Dynamics of carbon pool in Oak dominated community forests of District Tehri Garhwal, Uttarakhand, India

Ajendra Singh Bagri[1, 2*], Neeraj Singh[2], Ankit Singh[3], Hardeep Singh[2], Jaffer Hussian[2], Gulshan Dhingra[1], Prabhawati Tiwari[2]

[1]Department of Botany, Pt LMS Govt. PG College Rishikesh, Dehradun, India
[2]Department of Botany, Hemvati Nandan Bahuguna Garhwal, University, Uttarakhand, India
[3]High Altitude Plant Physiology Research Centre (HAPPRC), H.N.B.G.U. Uttarakhand, India
[*]corresponding author e-mail: ajendrabagri@gmail.com

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Abstract. The present study was carried out community forest of Tehri Garhwal Uttarakhand. The amount of growing stock volume density in the study region were ranges between 28.21 m^3/ha and 44.59 m^3/ha, above-ground biomass density ranges between 200.59 Mg ha^{-1} and 238.44 Mg ha^{-1}, belowground biomass density range between 128.03 and 192.96 Mg/ha, total biomass density was in the range of 287.76 and 431.40 Mg ha^{-1} and total carbon density ranges between 162.40 and 194.13 Mg ha^{-1}. The isolation of total biomass density into aboveground and belowground parts showed a similar pattern in every one of the forest locales. Present study proposes that community forests play a vital role in ecosystem health they are playing their job quietly in the moderation of environmental carbon and crucial for future planning. Loss of old community forestry system is centre for concern to the forest department, forest rangers and forestry researchers. Protection of community forests is an urgent need for the maintenance of community ecosystem in temperate region of Garhwal Himalaya Uttarakhand. Preservation of the both young and old growth forests is the best way to adapt to environmental change and a worldwide temperature alteration. As we probably are aware the pattern of old cultivating in the networks close to the urban communities is decrease and will be supplanted by present day procedures so we need to look through some new strategy and execution to monitor the old cultivating methods. The ground stock volume density shows moderate positive correlation with altitude (r =0.325) while above ground biomass density (r = 0.203) below ground biomass density, total biomass density and total carbon density shows week positive correlation with altitude (r =0.117, r = 0.194 and r = 0.194 respectively). The Linear regression shows that ground stock volume density, above ground biomass density, below ground biomass density, total biomass density and total carbon density not dependent only altitude some other factor affecting them. While as above ground biomass density show highly positive correlation with total biomass density and total carbon density whereas altitude show less positive correlation with below ground biomass density).

Keywords: community forests, Tehri Garhwal, growing stock volume density, total carbon density.

1. Introduction

Forest assumes a significant part in moderating a large number of the adverse consequences of environmental change. One of the manners in which trees alleviate effects of environmental change is by retaining carbon dioxide and putting away carbon in their wood, leaves, roots, and soil. Field evaluations are utilized to measure the carbon stockpiling across various forested scenes. The quantity of trees, their size, and whole region gauges regarding how much carbon they store. Naturally regenerating forests represent 93% of the world's forest region. Rests of 7% are manmade or artificially established forests. The space of established forests has expanded by 123 million hectares beginning during 1990 and at present it covers 294 million hectares, yet the pace of increment has eased back beginning around 2010 (FAO & UNEP, 2020). About 45% of the established forests (or 3% of all forests) are ranch forests, e.g. oversaw forest, majority of such forests type are dominated with one or few tree species they may be, local or exotic, similar age of height, planted with standard dividing and basically settled for useful purposes. The other 55% of established forests are forests that can take after normal forests at stand development and incorporate forests set up for biological system reclamation and security of soil and water. Forests are dependent on various regular aggravations (e.g. forest fires, bothers, sicknesses, unfavorable climate occasions etc) that can antagonistically influence their wellbeing and imperativeness by making tree mortality or diminishing their capacity give the full scope of labor and products. The impacts at public and neighborhood levels as well as for explicit forests species can be annihilating (FAO & UNEP, 2020).

