Original Research Article

Forest Dynamics and Diversity Assessment through Permanent Plot Inventories in Yellapur Forest Division

Abstract

The study aims to assess the forest composition, and structured biomass across various forest types in the Yellapur Forest Division, located in Uttara Kannada, Karnataka. The division is represented by three distinct forest types *viz.*, Dry Deciduous, Moist Deciduous and Semi-Evergreen forests. Ten permanent plots were established in these forest types to monitor long-term forest dynamics, with three plots in the Dry Deciduous, three in the Moist Deciduous and four in the Semi-Evergreen forest areas. The inventory parameters measured included tree count, species diversity, average tree height, girth at breast height (GBH)and total volume.Inthe Dry Deciduous forests, *Tectonagrandis* (Teak) was the dominant species in all plots, with co-dominant species like *Terminaliapaniculata* and *Terminaliaalata* also prevalent. The average tree height ranged from 8.9 m to 13.91 m, with volumes varying from 150.05 m³/ha to 409.40 m³/ha. Moist Deciduous forests showed a higher species diversity, with *Tectonagrandis*, *Lagerstroemia lanceolata* and *Dalbergialatifolia* being common. The average tree height was between 12.95 m and 16.08 and volumes ranged from 194.97 m³/ha to 309.37 m³/ha. In the semi-evergreen forests, species such as *Holigarnaarnottiana*, *Myristicamalabarica*and*Vitexaltissima* dominated the plots. These forests exhibited greater tree heights (up to 13.98 m) and higher volumes (up to 436.37 m³/ha) compared to the other forest types.This research provides valuable insights into the structural characteristics and ecological composition of forests in Yellapur, which are crucial for future forest management and conservation strategies. The data collected from these permanent plots will serve as a baseline for monitoring forest growth, carbon storage and biodiversity in the region.

Keywords: Forest types, Permanent plot, Volume, Tree Diversity

Introduction

Forests play a substantial role in terrestrial ecosystems, encompassing roughly 30 per cent of the Earth's land area (Anon, 2010). By means of photosynthesis, forests absorb carbon dioxide and store it as biomass, making a significant contribution to mitigating global climate change. It is estimated that most of the aboveground carbon (over 80 %) and a substantial

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portion of belowground carbon (about 40%) are held within forest ecosystems (Dixon *et al*., 1994). Forests have the remarkable ability to absorb double the carbon they release. Globally. they are responsible for absorbing 29 per cent of the carbon emissions generated from the combustion of fossil fuels (Harris *et al*., 2021). At present, Earth's forests contain 400 PgC (petagrams of carbon) in biomass, with the potential to increase this storage to 772 PgC (Pan *et al*., 2013), making them a powerful tool for combatting climate change. Among these forests, tropical forests stand out as centres of biodiversity and carbon sequestration. surpassing other forest types in their ability to capture carbon (Martin *et al*., 2013). In India, tropical forests cover 64 per cent of the total forested area and hold immense significance for local communities relying on them for sustenance (Anon, 2011).

In India's context, the tropical deciduous forest is divided into two categories based on precipitation patterns: moist deciduous forests and dry deciduous forests. Moist deciduous forests are prevalent in regions receiving rainfall between 1000 to 2000 mm annually, with a dry period lasting three to four months. Trees in these forests shed their leaves during winter and regrow them around March-April. These forests account for 19.73 per cent of India's forest types (Anon, 2021). They are widely distributed across states like Tamil Nadu, Arunachal Pradesh, Assam, Meghalaya, Mizoram, Bihar: West Bengal, OdishaandUttarakhand. Characterised by 2 to 3 layers of vegetation, they typically have a lower species diversity compared to tropical evergreen and semi-evergreen forests. Tropical dry deciduous forests encompass roughly 38.2 per cent of India's forested land (Anon, 2021). prevail in regions marked by distinct seasonal rainfall patterns and prolonged droughts during the year. These forests are characterized by trees not exceeding 25 meters in height, featuring a canopy of deciduous trees that thrive in well-lit conditions. Stretching from Kanyakumari to the base of the Himalayas, they thrive in regions receiving 800 to 1200 mm of rainfall, with extensive areas serving as suitable wildlife habitats. These forests are primarily dominated by Teak and dry Sal communities in the southern and northern areas, respectively some regions host a blend of tree species such as Anogeissuspendula, BoswelliasermaHardwickiabinata. Acacia nitric, MadhucasilicaandBatestmorsesperma, Notably Acacia catecha and Dalbergiasissooare prominently found in areas with recently developed soils.

India also has a significant stretch of area under Tropical semi-evergreen forests bordering tropical wet evergreen arcas, acting as a transition between evergreen and m deciduous forests. The lower canopy remains evergreen, while the upper canopy species leaves briefly in dry seasons. Covering 13.79 per cent of Indian forest types, they are deme multi-layered, 24-36 m tall, with rainfall between 1500-2500 mm annually (Anon, 2021)

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Canopies aren't continuous, with lower species diversity compared to evergreen forests. Trees like Myristicamalabaricaandvitexaltissimadisplay buttressed stems. These forests feature bamboo, canes, ferns, climbers and abundant epiphytes like ferns and orchids.The significant rise in atmospheric carbon dioxide, currently measured at 416 ppm continues to be a major driver of global warming. The storage of carbon across variouscompartmentswithin forest ecosystems plays a vital role in counteracting global warming and lessening the negative impacts of climate change. Presently, the total carbon stocks in global forests are approximately 861±66 Pg C (Pan *et al*., 2011). The collective carbon stored within forest vegetation is roughly estimated at 359 billion tonnes (Allen *et al*., 2010).

