica*	0.30	0.35
l	*Acacia katechu*	0.23	0.27
m	*Mallotusphilippensis*	0.19	0.22
n	*Cassia fistula*	0.03	0.04
o	*Wendlandiaheynei*	0.01	0.02
p	*Symplocossps*	0.01	0.01
q	*Schimawallichii*	0.01	0.01
	Total	**85.61**	**100**

Discussion

In total, 17 tree species from 11 families and 15 genera were identified in the studied CF (Table 1). In comparison to other species, *Shorearobusta* was determined to be a dominating species with greater relative density, relative frequency, and important value index (Table 1). The dominancy of *Shorearobusta* in the study area might be due to the community's active protection and recognition of its ecological significance and essential ecosystem services (Mandal and Joshi, 2014). Since *Shorearobusta* is a valuable wood species,community forest users might have little incentive to promote other species in the CF. However, compared to other research conducted in Nepali forests with a Shorearobusta predominance, our study found fewer species of trees(Timilsina*et al*., 2007; Basyal*et al*., 2011; Paudyal, 2013; Napit, 2015) and India (Deka*et al*., 2012; Manna and Mishra, 2017). This could be due to differences in habitat, climate, soil conditions, geographic location, disturbances, and management practices(Das *et al*., 2018; Khaine*et al*., 2018). The presence of *Shorearobusta* is significant for both the conservation of biodiversity and commercial purposes (Gautam and Devoe, 2003). Therefore, *Shorearobusta* removal may have a significant impact on the forest ecology. Although the loss of less frequent, rare, or sparsely dispersed species might not have a significant overall effect, protecting and conserving these species is still crucial to ensuring their long-term survival(Rahman *et al*., 2011).

The tree density of our study area was found to be 595 treesha^{-1} which was higher than Oli and subedi (2015) from the *Shorearobusta*forests in mid hill of Nepal.However, the tree density in our study was lower than that obtained from the *Shorearobusta*forests in Nepal (Timilsina*et al*., 2007; Basyal*et al*., 2011; Napit, 2015) and India (Deka*et al*., 2012; Manna and Mishra, 2017). Differences in tree density between forests can be attributed to variations in species assemblage, level of disturbance, human activities, and soil characteristics, which collectively influence tree growth, survival, and regeneration (Sapkota*et al*., 2009; Naidu and Kumar, 2016).

In order to evaluate the potential for timber production in forest ecosystems, one important factor is the basal area (Agrawal, 1992). Sringar CF's total tree basal area was measured to be 29.52 m2 ha^{-1}, which was greater than that of Deka*et al.* (2012) and Napit (2015). But compared to Timilsina*et al.* (2007), Oli and Subedi (2015), Basyal*et al.* (2011), and Paudyal (2013), the basal area of the current study was smaller. The observed differences in the basal area between present and previous studies may be attributed to historical deforestation that occurred in Sringar CF, where the removal of trees had played a significant role in area degradation and consequent reduction in basal area (Sapkota*et al*., 2009; Naidu and Kumar, 2016).

The distribution of trees throughout girth classes demonstrates the potential of the developing forest to use resources (Naidu and Kumar, 2016). The size class distribution diagram of our study area revealed a reverse J-shaped structure, with higher tree density observed in smaller girth sizes compared to larger girth sizes. (Figure 2). The preservation of smaller-sized trees that are well-suited to the current climatic conditions may be the cause of the higher stem density in the lower girth class, while the removal of larger-sized trees may be the cause of the lower stem density in the higher girth class (Sapkota*et al.,* 2009; Sarkar and Devi, 2014).In addition to indicating a stable and sustainable regeneration state of the forest (Basyal*et al.*, 2011; Awasthi*et al.,* 2015; Manna and Mishra, 2017), the higher density of trees with smaller girth sizes compared to larger girth sizes also indicates the forest's ability to efficiently utilize its resources (Naidu and Kumar, 2016).Our results are in line with earlier research that found a similar inverted J-shaped curve in *Shorearobusta* forests in India (Deva *et al.,* 2012; Manna and Mishra, 2017) and Nepal (Basyal*et al.,* 2011; Oli and Subedi, 2015).