Natural community forest regions frequently have more noteworthy tree density contrasted with trees planted in planned cityscapes recommending that normal region forests could be a significant carbon stock for urban areas, community forests are net wellsprings of fossil fuel byproducts and human activities and urbanization has been connected to misfortune in tree cover worldwide (Rosenzweig et al., 2010; Crowther et al., 2015). As a piece of tending to these adverse consequences, urban communities have been authorizing arrangements and projects to reduce net discharges (Kabisch et al., 2016). These evaluations rely upon precise portrayal of tree species, size, thickness, and developing conditions related with metropolitan tree coverage's. Tree density, basal cover and biomass change uniquely among tree species types in urban areas, particularly among planned and natural forests (Pregitzer et al., 2019). Community forests grows in inconsistent spatial game plans in spaces of saved parkland or private property, rather than along straight streetscapes, squares or lawns (Zipperer et al., 1997). Because of this sketchy spatial plan and low relative land region as an extent of city-scale tree-shelter cover, forested regular regions frequently get missed or underrated in appraisals of community forests. This study proposes that community forests can possibly added to city-level regular environmental change arrangements. In any case, most gauges of the carbon moderation potential for community forests and trees doesn't represent spatial variety in tree densities and arrangement inside community forests (Nowak et al., 2008, 2013). At the point when evaluations truly represent contrasts in forests types, community forests are frequently inadequate with regards to information and along these lines thought to be more like country forests than other community forests types, and henceforth gauges of carbon stockpiling depend on provincial qualities (Fargione et al., 2018). To test the veracity of such suspicions requires exact estimation of carbon stocks and transitions in community forests, which would then record for any distinctions in forests design, piece and cycles because of the community setting (e.g. expanded obtrusive species, more established trees) that, may affect assessed carbon financial plans. To more readily comprehend and describe the job that community forests could play in moderating fossil fuel byproducts through city-level normal environment arrangements. This study could be helpful for assessment of present carbon stockpiling un community forests and in rural forests as well as for making future policies and strategies for sustainable uses of community forests.

2. Material and Methods

2.1. Study Area

Tehri district in Garhwal region lies between 30-31° latitude and 78-79° longitude. In the east, lies region Rudraprayag; west side is limited by region Dehradun and in the north region Uttarakashi structures its limit while southern limit is outlined by area Pauri Garhwal. Geological area of the district is 3642 km^2. in terms of area it is fifth largest district in Uttarakhand. During April to June is warm though winters during November to February are freezing. The northern part e.g. high altitude regions cooler than the valleys throughout the late spring season. Valleys are exceptionally warm during summer. the greenery found in the area might be partitioned in six principle plant divisions, viz. (I) the tropical dry deciduous forests (ii) the Sal forests (iii) the Chir forests (iv) the Oak backwoods (v) the Deodar, fir and tidy forests and (vi) the snow capped pastures. A large portion of the spaces in western part of Himalaya are covered with thick blended wilderness predominantly of pine. High elevation zones are covered with thick blended wildernesses predominantly of pine and Oak. Slopes are generally covered with open scours and saved timberlands. Characteristics of forest sites are given in Table 1.

2.2. Data Collection

Five community forests stand were selected for present study. Ten sampling plots of (31.62 m ×31.62 m) 0.1 ha each was spread out on each stand (absolute of 5×10=50) to address the specific woods region (Table 1). The height and DBH (distance across at bosom stature) of the relative multitude of trees falling inside the example plot were estimated. The 0.1 ha square plots were spread out by deciding the plot community. In the wake of spreading out