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India is ranked fourth globally for its notable CO, emissions (Muntean*et al*., 2018) However, in a seemingly paradoxical scenario, India also boasts a considerable forest cover spanning an area of 7,12,249 square kilometres. This expansive forest expanse holds a substantial capacity for carbon storage, contributing to mitigating environmental impacts. The total carbon stock within the Indian forest ecosystem is estimated to reach a noteworthy 7.124.6 million tonnes (Anon, 2021). However, it is important to note that these figures encompass not only natural forests but also encompass tree plantations, which are often dominated by non-native species. Turning our focus to the intricate landscapes of the Western Ghats, a region of ecological significance, there exists a notable gap in research assessing the carbon stocks within its natural forests. A study by Seen *et al*. (2010), discovered that despite acknowledging the mounting pressures of deforestation and land-cover changes, unveiled that the forests of the Western Ghats retain a considerable 0.43 petagrams (Pg) carbon stock. This underscores the resilience of these ecosystems in the face of challenges. However, an alternative perspective emerges from the research by Osuri*et al*. (2014), indicating that even large, well-protected forest fragments within the Western Ghats showcase a 40 per cent reduction in above-ground biomass carbon (AGBC) when compared to contiguous forests. This reduction can be attributed to alterations in structural attributes, shifts in tree sizes and compositional changes. This brings into focus the intricate dynamics that govern carbon storage in varying environmental contexts. Further insights from Padmakumar*et al*. (2018) underscore the importance of structural attributes in carbon storage. Their examination of tree carbon stocks in the Chinnar Wildlife Sanctuary within the Western Ghats demonstrated a robust positive correlation between carbon stocks and basal area, a crucial structural metric. However, the broader picture presents a gap in our understanding of ecosystem-level carbon stocks, their intricate relationships with biodiversity, structural attributes and environmental factors in India's tropical forests, specifically in the context of the Western Ghats. Such insights would not only provide a comprehensive perspective on carbon storage mechanisms but would also shed light on the impact of structural attributes on the distribution of carbon among various ecosystem components, including trees. Such insights are invaluable in developing strategies to sustain carbon stocks and safeguard biodiversity within the complex tapestry of tropical forests.

India, an expansive nation teeming with diverse biological richness, features an extensive landscape. In this context, forests occupy the position of the second-largest land use, closely following agriculture. Notably, approximately 275 million rural inhabitants of India draw upon forests as a source of sustenance and a component of their livelihoods, as articulated by the World Bank. Therefore, the quantum of carbon stocked in various forest ecosystems is a priority task.

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 Figure 1.The total forest area of the division including Betta lands (protected forest) is 1,68,986.66 hectares. TheYellapurforest 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-evergreen forests in the western part.Major tree species found in tropical dry deciduous forest of Yellapur forest division include *Tectonagrandis*, *Terminaliaalata*, *Terminaliapaniculata*, *Dalbergialatifolia*, *Anogeisuslatifolia*and *Lagerstroemia lanceolata*. In tropical moist deciduous forest typeofYellapur forest division, the floristic composition includes, *Tectonagrandis*, *Terminaliaalata*, *Lagerstroemia lanceolata*, *Lanneacoromandelica*, *Pterocarpusmarsupium*, *Dalbergialatifolia*, *Anogeissuslatifolia*, *Mitragynaparviflora*, *Terminaliabellerica*, *Bombaxceiba*, *Grewiatiliaefolia*, *Terminaliapaniculata*, *Madhuca species*, *Schliecheraoleosa*, *Adina cardifolia*, *Xyliaxylocarpa*and*Diospyros species*. In the tropical semi evergreen forest type, the diversity of the tree species is high. This region contains species like *Holigarnaarontiana*, *Artocarpushirsutus*, *Myristicamalabarica*, *Aporosalindleyana*, *Polyalthiafragrans*, *Vitexaltissima*, *Syzigiumlacetum* and *Hopeaparviflora*.

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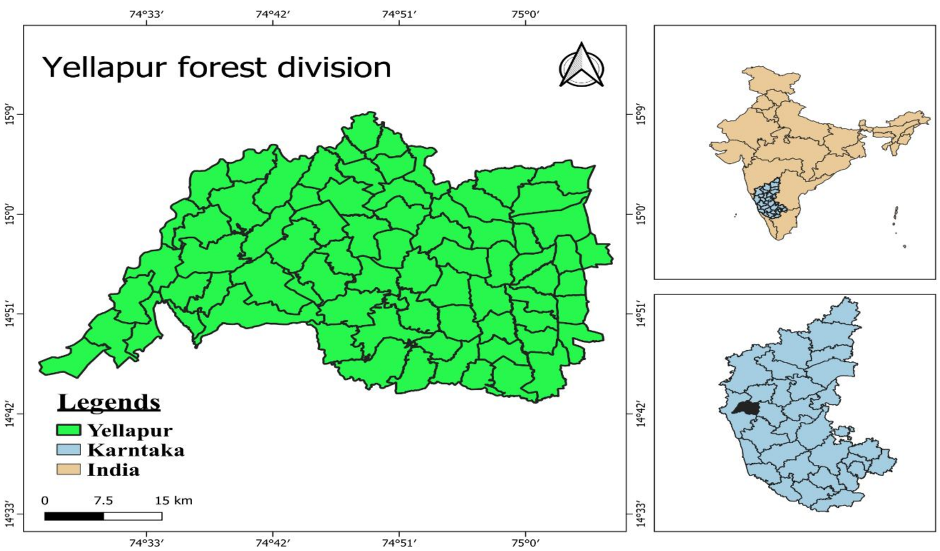

