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RESEARCH PAPER

Estimation of standing volume of natural forest across different forest types in Yellapur forest division

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Abstract: Forest plays a vital role in mitigating the climate change. Forest can act as a carbon sink and carbon source. The estimation of volume in different forest types act as an important variable to estimate the biomass accumulation and carbon sequestration potential of forests. The objective of the study was to estimate the standing volume in different forest types of Yellapur forest division by laying permanent plot. The total of 9 permanent plots, three plots each in dry, moist deciduous and semi-evergreen forest, each of 1ha (100 ×100 m) were laid out. The trees having girth at breast height ≥30 cm within the plots were given number using paint. The total of seven sub plots in each forest types were selected from permanents plots for the enumeration. The observations on growth parameter (tree height, girth at breast height and girth at base), were recorded. The findings of the study indicated that the highest number of stems were recorded in semi evergreen forest (578 stems ha^{-1}) and lowest was recorded in moist deciduous forest (439 stems ha^{-1}). The study revealed that the maximum average height was recorded in moist deciduous forest (13.61 m). It was observed that higher basal area (47.21 m^2 ha^{-1}) and volume (612.33 m^3 ha^{-1}) was recorded in semi evergreen forest and the lowest volume was recorded from dry deciduous forest (269.86 m^3 ha^{-1}). There was a significant difference in basal area and volume across different vegetation types in Yellapur forest division.

Key words: Basal area, Forest types, Permanent plot,Volume

Introduction

Forest plays a vital role in mitigating the climate change. Forest can act as a carbon sink and carbon source. The Forest is defined as an area set aside for the production of timber and other forest produce or maintained under woody vegetation for certain benefits (Khanna, 1977). Healthy forest vegetation stores and sequesters a greater amount of carbon compared to other terrestrial ecosystems. The presence of forest resources significantly contributes to the sustainability of life on the Earth. Innumerable services that support human existence and quality of life are provided by forests, which are essential ecological units that regenerate on their own. A significant proportion of the carbon is stored in the form of above-ground biomass making these forests vital for regulating the global carbon cycle and maintaining the stability of the biosphere's climate (Shi and Singh, 2002). The estimation of volume in different forest types act as an important variable to estimate the biomass accumulation and carbon sequestration potential of different forest types. Forest inventories are aimed at assessing growing stock and other quantitative, qualitative parameters of the forest such as standing volume, biomass, carbon stock, regeneration status, population and structure *etc*. India's forests are renowned for being among the most ecologically diverse terrestrial ecosystems on the planet housing a substantial portion of the world's terrestrial carbon (Shi and Singh, 2002). The growing stock estimation has traditionally been used for calculation of sustainable yield of timber from forests (Anon, 2019). The majority of tropical forests in the region have been impacted by various forms of cultural disturbances, with the exception of few pockets of undisturbed forests. Currently many studies have focused on quantification of floristic diversity and soil ecology in different forest types. But there are few studies on growth pattern and volume estimation of different vegetation in these areas. This study helps to understand the volume accumulation across forest types of Yellapur forest division.

Material and methods

The study was carried out in different forest types of Yellapur Forest Division of Uttara Kannada District. The study area map is shown in Fig 1. The total forest area of the division including Betta lands (protected forest) is 1,68,986.66 hectares. The Yellapur forest division is situated in the eastern part of Uttara Kannada district. It has dry deciduous forest in its eastern part, moist deciduous forests in the central part and semi-