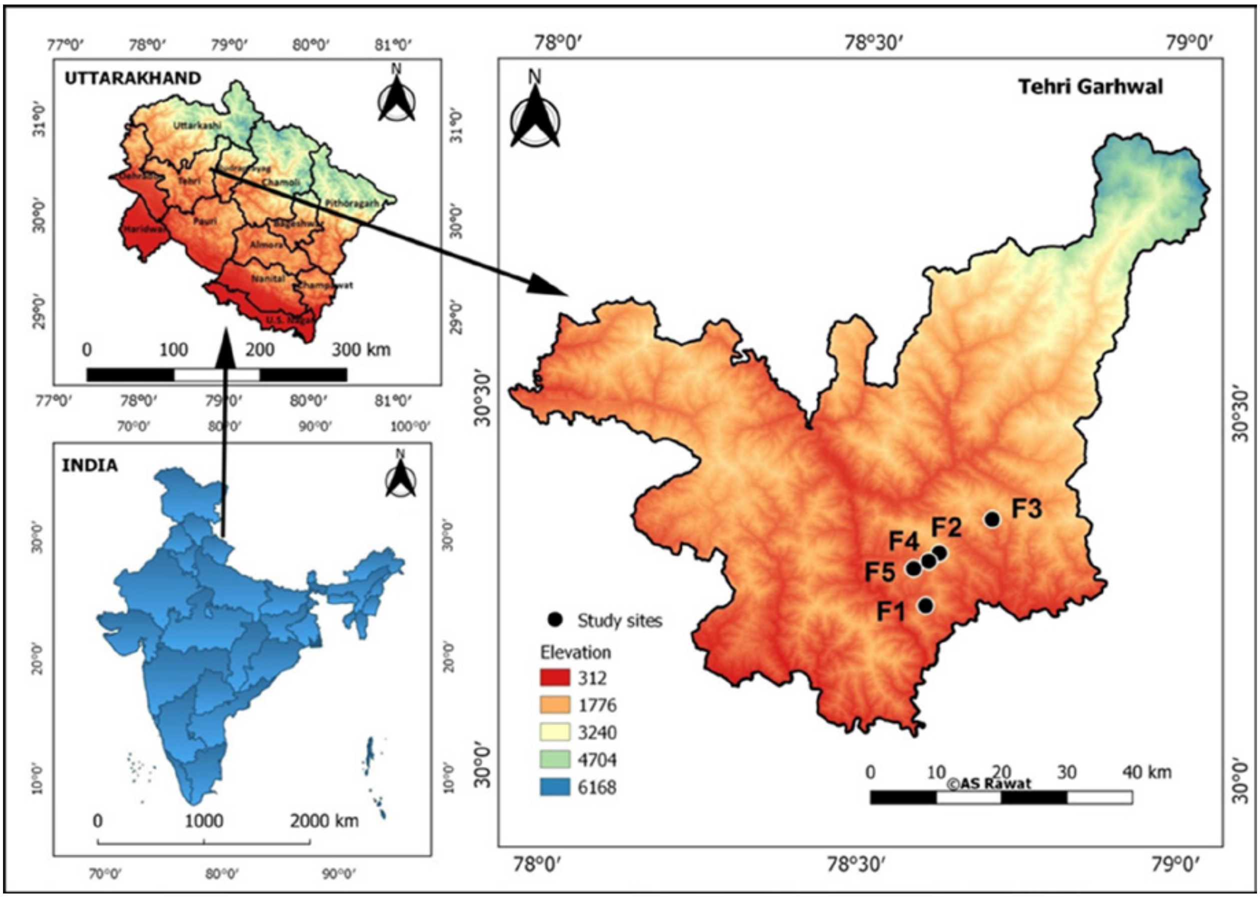

Figure 1. Map of the study area showing Oak dominated community forests (F1-F5) in Tehri district of Uttarakhand, India

the plot, estimations were done on individual tree premise. The incline point was estimated utilizing a clinometer. The tree height was estimated utilizing a Ravi multimeter. The height of the trees on various slant positions was estimated following MacDicken et al. (1991). Trees were viewed as individual ≥10 cm dbh (measurement at bosom height, i.e. 1.37 m) according to Knight (1963).

2.3. Data analysis

The growing volume stock density (GSVD) was assessed utilizing volume tables or volume equations (Appendix A) in light of the Forest Research Institute (FRI) and Forest Survey of India (FSI) distributions for the separate species (FSI, 1996). The assessed GSVD (m^3 ha^{-1}) was then changed over into above ground biomass density (AGBD) of tree parts (stem, branches, twigs and leaves), which was determined by increasing GSVD of the forest with proper biomass extension factor (BEF) (Brown et al., 1999). The BEF (Mg m^{-3}) is characterized as the proportion of above ground biomass density of all living trees at width at Breast height (DBH) ≥2.54 cm to GSVD for all trees of DBH ≥12.7 cm. The BEFs for hardwood, determined utilizing the accompanying conditions:

Hardwood: BEF = exp {1.91 − 0.34 × ln (GSVD)} (for GSVD≤200 m^3 ha^{-1}), BEF = 1.0 (for GSVD > 200 m^3 ha^{-1})
The belowground biomass density (BGBD) of fine and coarse roots, was assessed by utilizing the equation:
BGBD = exp{−1.059 + 0.884 × ln (AGBD) + 0.284}

The all out biomass was changed over into carbon stock by multiplying AGBD (above ground biomass density) + BGBD (belowground biomass density) with the variable 0.45 (here this element is utilized as constant), as utilized by Woomer (1999).