Fig 1: study area

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A reconnaissance survey was carried out in the study area to identify and finalize the sample site locations for collecting the ground inventory data. The9permanentplots of 1ha (100 m×100 m) each were laid outas per CEOS (Committee on Earth Observation Satellites) protocol. There were 9 subplots each of size 33.33m×33.33m marked using nylon ropes. A total of 9 permanent plots, three plots each in dry, moist deciduous and semi-evergreen forests were laid 9 (Fig 2).All the trees having girth at breast height ≥30 cm within the plots were given numbers and marked using permanent paint (Tamilselvan*et al*., 2021). Each tree within a subplot was measured for its girth at breast height and at base and height (Fig.2).

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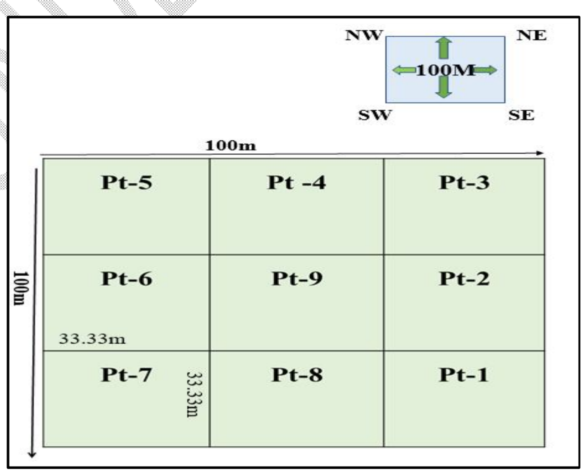

Fig.2 Layout of permanent plot

The experiment was laid out in Randomised Block Design (RBD) with three treatments and seven replications. Three different forest types of the 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 a 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 ≥ 30cm was calculated using formula (Chaturvedi and Khanna, 1984).

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

Where, G is the girth at breast height and expressed in meter (m).

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^2ha^{-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.

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

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^3ha^{-1}) = Basal area (m^2) ×Height (m) ×Form factor

Biodiversity assessment

The study was conducted in 10 permanent plots, each measuring 1 ha, within the Yellapur forest division, representing various forest types and conditions. Systematic sampling was carried out within each plot, with subplots of fixed dimensions laid out for detailed measurements. All trees within the plots were identified to species level using field guides and local expertise and the dominant and co-dominant species were determined based on relative abundance and basal area. Tree height was measured using a clinometer or laser rangefinder and categorized into classes such as <10 m, 10–20 and>20 m. Diameter at breast height (DBH) was recorded using a diameter tape and classified into categories such as <10 cm, 10–30 and >30 cm.

Result and discussion

Table 1: Tree species and their distribution found in the 10 inventoried permanent plots

Name of the species	Total no. of trees	Plot-wise occurrence of tree species and their frequency									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Adina cordifolia	2					*					
Anogeissuslatifolia	174	*	*	*		*					
Aporosalindleyana	116						*	*	*	*	*
Arashinanoga	23									*	*
Artocarpuslakoocha	6							*	*		*
Artocarpushirsutus	136					*	*	*	*	*	*
Averrhoacarombola	1					*					
Bauhinia spp	4		*		*		*				
Bekkenaucchu	6							*	*		
Bombaxceiba	1										*
Calophyllumapetalum	25							*	*		*
Careyaarborea	13			*		*	*				
Carissa carandus	6	*				*	*				
Caryotaurens	8						*		*	*	*
Chandakal	6					*	*				
Cinnamomummalabatrum	6					*					
CinnamomumZeylenicum	32							*	*	*	*
Cordiadichotoma	9	*	*	*		*					
Cordiamyxa	1			*							
Dalbergialatifolia	90	*	*	*	*						
Dalbergiasissoo	1						*				
Terminaliaanogeissiana	6					*					
Dilleniapentagyna	28					*	*				
Diospyrosmelanoxylon	8			*							
Diospyrosmicrophylla	72							*	*	*	*
Dysoxylonglandulosum	18									*	
Emblicaofficinalis	3			*			*				
Eugenia utilis	46							*	*	*	
Ficusmicrophylla	2			*							
Ficustsjahela	1							*			
Ficusvirens	1					*					

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Flacourtiamontana	3					*					
Gandhagarige	1					*					
Garcinia indica	4					*		*			*
Garcia parviflora	2								*		
Glachidionmalabaricum	58							*	*	*	
Gmelinaarborea	2					*	*				
Grewiatilifolia	8						*		*		
Holarrhenapubescens	6						*				
Holopteleaintegrifolia	4						*				
Holigarnaarnottiana	145					*		*	*	*	*
Hopeaspp	1										*
Crassulaovata	1					*					
Holiptelea sp.	1					*					
Syzygiumcumini	5					*					
Calotropisgigantea	56							*	*	*	
Murrayakoenigii	16										*
Camphoraofficinarum	1										*
Lagerstroemia lanceolata	149	*	*	*	*	*	*				
Lagerstroemia parviflora	10							*			
Lagerstroemia spp	4				*						
Lanneacoromandelica	9	*					*				
Linocieramalabarica	41										*
Lophopetalumwightianum	29							*	*	*	*
Machilusmacrantha	3					*					
Mammeasuriga	11							*	*	*	
Mangifera indica	7					*		*			*
Micheliachampaca	11					*		*	*	*	*
Mimusopselengi	60							*	*	*	*
Mitragynaparviflora	3					*					
Myristicamalabarica	310					*		*	*	*	*
Terminaliaelliptica	1								*		
Perseamacrantha	15								*	*	*
Polyalthiacoffeoides	43							*		*	
Polyalthiafragrans	75							*	*	*	
Prosopis cineraria	1					*					
Pterocarpus marsupium	7	*				*					
Sideroxylon tomentosum	4								*		*
Strychnosnux vomica	22					*	*				*
Sygygiumzeylanicum	5							*	*		
Syzygiumcumini	24					*	*		*	*	*
Syzygiumlaetum	140							*	*	*	*
Tabernaemontanadivaricata	2						*				
Tectonagrandis	1728	*	*	*	*	*	*				