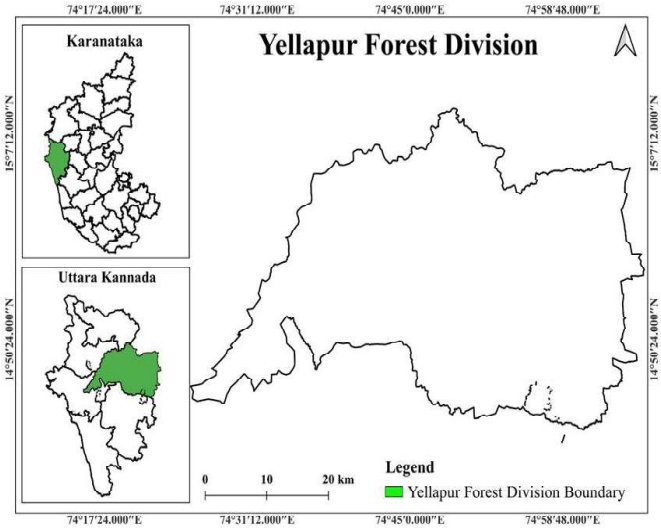

Fig 1. Study area map

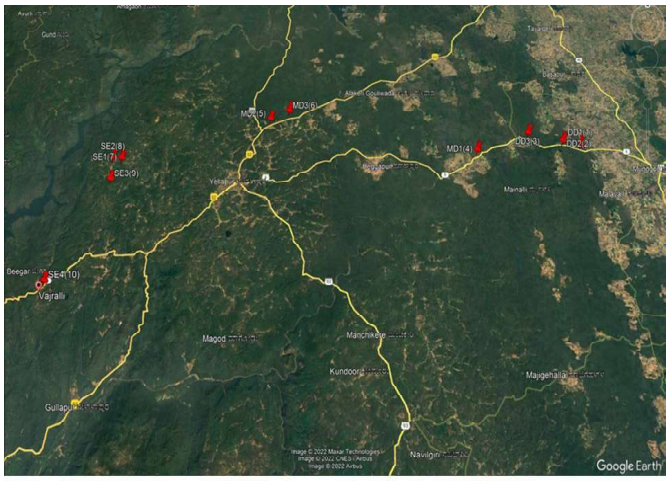

Fig 2. Location of permanent plots across different forest type of Yellapur forest division

evergreen forests in the western part. Major tree species found in tropical dry deciduous forest of Yellapur forest division include *Tectona grandis*, *Terminalia alata*, *Terminalia paniculata*, *Dalbergia latifolia*, *Anogeisus latifolia* and *Lagerstroemia lanceolata*. In tropical moist deciduous forest type of Yellapur forest division, the floristic composition includes, *Tectona grandis, Terminalia alata, Lagerstroemia lanceolata, Lannea coromandelica, Pterocarpus marsupium, Dalbergia latifolia, Anogeissus latifolia, Mitragyna parviflora, Terminalia bellerica, Bombax ceiba, Grewia tiliaefolia, Terminalia paniculata, Madhuca species, Schliechera oleosa, Adina cardifolia, Xylia xylocarpa* and *Diospyrospecies*. In the tropical semi evergreen forest type, the diversity of the tree species is high. This region contains species like *Holigarna arontiana*, *Artocarpus hirsutus*, *Myristica malabarica*, *Aporosa lindleyana*, *Polyalthia fragrans*, *Vitex altissima*, *Syzigium lacetum* and *Hopea parviflora*.

Reconnaissance survey was carried out in the study area to identify and finalize the sample site locations for collecting the ground inventory data. The permanent plots of 1ha (100 m×100 m) each were laid out as per CEOS (Committee on Earth Observation Satellites) protocol. There were 9 subplots each of size 33.33m×33.33m were marked using nylon ropes. The total of 9 permanent plots, three plots each in dry, moist deciduous and semi-evergreen forest were laid 9 (Fig 2). The total of 7 sub plots were selected from three permanents plots (one ha) laid randomly in different forest area for the enumeration. All the trees having girth at breast height ≥30 cm within the plots were given number and marked using permanent paint (Tamilselvan *et al*., 2021). Each tree within a sub plot were measured for its girth at breast height and at base and height.

The experiment was laid out in Randomised Block Design (RBD) with three treatments and seven replications. Three different forest types of Yellapur forest division of Uttara Kannada district were considered as three treatments and seven subplots from each forest types were taken as replications.

The total height of the tree was measured using digital hypsometer, Girth at Breast Height (GBH) and Girth at Base (GAB) were recorded using measuring tapes.