3. Results and discussion

The dominant and associated tree species in various forest types are displayed in Table 1. The outcomes showing benefits of growing stock volume thickness, above ground biomass density, belowground biomass thickness, total biomass

Table 1. General properties of forest sites

F types	Locality	Cordinates	Altitute	Slope	Aspect	Associated species
F1	Hindolakhal	30°13'49.17" 78°35' 58.74"	1400-1500	22°	N	*Rhododendron arboreum, Lyonia ovalifolia, Prunus cerasoides*
F2	Jurana	30°18'8.43" 78°37'10.47"	2000-2200	29°	NE	*Myrica esculenta, Lyonia ovalifolia, Cornus capitata*
F3	Dagar	30°20'59.6" 78°42' 5.32"	1350-1550	26°	N	*Lyonia ovalifolia, Ficus religiosa, Pinus roxburghii*
F4	Karash	30°17'27.60" 78°36' 11.33"	1600-1800	16°	NE	*Myrica esculenta, Pyrus pashia, Juglans regia*
F5	Chhadiyara	30°16' 50.14" 78°34' 46.40"	1500-1700	18°	SW	*Lyonia ovalifolia, Rhus chinensis, Rhus punjabensis*

Table 2. Tree parameters, locality, GSVD, AGBD, BGBD, TBD, TCD for studied forests

Forests types	Locality	GSVD	AGBD	BGBD	TBD	TCD
F1	Hindolakhal	35.99	202.00	25.69	227.69	102.46
F2	Jurana	44.59	231.67	28.09	259.76	116.89
F3	Dagar	44.18	238.44	29.64	268.08	120.64
F4	Karash	28.21	159.73	20.39	180.13	81.06
F5	Chhadiyara	34.69	200.59	25.92	226.52	101.93

Abbreviations: GSVD – Ground stock volume density, AGBD – Above ground biomass density, BGBD – Below ground biomass density, TBD – Total biomass density, TCD – Total carbon density.

density and total carbon density in various local area forests type are set in Table 2 and Figs 2–6).

3.1. Growing stock volume density (GSVD)

The amount of growing stock volume density in the present study ranges between 28.21 m^3 ha^{-1} and 44.59 m^3 ha^{-1}. Maximum growing stock volume density was recorded at F2 (Jurana) 44.59 m3ha-1 followed by F3 (Dagar) 44.18 m^3 ha^{-1}, F1 (Hindolakhal) 35.99 m^3 ha^{-1}, F5 (Chhadiyara) 43.69 m^3 ha^{-1} respectively least growing stock volume density was recorded for site F4 (Karash) 28.21 m^3 ha^{-1}.

3.2. Above-ground biomass density (AGBD)

Above-ground biomass density in present review ranges between 200.59 Mg ha^{-1} and 238.44 Mg ha^{-1}. Maximum rate of above ground biomass density was recorded at F3 (Dagar) 238.44 Mg ha^{-1} followed by F2 (Jurana) 231.67 Mg ha^{-1}, F1 (Hindolakhal) 202 Mg ha^{-1}, F5 (Chhadiyara) 200.59 Mg ha^{-1} respectively while minimum rate of above ground biomass density was recorded at F4 (Karash) 159.73 Mg ha^{-1}.

3.3. Belowground biomass density (BGBD)

Below ground biomass density ranges between of 128.03 and 192.96 Mg ha^{-1}. Minimum values of below ground biomass density was recorded at F3 (Dagar) 29.64 Mg ha^{-1} followed by F2 (Jurana) 28.09 Mg ha^{-1}, F5 (Chhadiyara) 25.92 Mg ha^{-1}, F1 (Hindolakhal) 25.69 Mg ha^{-1} respectively while minimum value of below ground biomass density was recorded at F4 (Karash) 20.39 Mg ha^{-1}.