Terminaliaalata	118	*	*	*			*		*		*
Terminaliabellarica	19					*	*		*		*
Terminaliapaniculata	374	*	*	*	*	*	*	*	*		*
Terminaliatomentosa	11	*									
Toonaciliata	65					*	*	*	*	*	*
Vateria indica	3					*				*	
Vitexaltissima	103					*	*	*	*		*
Xyliaxylocarpa	48						*	*	*	*	*
Moringaolerifera	60										*
Total no. of trees =	4680										

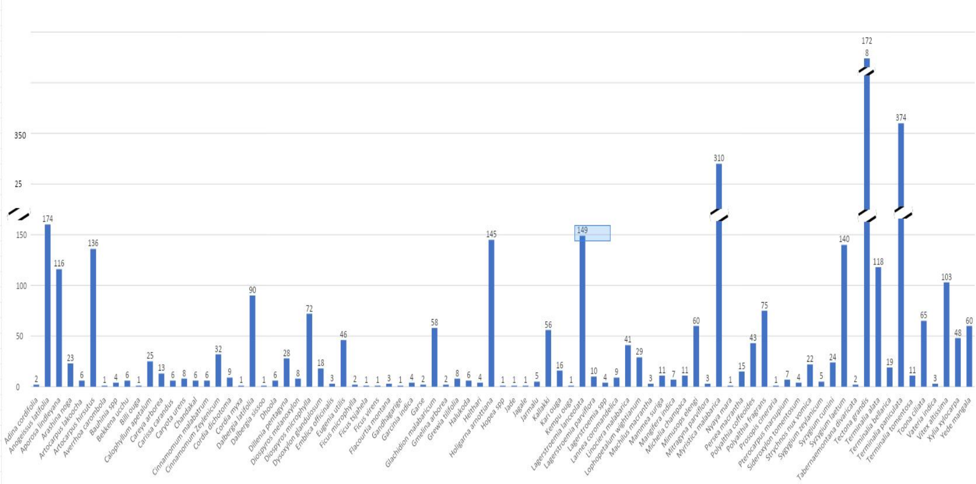

Figure.3. Tree species and their frequency over 10 plots

A total of 4,680 individual trees belonging to 82 species were recorded across 10 plots, highlighting significant species diversity in the study area. *Tectonagrandis* was the most dominant species, with 1,728 individuals, followed by *Terminaliapaniculata* (374 individuals) and *Myristicamalabarica* (310 individuals), collectively accounting for a substantial proportion of the tree population. Other notable species in terms of abundance included Lagerstroemia lanceolata, *Vitexaltissima* and *Holigarnaarnottiana*, which also demonstrated considerable presence across multiple plots (Table 1).

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The distribution of species varied, with some, such as *Tectonagrandis*, *Terminaliapaniculata* and *Lagerstroemia lanceolata*, being widely distributed across most plots, indicating their adaptability to different site conditions. In contrast, species like Caryotaurens, *Polyalthiafragrans* and *Mimusopselengi* were observed in fewer plots, reflecting more localized patterns of occurrence. This variation in distribution suggests differences in ecological preferences and potential microhabitat requirements among species. Overall, the

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findings indicate a diverse and heterogeneous forest composition with both widespread and spatially restricted species, contributing to the ecological complexity(Fig. 3).

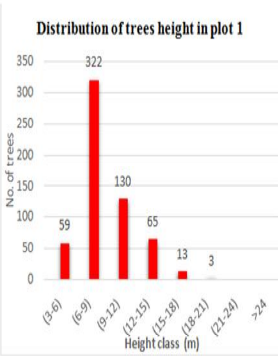
Table 2: Average height, Basal area and Volume in different forest types of Yellapur forest division of Uttara Kannada district.

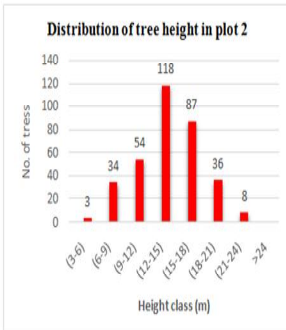
Forest type	**Average height (m)**	**Basal area(m^2/ha)**	**Volume(m^3/ha)**
Dry deciduous	11.76	28.77	289.79
Moist deciduous	15.25	23.59	233.55
Semi evergreen	12.39	31.44	342.35
C.D@5%	NS	NS	NS
SE m ±	1.26	3.99	61.80

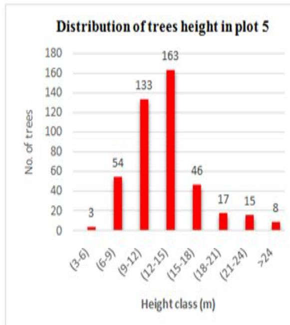
Figures in column are NS = Non-significant,CD = critical difference, SEm- Standard error of mean.