Tree diversity plays a critical role in bolstering the resilience of ecosystems by enhancing their stability and adaptability (Albrich*et al*., 2018). A wide variety of tree species within a community equips it to better withstand environmental stressors such as climate fluctuations, pests, diseases, and natural calamities (Silva, 2018).However, our study found lower tree diversity in Sringar CF than previous studies in *Shorearobusta* forests of Nepal (Timilsina*et al*., 2007; Oli *et al*., 2015) and India (Deka*et al*., 2012; Sarkar and Devi, 2014) and Bangladesh (Das *et al*., 2018). Our study highlights the need for conservation and management efforts to address the factors leading to reduced tree diversity in the specific study area. By promoting tree diversity and preserving natural ecosystems, we can contribute to the overall resilience and sustainability of the CF.

The carbon stock in the currently studied CF was 138.18 ton hac^{-1}(Figure 3). Notably, this value surpasses the findings reported in previous studies conducted by Shrestha (2009), Bhattarai*et al.* (2012), Thapa-Magar and Shrestha (2015), Subedi*et al.* (2020), and Rawaland Subedi(2022). Conversely, it is lower than the carbon stock reported in earlier studies conducted by Shrestha and Singh (2008), Baishya*et al.* (2009), and Bohara*et al.* (2021).These contrasting findings highlight the variability in carbon storage within different forest ecosystems, suggesting the influence of various factors such as forest management practices, ecological conditions, and data collection methodologies.Similarly, our study found a higher contribution of *Shorearobusta* in carbon storage (Table 3) which aligns with previous studies in Nepal (Mandal *et al*., 2016; Subedi*et al*., 2020). This might be due to the dominance of *Shorearobusta* in studied CFs. Currently, carbon storage has emerged as a highly promising and extensively discussed strategy for addressing the challenges of climate change (Hepburn *et al*., 2019).Therefore, it is crucial to conduct more comprehensive and updated studies to gain a better understanding of carbon storage dynamics in *Shorearobusta* forests and further refine our knowledge of their contribution to mitigating climate change.

Conclusion

In this study, we conducted an assessment of species composition, diversity, and carbon stock in Sringar CF.Our study revealed that the study area exhibits a diverse range of tree species (n=17). Among these, *Shorearobusta* emerged as the dominant species, as evidenced by its substantial contributions to the total basal area (21.58 m^2 ha^{-1}), frequency (100 %), stand density (431.58 trees ha^{-1}), and Importance Value Index (IVI) (176.15). The prevalence of *Shorearobusta*highlights the predominance of deciduous vegetation within the studied area.Furthermore, the analysis of diameter distribution provided insights into the maturity of the forest. The presence of smaller-sized trees in the diameter distribution figure indicates the immaturity of the forest. It suggests that the majority of the carbon stored in the forest is concentrated in these smaller trees, highlighting the potential for future carbon sequestration as the forest matures. Also, *Shorearobusta*exhibited the highest estimated carbon stock (61.22 ton ha^{-1}), emphasizing its crucial role in carbon sequestration within CF. Preserving the presence of dominant species like *Shorearobusta* is vital for maximizing carbon storage potential in CF.

Moving forward, it is essential for future research to conduct longitudinal studies that track the dynamics of carbon stock in CF over time. Such studies would provide valuable insights into the long-term carbon storage potential of CF ecosystems. Additionally, the integration of advanced technologies, including remote sensing and machine learning, can significantly enhance the accuracy and efficiency of assessing carbon stock and monitoring changes in CF ecosystems. Furthermore, incorporating assessments of soil carbon stocks is crucial to obtaining a holistic understanding of carbon sequestration in CF. These efforts will contribute to the development of effective management strategies and support global initiatives to mitigate climate change.

Acknowledgements

We are incredibly appreciative to Hira Lal Sharma, an Assistant Forest Officer at the Division Forest Office in Udaypur (Triveni), for providing them with the chance to carry out this study and for your constant encouragement and support during the entire research. The authors also thank the Sringar Community Forest User Group and the employees of the Division Forest Office, Udaypur (Triveni), for providing essential information about the community forest during the study.

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