3.4. Total biomass density (TBD)

Total biomass density was ranges between 180.13 and 268.08 Mg ha^{-1}. Maximum value of total biomass density was recorded at F3 (Dagar) 268.08 Mg ha^{-1} followed by F2 (Jurana) 259.76 Mg ha^{-1}, F1 (Hindolakhal) 227.69 Mg ha^{-1}, F5 (Chhadiyara) 226.52 Mg ha^{-1}, respectively while minimum value of total biomass density was recorded at F4 (Karash) 180.13 Mg ha^{-1}.

3.5. Total carbon density (TCD)

Total carbon density was ranges between 81.06 and 120.64 Mg ha^{-1}. Maximum value of total carbon density was recorded at F3 (Dagar) 120.64 Mg ha^{-1} followed by F2 (Jurana) 116.89 Mg ha^{-1}, F1 (Hindolakhal) 102.46 Mg ha^{-1}, F5 (Chhadiyara) 101.93 Mg ha^{-1}, respectively while minimum value of total carbon density was recorded at F4 (Karash) 81.06 Mg ha^{-1}.

3.6. Variations in total biomass density

The isolation of total biomass density into above and belowground parts in all the forests sites is shown in Figure 7.

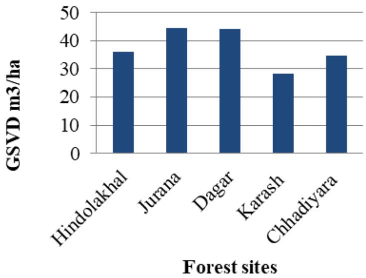

Figure 2. GSVD with different sites

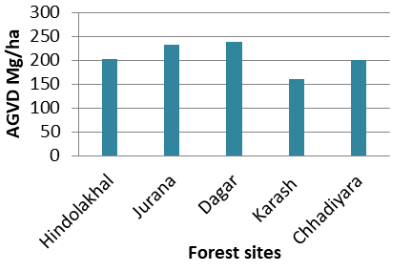

Figure 3. AGBD in different sites

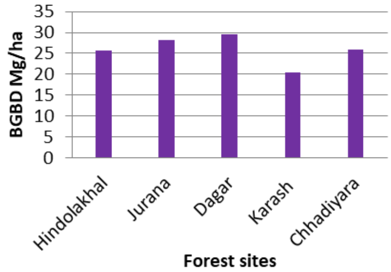

Figure 4. BGBD in different sites

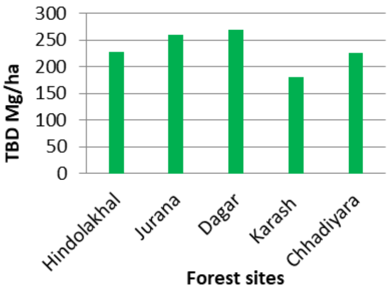

Figure 5. TBD in different sites

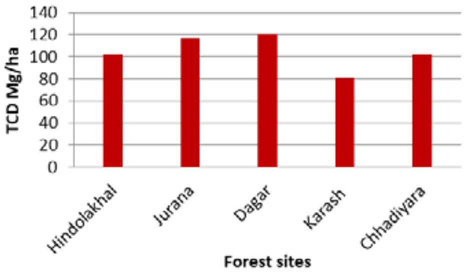

Figure 6. TCD in different sites

The Contribution to the total biomass density by above ground biomass density ranges from 88.55% to 89.18% and below ground biomass density ranges from 10.82% to 11.44%. The contribution to the total biomass density of above ground biomass density at F1 (88.72%) and below ground biomass density (11.28%), at F2 above ground biomass density (89.18%) and below ground biomass density (10.82%), at F3 above ground biomass density (88.94%) and below ground biomass density (11.06%), at F4 above ground biomass density (88.68%) and below ground biomass density (11.32%) and F5 above ground biomass density (88.55%) and below ground biomass density (11.44%) in the present study.