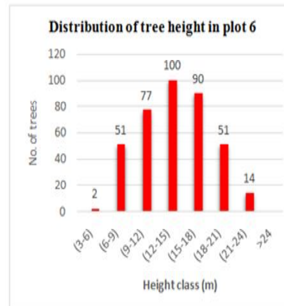
The comparative study of forest types in the Yellapur forest division of Uttara Kannada district revealed notable differences in average height, basal area, and volume. Moist deciduous forests recorded the tallest average height at 15.25 meters, followed by semi-evergreen forests at 12.39 meters, while dry deciduous forests had the shortest height at 11.76 meters. In terms of basal area, semi-evergreen forests showed the highest value at 31.44 m^2/ha, followed by dry deciduous forests at 28.77 m^2/ha. Moist deciduous forests recorded the lowest basal area at 23.59 m^2/ha. Similarly, the volume of wood was the highest in semi-evergreen forests (342.35 m^3/ha), followed by dry deciduous forests (289.79 m^3/ha), with moist deciduous forests showing the lowest value (233.55 m^3/ha) (Table 2).

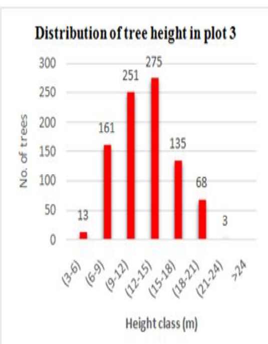
The observed differences in average height, basal area, and volume were significant, indicating variability in forest structure among the different forest types. Semi-evergreen forests demonstrated a better growth performance in terms of basal area and volume, while moist deciduous forests excelled in tree height. Dry deciduous forests showed intermediate values for most parameters.

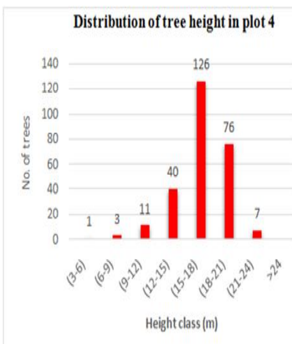

Distribution of trees height in plot 1
No. of trees
Height class (m)
59 322 130 65 13 3
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24

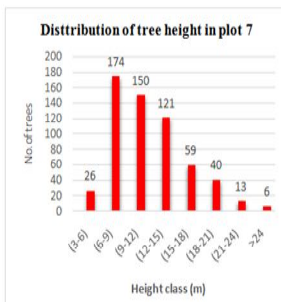

Distribution of tree height in plot 2
No. of trees
Height class (m)
3 34 54 118 87 36 8
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24

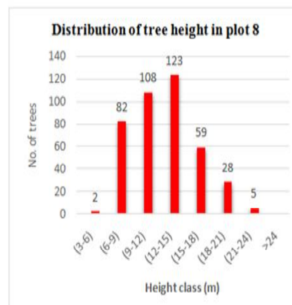

Distribution of trees height in plot 5
No. of trees
Height class (m)
3 54 133 163 46 17 15 8
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24

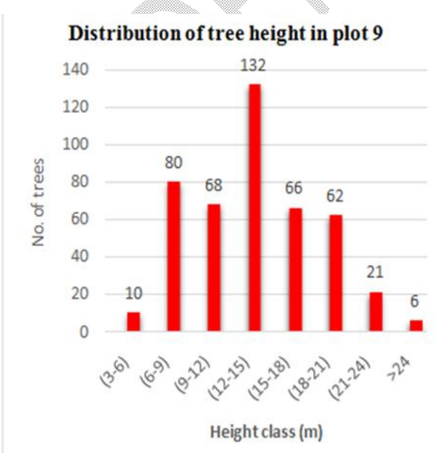

Distribution of tree height in plot 6
No. of trees
Height class (m)
2 51 77 100 90 51 14
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24


Distribution of tree height in plot 3
No. of trees
Height class (m)
13 161 251 275 135 68 3
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24


Distribution of tree height in plot 4
No. of trees
Height class (m)
1 3 11 40 126 76 7
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24


Disttribution of tree height in plot 7
No. of trees
Height class (m)
26 174 150 121 59 40 13 6
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24


Distribution of tree height in plot 8
No. of trees
Height class (m)
2 82 108 123 59 28 5
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24


Distribution of tree height in plot 9
No. of trees
Height class (m)
10 80 68 132 66 62 21 6
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24

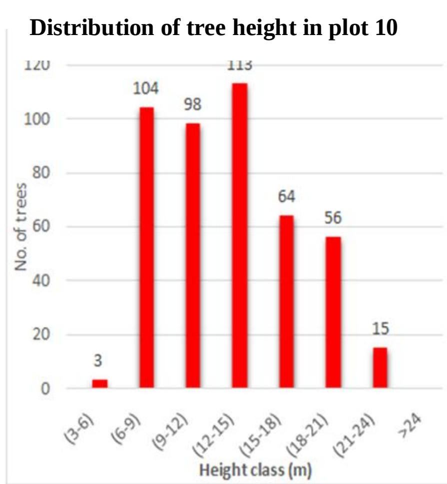

Distribution of tree height in plot 10
No. of trees
Height class (m)
3 104 98 113 64 56 15
(3-6) (6-9) (9-12) (12-15) (15-18) (18-21) (21-24) >24