Basal area measures the collective cross-sectional area of trunk within a defined area in the forest. The basal area of individual trees having girth at breast height ≥ 30 cm was calculated using formula (Chaturvedi and Khanna, 1984).

$$\text{Basal area } (m^2ha^{-1}) = \frac{G^2}{4\pi}$$

Where, G is the girth at breast height and π is constant equal to 3.14

Basal area of individual tree in each quadrat were calculated and summed to get total basal area of the quadrat. Further it was extrapolated to per hectare basis and expressed in $m^2 ha^{-1}$.

The Form factor is the ratio of volume of a tree or its part to the volume of a cylinder having the same length and cross-sectional area (Chaturvedi and Khanna, 1984). The artificial form factor was calculated using the formula.

$$\text{Form factor} = \frac{(\text{Girth at breast height})^2}{(\text{Girth at base})^2}$$

The data collected on various parameters like GBH, GAB, tree height was used to estimate the volume of standing tree. The volume of standing tree was calculated using formula stated below as suggested by (Chaturvedi and Khanna,1984) and expressed in m^3. Based on the mean total volume per tree, total volume per hectare was calculated.

Volume of tree ($m^3 ha^{-1}$) = Basal area (m^2) ×Height (m) ×form factor

Results and discussion

The number of individuals in various vegetation types within the Yellapur forest division is shown in Table 1. The highest number of trees, amounting to 578 trees per hectare, was observed in the semi-evergreen forest, followed by the dry deciduous forest with 515 trees per hectare. In contrast, the moist deciduous forest exhibited the lowest number of trees, (439 trees per hectare). The greater number of trees in semi

Table 1. Tree density, average tree height, GBH, GAB in forest types of Yellapur forest division of Uttara Kannada district

Forest type	Tree density(Stems ha^{-1})	Average tree height(m)	Average GBH(cm)	Average GAB(cm)
Dry deciduous	515±84.55	11.93±0.32	80.34±8.25	96.72±11.21
Moist deciduous	439±38.31	13.61±0.41	86.48±3.71	99.66±4.00
Semi evergreen	578±40.57	12.05±0.91	84.27±1.72	96.12±2.46
S. E m (±)	49.30	0.61	5.65	7.25
C.D@5%	NS	NS	NS	NS

*Fig in column are GBH-Girth at breast height, GAB-Girth at base, NS = Non-significant, CD = Critical difference, SEm-Standard error of mean.

evergreen forest can be attributed to the increased soil productivity and moisture availability, which in turn enhanced regeneration status of trees.

These findings are in comparable with the Khaple *et al.* (2016); they reported the similar trend, where greater number of individuals were recorded in dry deciduous forest than in moist deciduous, which shows presence of a greater number of stems from lower diameter class. The number of individuals in the present study are comparatively lesser than the study report from Baishya *et al.* (2009).

In the current study, the average height of trees across different vegetation types in the Yellapur forest division were compiled and presented in Table 1. The results revealed that the higher average tree height was recorded in the moist deciduous forest (13.61 m) followed by the semi evergreen forest with an average height of 12.05 m. Conversely, the dry deciduous forest exhibited the minimum tree height, measuring at 11.93 m. It was determined that there was no significant variation in tree height across the various vegetation types. The maximum tree height in semi evergreen forest compared to dry deciduous forest was due to continuous availability of moisture compared to other forest type. The semi evergreen forest often includes canopy dominant species that are well adapted to utilizing available resource efficiently. The competition for sunlight is usually intense due to dense vegetation. As a result, trees grow taller to reach the light. The maximum height can be attributed to higher photosynthetic structure of plant (Kumar *et al.,* 2011).

It was observed that the moist deciduous forest exhibited the highest GBH, with an average measurement of 86.48 cm, closely followed by the semi-evergreen forest, which recorded an average GBH of 84.27 cm. On the other hand, the dry deciduous forest exhibited the lowest average GBH, measuring at 80.34 cm (Table.1).

The average girth at base (GAB) across various forest types in the Yellapur forest division is given Table 1. The moist deciduous forest exhibited the highest average GAB measuring 99.66 cm, closely followed by the dry deciduous forest with an average GAB of 96.72 cm. In contrast, the semi evergreen forest displayed the lowest average GAB recording 96.12 cm. While overall statistical analysis showed no significant variation in GAB among the different vegetation types.