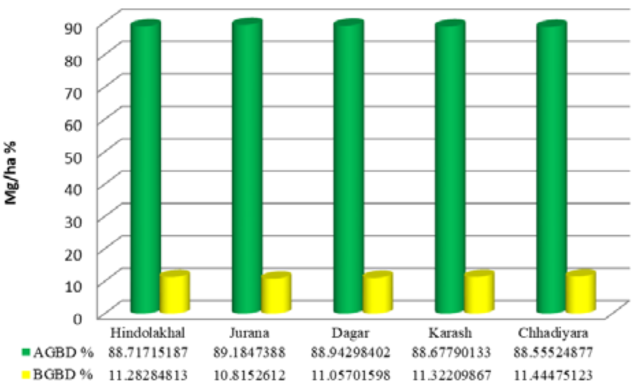

Figure 7. Percentage isolation of TBD into AGBD and BGBD in different sites

3.7. Correlation

The growing stock volume density (r = 0.325) and above ground biomass density (r = 0.203) were found to be moderate positively correlated with altitude and below ground biomass density , total biomass density and total carbon density shows week positive correlation with altitude (r =0.117, r = 0.194 and r = 0.194). The Linear regression shows that growing stock volume density, above ground biomass density, below ground biomass density, total biomass density and total carbon density not dependent only altitude some other factor e.g. aspects, soil types, or slopes may affecting them (Fig. 8). While as above ground biomass density shows highly positive correlation with total biomass density and total carbon density whereas altitude shows less positive correlation with below ground biomass density (Fig. 9).

The present study revealed that established forest communities show low carbon stock in compare to naturally established forests confirming the previous findings of Sharma et al. (2010, 2011). The normal total carbon density is higher than naturally regenerating forest which is because of the trees density, development pattern and climatic variety. *Quercus oblongata* is the keystone species in the community forests of Garhwal Himalaya, being evergreen actually have higher carbon content in their wood alongside a more extended revolution period when contrasted with other evergreen species prompting higher total carbon density. The values of growing stock volume density, above

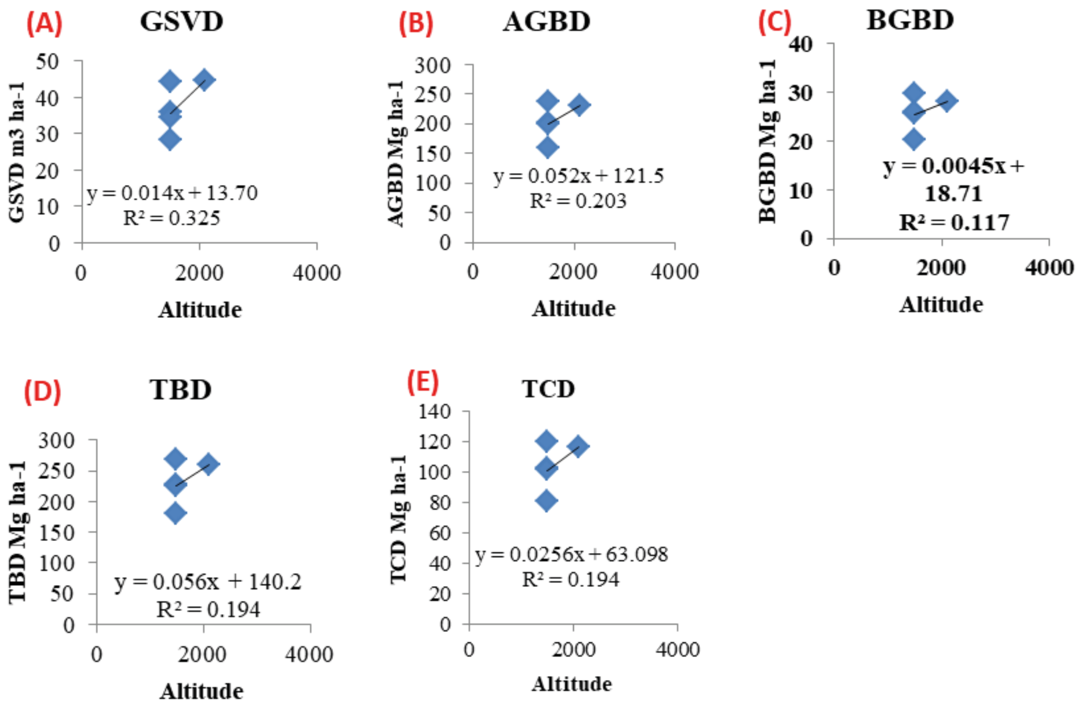

Figure 8. Correlation altitude with different carbon pools. (A) GSVD – Ground stock volume density; (B) AGBD – Above ground biomass density; (C) BGBD – Below ground biomass density; (D) TBD – Total biomass density; (E) TCD – Total carbon density