Fig. 4. Distribution of trees in different height (m) classes in the inventoried permanent plots (1-10)

The tree height distribution across all ten inventoried permanent plots reveals a consistent dominance of medium-height trees, primarily in the 12–15 m and 15–18 m height classes. In Plot 1, the 12–15 m class is most prominent, with 322 trees, followed by the 9–12 m class (130 trees), while lower and taller height classes contribute minimally. Similarly, Plot 2 shows a peak of 118 trees in the 12–15 m class, with declining numbers in adjacent classes. Plot 3 also exhibits a strong concentration in the 12–15 m class (275 trees), gradually decreasing toward lower and taller classes. In Plot 4, the 12–15 m height class dominates (126 trees), with a sharp decline in other classes. Plot 5 and Plot 6 show a similar pattern, with the majority of trees in the 12–15 m class (163 and 100 trees, respectively), supported by smaller contributions from the 9–12 m and 15–18 m classes (Fig. 4).

Plots 7 and 8 also exhibit a dominance of mid-range height classes. Plot 7 peaks at 174 trees in the 12–15 m class, with moderate contributions from the 9–12 m and 15–18 m classes. Plot 8 shows 123 trees in the 12–15 m class and a gradual decrease across other height classes. Plot 9 is characterised by 132 trees in the 12–15 m class, followed by 80 and 68 trees in the 9–12 m and 15–18 m classes, respectively. Lastly, Plot 10 displays a similar trend, with 113 trees in the 12–15 m class and a gradual decrease in both lower and higher height classes.

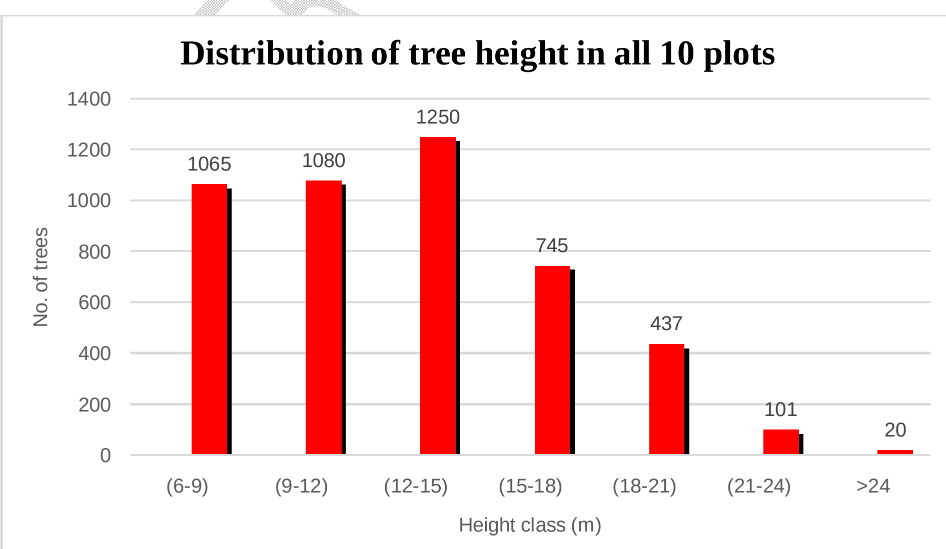
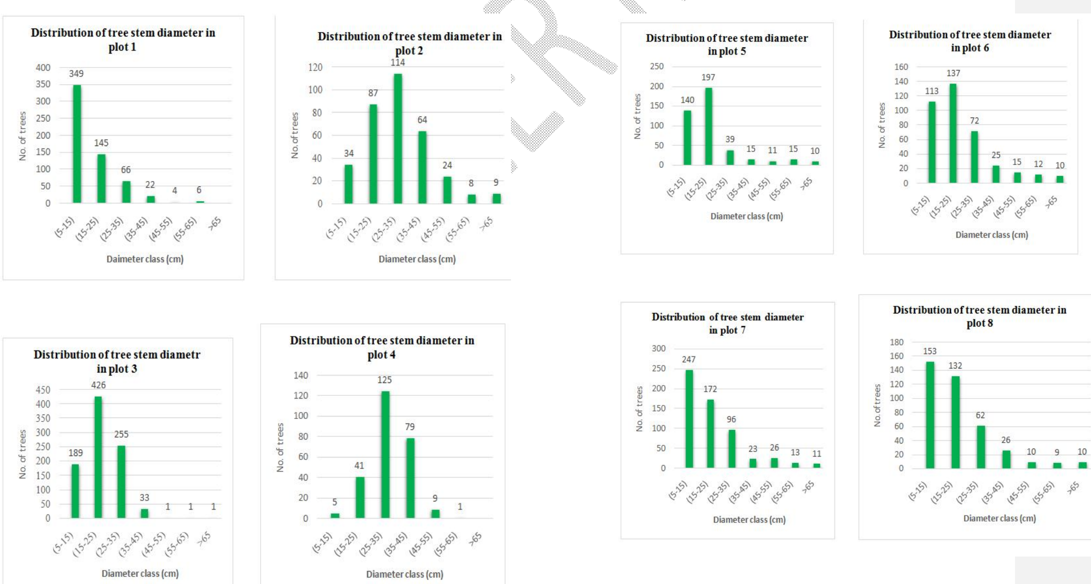
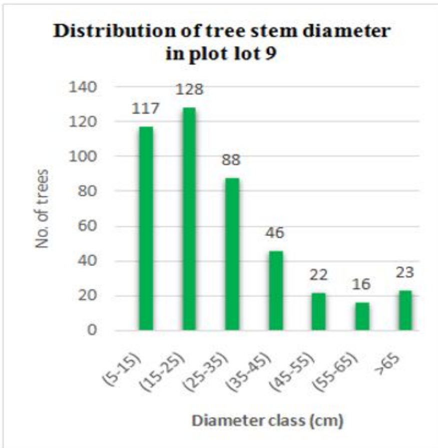