In the current study, the form factor of each tree across different vegetation types in the Yellapur forest division were calculated and presented in Table 2. The maximum form factor was recorded from semi evergreen forest (0.76) and least was recorded from dry deciduous forest (0.71) and it was found to be statistically non-significant among various forest type.

Table 2. Form factor, basal area, volume in different forest types of Yellapur forest division of Uttara Kannada district

Forest type	Form factor	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})
Dry deciduous	0.71±0.02	27.25±2.28	269.86±35.47
Moist deciduous	0.75±0.008	32.14±1.31	402.80±14.96
Semi evergreen	0.76±0.01	47.21±2.86	612.33±28.61
S. Em (±)	0.01	2.13	27.66
C.D@5%	NS	6.66	86.19

*Fig in column are NS = Non-significant, CD = Critical difference, SEm- Standard error of mean.

Fig 3. A comparative analysis between basal area/ha and volume/ha in different forest types of Yellapur forest division

The basal area per hectare of different vegetation types within the Yellapur forest division is presented in Table 2. The values ranged from 27.25 m^2 ha^{-1} in the dry deciduous forest to 47.21 m^2 ha^{-1} in the semi-evergreen forest. The more basal area was recorded in semi evergreen forest (47.21m^2 ha^{-1}) and lowest was in dry deciduous forest (27.25 m^2 ha^{-1}). The moist deciduous forest displayed a basal area of 32.14 m^2 ha^{-1}, which was low comparable to that of the semi-evergreen forest. Basal area of evergreen forest of Western Ghats of India was found to be 33.7 to 48.7 m^2 ha^{-1} (Pascal, 1992) and these results are found to be lesser than the current study which reported 47.21 m^2 ha^{-1} in semi evergreen forest. A statistically significant difference in basal area was observed among the various vegetation types. Conversely though the number of trees per ha was less in moist deciduous forest, the basal area per ha was more (32.14 m^2 ha^{-1}) compared to dry deciduous forest (27.25 m^2 ha^{-1}) indicating that number of trees will not decide the higher basal area but other parameters like GBH and height. The results are in line with the Khaple *et al.,* (2016) who reported higher basal area of 20.58 $m^2$$ha^{-1}$ in moist deciduous forest compared to dry deciduous forest (10.28 m^2 ha^{-1}). Among all the forest type of Yellapur forest division higher basal area was recorded in semi evergreen forest (47.21 m^2 ha^{-1}) due to a greater number of buttressed trees which directly contribute to maximum volume in trees.

The volume per hectare of different vegetation types within the Yellapur forest division is given in Table 2. The highest volume was recorded in the semi-evergreen forest, measuring 612.33 m^3 ha^{-1}, followed by the moist deciduous forest with a volume of 402.80 m^3 ha^{-1} and least volume in dry deciduous forest (269.86 m^3 ha^{-1}). Furthermore, the volume of the moist deciduous forest was found significant variation to that of the dry deciduous forest. A statistically significant difference in volume was observed among the various vegetation types, particularly in the semi-evergreen and dry deciduous forests. The high volume estimated in semi evergreen forest is due to higher basal area (47.21 m^2 ha^{-1}) in semi evergreen forest (Fig.3).

Conclusion

In this study, the semi-evergreen forest stood out with the highest tree density, with 578 trees per hectare, closely followed by the dry deciduous forest with 515 trees per hectare. The moist deciduous forest on the other hand exhibited the tallest trees, reaching a remarkable average height of 13.61 m, while the semi-evergreen forest featured slightly shorter trees with an average height of 12.05 m. Notably, the semi-evergreen forest also excelled in terms of basal area, recording a substantial 47.21 m^2 ha^{-1}, indicative of a dense and larger trees. In contrast the moist deciduous forest displayed a basal area of 32.14 m^2ha^{-1}. Furthermore, the semi-evergreen forest displayed maximum tree volume with 612.33 m^3 ha^{-1} followed by moist deciduous forest closely at 402.80 m^3 ha^{-1}. There was a significant difference in basal area and volume across different vegetation types in Yellapur forest division. These findings provide valuable insights into the characteristics and ecological significance of different forest types within the study area.

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