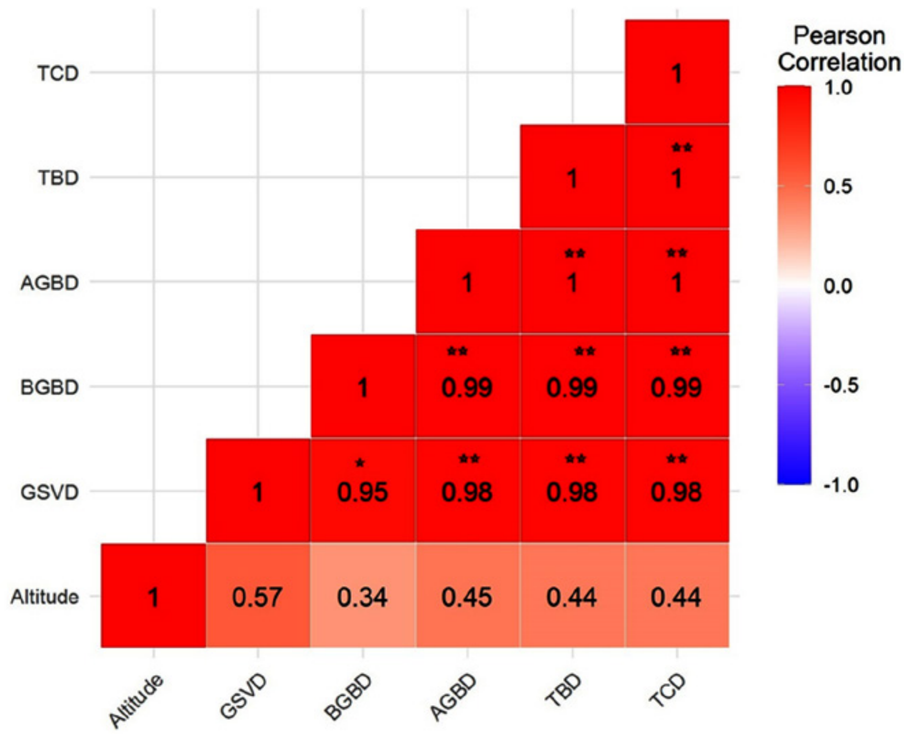

Figure 9. Pearson correlation among community biomass parameters and altitude. GSVD – Ground stock volume density, AGBD – Above ground biomass density, BGBD – Below ground biomass density, TBD – Total biomass density, TCD – Total carbon density.

**P<0.05, **P<0.01*

ground biomass density, below ground biomass density, total biomass density and total carbon density in the current study is similar to the worth detailed by Sharma et al. (2010, 2018) for Garhwal Himalayas. The isolation of total carbon density into above and below parts showed a similar pattern in every one of the forest locales. The commitment to the total carbon density of above ground biomass density at F1 (88.72%) and below ground biomass density (11.28%), at F2 above ground biomass density (89.18%) and below ground biomass density (10.82%), at F3 above ground biomass density (88.94%) and below ground biomass density (11.06%), at F4 above ground biomass density (88.68%) and below ground biomass density (11.32%) and F5 above ground biomass density (88.55%) and below ground biomass density (11.44%) in the current study is near the worth detailed (78.54% above ground biomass density and 21.46% below ground biomass density) by Sharma et al. (2018) for Garhwal Himalayas, (79% above ground biomass density and 21% below ground biomass density) for Pan India biomass (Chhabra et al., 2002), and Brazilian Amazon tropical clammy timberland (10-half by below ground biomass density) (Brown & Lugo, 1992). The pattern for total carbon density was like that of biomass (above ground biomass density / below ground biomass density), in light of the fact that carbon is straightforwardly connected with biomass, i.e., the higher the biomass the more noteworthy the carbon (Sharma et al., 2010).