Fig. 5. Distribution of overall tree height (m) classes in all 10 permanent plots

The graph represents the overall distribution of tree heights across all ten inventoried plots. The majority of trees are concentrated in the 12–15 m height class, with 1,250 trees, followed by the 9–12 m (1,080 trees) and 6–9 m (1,065 trees) classes. These three height classes together make up the largest portion of the forest, indicating a predominance of medium-sized trees. The 15–18 m class has 745 trees and the taller height classes (18–21 m, 21–24 and>24 m) show a noticeable decline, with 437, 101and 20 trees, respectively. The 3–6 m class also has relatively fewer trees (122). This overall distribution suggests that the forest is primarily made up of trees in intermediate growth stages, with few very young or mature trees. The results indicate a forest structure that is likely in a phase of growth, with a significant proportion of trees yet to reach their full height potential and fewer older, tall trees (Fig.5).





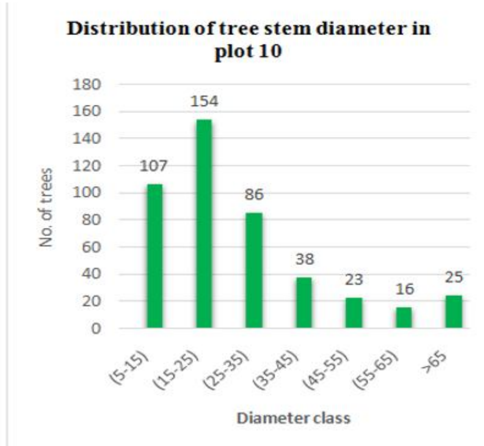


Figure. 6: Distribution of trees in different diameter classes in differentinventoried permanent plots (1-10)

The tree distribution across diameter classes in ten permanent plots. In Plot 1, the highest number of trees is in the 10–20 cm diameter class (approximately 200), with numbers gradually declining across larger diameter classes and fewer than five trees in the >60 cm class. Similarly, in Plot 2, the 10–20 cm class dominates with about 160 trees, while larger diameter classes show progressively fewer trees, indicating a regenerating forest structure. Plot 3 also exhibits a similar trend, with around 150 trees in the 10–20 cm class, followed by a sharp decline in larger classes, indicating early regeneration. In Plot 4, the 10–20 cm diameter class has about 120 trees and the numbers steadily decrease, with fewer than 10 trees in the >50 cm classes, suggesting a comparable regeneration stage but with fewer younger trees.

Plot 5 has around 140 trees in the 10–20 cm class the numbers drop to around 70 in the 20–30 cm class, with very few trees beyond the 40 cm diameter, indicating a regenerating forest with limited older trees. In Plot 6, the 10–20 cm diameter class has approximately 110 trees, with numbers decreasing to around 60 in the 20–30 cm class and continuing to decline across larger diameter classes. In Plots 7 and 8, a similar pattern is observed, with the 10–20 cm diameter class being dominant, followed by a steady decline in the number of trees as the diameter increases. Plot 9 shows a slightly different trend, with 128 trees in the 10–20 cm class and relatively higher numbers in the medium diameter classes (e.g., 86 in 20–30 cm and 46 in 30–40 cm), suggesting a mix of younger and older trees. Finally, Plot 10 has 154 trees in the smallest class, with a noticeable presence of trees in medium and larger diameter classes, indicating a more mature forest structure than other plots (Fig. 6).

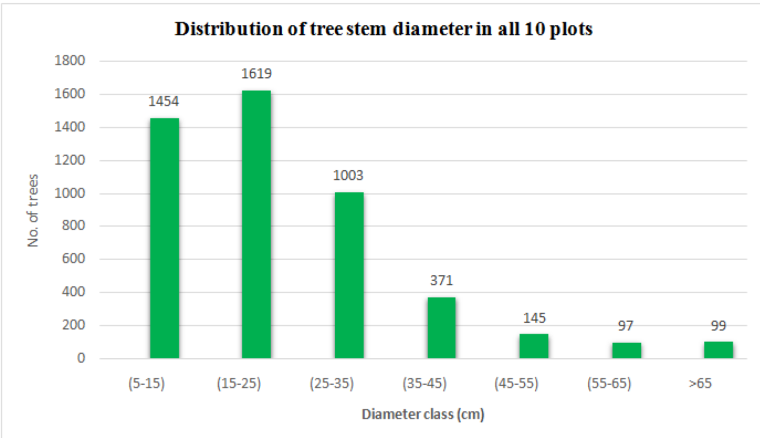


Figure 7: Distribution of overall tree diameter classes in all ten permanent plots

The tree diameter distribution across all ten permanent plots highlights a forest ecosystem predominantly in a regenerating phase. Most plots exhibit a reverse J-shaped diameter distribution, with a higher concentration of trees in smaller diameter classes (5–15 cm and 15–25 cm) and a progressively lower number in larger diameter classes (>35 cm). Collectively, the overall distribution indicates that the majority of trees fall within the smaller and medium diameter classes, with 1619 trees in the 15–25 cm range and 1454 in the 5–15 cm range, compared to only 99 trees in the >65 cm class.The pattern reflects active regeneration and recruitment processes within the forest, as younger trees dominate most plots. Several factors could contribute to this structure, including favourable climatic and soil conditions for seedling establishment, successful natural regeneration and low levels of anthropogenic disturbance, which allow younger trees to flourish. Additionally, the relatively lower numbers of large-diameter trees suggest a limited representation of older or mature trees, possibly due to historical disturbances, selective logging, or natural tree mortality (Fig.7).

The variation between plots, such as the slightly higher number of larger-diameter trees in plots 9 and 10, indicates localized differences in stand dynamics, management interventions, or site-specific ecological conditions. Overall, the forest appears to be in a healthy regenerating state, with a balanced structure that ensures sustainability if protected from further disturbances. For long-term stability, conservation measures should focus on protecting larger trees for seed production and maintaining the ecological balance of these forests.

Conclusion

The study of the Yellapur forest division reveals a highly diverse and heterogeneous forest ecosystem, with 4,680 individual trees belonging to 82 species recorded across 10 permanent plots. Tectonagrandis, Terminaliapaniculata, and Myristicamalabaricawere the most dominant species, with considerable variation in their distribution across plots. Forest structure analysis showed a predominance of medium-sized trees in the 12–15 m height class and the 10–20 cm diameter class, reflecting a regenerating forest with active recruitment and growth. Differences in forest types highlighted the superior basal area and volume in semi-evergreen forests, while moist deciduous forests exhibited greater tree height. The overall findings suggest that the forest is in a healthy state of regeneration, with younger trees dominating most plots and limited representation of mature trees. Conservation efforts should focus on preserving larger trees and reducing disturbances to ensure long-term ecological sustainability.

Comment [M20]: Italics

The height and diameter class distributions indicate that the forest is in an intermediate growth phase, characterized by a substantial proportion of medium-sized trees and active natural regeneration. However, the limited presence of older, larger trees points to possible past disturbances, such as selective logging or natural mortality. Variations between plots, such as the higher number of mature trees in plots 9 and 10, underscore localized differences in ecological conditions and management histories. These findings emphasize the importance of site-specific conservation strategies to maintain biodiversity and promote sustainable forest dynamics. Protecting existing mature trees while encouraging regeneration will be crucial for maintaining ecological balance and ensuring the forest's role in carbon sequestration and habitat conservation..

Discussion

The average height of the trees across different vegetation types in the Yellapur forest division is presented in Table 1. The results showed that the higher average tree height was recorded in the moist deciduous forest (15.25 m) followed by semi evergreen (12.39 m) and the least was found in dry deciduous forest (11.76 m).The dry deciduous forests experience lower rainfall and prolonged dry periods. This limited water availability restricts the growth of trees, resulting in shorter and less dense forests.The intense competition for sunlight within dense vegetation often compels trees to grow taller. This adaptive strategy, driven by the plant's photosynthetic capacity, allows for optimal light interception (Kumar *et al.*, 2011). The maximum basal area (31.44 m^2/ha) was found in semi evergreen forest due to a greater number of buttressed trees and larger trees. The volume was also found maximum in semi evergreen forest (342.35 m^3/ha). The Semi-evergreen forests often have a higher proportion of larger, mature trees compared to other forest types. These larger trees contribute more to the basal area and volume. Wood specific gravity plays a vital role in the conversion of forest volume data into biomass and is known to be significantly influenced by factors such as location, climate and potentially management practices (Ketterings*et al.,* 2001).

The findings of this study align with earlier research that emphasizes the importance of tree diameter distribution as a critical indicator of forest structure, dynamics, and regeneration. The observed reverse J-shaped distribution in the Yellapur Forest Division, with the majority of trees in smaller diameter classes, reflects a regenerating forest, consistent with findings by Rubin*et al*. (2006), who highlighted that such a pattern signifies active recruitment in forests with minimal disturbances. The dominance of trees in the 5–15 cm and 15–25 cm classes underscore the forest's ability to sustain a healthy recruitment cycle, ensuring long-term structural stability.

The lower representation of larger-diameter trees (>45 cm) could be attributed to factors such as selective logging, as suggested by Singh*et al*. (2018), or natural mortality due to competition and ageing. This imbalance may affect the forest's ecological functionality, as larger trees are known to play a vital role in carbon sequestration and biodiversity conservation (Pond*et al.*, 2015). Furthermore, localized variations observed between plots, such as higher numbers of medium to large-diameter trees in plots 9 and 10, might be explained by differences in site conditions or past management interventions, as discussed by Krooks*et al*. (2019). Addressing these challenges will require focused management strategies, including the protection of mature trees and minimizing human interference, to preserve the forest's ecological balance and ensure its sustainable use for future generations.

The differences observed between plots emphasize the need for more targeted forest management practices. Some areas of the forest, particularly those with higher numbers of larger trees, might benefit from better protection or less disturbance, while others may be experiencing more pressure from human activities or natural factors. To address the challenges of regenerating forests with a lack of mature trees, it is essential to focus on long-term conservation strategies that include the protection of existing large trees, controlling human-induced disturbances, and promoting the growth of young trees into larger diameter classes. Sustainable management practices that balance regeneration with the preservation of older trees are crucial for ensuring the continued ecological health and resilience of the Yellapur Forest Division.

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Comment [M21]: Referencing style is not correct

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