Local area backwoods are ranch timberlands planted by local people for their merchandise and needs however because of current authorization of government towards transport framework, the streets are shown up to these networks their pattern of residing is changed, fuel wood is supplanted by biogas burners and in house utilizing wood is supplanted by a few sort of metallic combinations for example iron, silver, aluminum, even the old horticultural framework is being supplanting by current method (low weight farm vehicles) day by days, which are less tedious in contrast with old strategies for example Wooden Plow and so forth Canadell and Raupach (2008) called attention to that the general capability of the old growth forests to build C density can be considerable and tantamount to that of reforestation. With the assistance of above outcomes, it is presumed that local area backwoods can sequester same measure of carbon, sequester by old development remain, there are additionally illustration of mature dealt with that store comparable measure of C in biomass to practically identical old developed forest (Hoover et al., 2012; Molino-Valero et al., 2021). Old developed stand are on center lately and environmental examinations on these backwoods are generally regular, as we probably are aware each woodland is significant for us, growth of estate timberlands is connected with tree thickness of woods, with the foundation of the woodlands, as they become old the tree thickness inside the woods is diminished and woods become set up, so preservation of both old developed stands or naturally regenerating forests and community forests is a significant method for lessening CO_2 emanation as it very well might be more gainful than afforestation.

4. Conclusion

Present research proposes that community forests are playing their job quietly in the moderation of environmental carbon and vital for planned future. Loss of old community forestry system or established forests is centre for concern to the forest department, forest rangers and forestry researchers. Protection of community forests is truly necessary for the development of healthy ecosystem in future near human population in temperate area of Garhwal Himalaya Uttarakhand. Community forests are less inclined to forest fire in contrast with old development forests, since community forests possesses the high tree density which support the forest floor to stay muggy and cold and save the timberland floor from direct daylight, where as now and again the slant viewpoint likewise assume a critical part. While old developed forests doesn't have that a lot of tree thickness because of the battle for supplement, and the daylight came to the surface effectively and the floor stay less muggy in contrast with local area backwoods, and they stay dry throughout the mid year and are more inclined to flames. Disregarding one of their protection or conservation is risky for people in the future. Preservation of the two of them is the best way to adapt to environmental change and a worldwide temperature alteration. As we probably are aware the pattern of old cultivating in the networks close to the urban communities is decrease and will be supplanted by present day procedures so we need to look through some new strategy and execution to monitor the old cultivating methods.

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Appendix 1.
List of volume equations for the tree species in the study sites

Tree species	Volume equations
Alnus nepalensis D.Don	= – 0.136676 + 3.60113D
Cedrus deodara (Roxb. ex D. Don) G.Don	V = – 0.00165 + 8.209795D2
Cornus capitata Wall.	- 0.60124+5.32265 – 2:92195
Cupressus torulosa D.Don ex Lamb.	$\log_e V = 2.101388 + 2.418695 \log_e D$
Ficus religiosa L.	V= 0.03629 + 3.95389D – 0:84421
Ilex dipyreana Wall	- 0.60124+5.32265 – 2:92195
Juglans regia L.	V= – 0.207229 + 3.254007D
Lyonia ovalifolia (Wall.) Drude	$V = 0.03468 - 0.56878D + 4.72282D^2$
Myrica esculenta Buch.-Ham. ex D. Don	$V = 0.01284 + 0.2138\ D^2H$
Pinus roxburghii Sarg.	$V = 0.12844 - 2.23711D + 11.78506D^2 - 0.56094D^3$
Prunus cerasoides D.Don	$V = 0.00855 + 0.4432D^2 + 0.28813D^2H$
Pyrus pashia Buch.	- 0.60124+5.32265 – 2:92195
Quercus oblongata D. Don	$V = 0.06839 - 0.95816D + 6.06105D^2 + 2.66635D^3$
Rhododendron arboreum Sm.	$V= 0.06007 - 0{:}21874 + 3.63428D^2$
Rhus chinensis Mill.	$V = 0.01284 + 0.2138D^2H$
Rhus punjabensis J.L. Stew. ex Brand.	$V = 0.01284 + 0.2138D^2H$