

**SPECIES COMPOSITION, BIOMASS, CARBON STOCK AND
CARBON SEQUESTRATION IN TROPICAL DRY DECIDUOUS
FOREST OF KANKE RANGE, RANCHI DIVISION, JHARKHAND**



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Registration No. FP/BAU/5079/2019

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

**MASTER OF SCIENCE IN FORESTRY
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT**

**FACULTY OF FORESTRY
BIRSA AGRICULTURAL UNIVERSITY
KANKE, RANCHI – 834006 (JHARKHAD)**

2022

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**THESIS
SUBMITTED TO THE
BIRSA AGRICULTURAL UNIVERSITY
RANCHI, JHARKAND**

**By
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DEDICATED TO
THE ALMIGHTY
MY PARENTS
ALL THOSE WHO ARE BEING PART OF
MY TEARS AND HAPPINESS
&
ALL THE LIVING CREATURES
AFFECTED BY CLIMATE
CHANGE

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*Place: Kanke, Ranchi
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ABSTRACT

Study entitled “**Species composition, Biomass, Carbon stock and Carbon sequestration in tropical dry deciduous forest of Kanke Range, Ranchi Division, Jharkhand**” was conducted in Patratu valley forest of Kanke range, Ranchi Division during the year 2020-2021 with the following objectives

- (i) To determine the species composition and diversity of the Patratu valley forest.
- (ii) To estimate the biomass and carbon stock of the Patratu valley forest.
- (iii) To estimate the carbon sequestration in the Patratu valley forest.

The simple random sampling procedure was adopted for characterization of vegetation. The phyto-sociological analysis of the forest was carried out by randomly placing 10 quadrates of 10x10 m². In each quadrate, GBH (Girth at Breast Height) of individuals (\geq 30 cm girth) trees and saplings (individuals >10 cm - \leq 30 cm girth) were measured. In centre of each 10x10m² quadrate, a 2x2m² area will be marked for enumeration of seedlings (individuals <10 cm girth). Stem girth of adults and saplings were measured at 1.37m from the ground and for seedlings at collar region. Shrubs were measured in the 10 x 10m² quadrate at base. As the research work was conducted in summer months, the contribution of herbaceous vegetation towards carbon sequestered can be neglected for the time being.

A total of 1670 trees ha⁻¹ representing 19 species and 14 families were encountered in study site and *Shorea robusta* showed highest value of IVI (129.87) followed by *Diospyros melanoxylon* (39.32) and *Adina cordifolia* (27.11). A total of 1280 saplings ha⁻¹ representing 16 species and 13 families were encountered and *Shorea robusta* showed highest value of IVI (102.18) followed by *Diospyros melanoxylon* (48.72) and *Terminalia catappa* (26.29). A total of 13640 seedlings ha⁻¹ representing 15 species and 13 families were encountered and *Shorea robusta* showed highest value of IVI (91.68) followed by *Syzygium cumini* (45.60) and *Diospyros melanoxylon* (44.71). A total of 9330 shrubs ha⁻¹ representing 6 species and 5 families were encountered and *Lygodium japonicum* showed highest value of IVI (97.06) followed by *Woodfordia fruticosa* (80.35) and *Lantana camara* (40.04).

Shannon index was calculated to be 1.98 for trees, 2.09 for saplings, 2.06 for seedlings, and 0.99 for shrubs. The Concentration of dominance was calculated to be 0.262 for trees, 0.2 for saplings, 0.185 for seedlings, and 0.52 for shrubs. Equitability was calculated to be 0.67 for trees, 0.75 for saplings, 0.76 for seedlings, and 0.55 for shrubs. Species richness was calculated to be 2.42 for trees, 2.09 for saplings, 1.47 for seedlings, and 0.54 for shrubs.

Total tree biomass recorded was 326.646 t ha⁻¹ of which 288.14 t ha⁻¹ was AGB and 33.504 t ha⁻¹ BGB and among the individual species *Shorea robusta* constituted the highest biomass i.e. 221.4 t ha⁻¹. Total sapling biomass recorded was 24.301 t ha⁻¹ of which 19.92 t ha⁻¹ was AGB and 4.38 t ha⁻¹ BGB and among the individual species *Shorea robusta* constituted the highest biomass i.e. 11.38 t ha⁻¹. Total seedling biomass recorded was 2.887 t ha⁻¹ of which 2.196 t ha⁻¹ was AGB and 0.691 t ha⁻¹ BGB and among the individual species *Shorea robusta* constituted the highest biomass i.e. 0.521 t ha⁻¹. Total shrub biomass recorded was 5.12 t ha⁻¹ of which 4.24 t ha⁻¹ was AGB and 0.882 t ha⁻¹ BGB. Among the individual species *Woodfordia fruticosa* constituted the highest biomass i.e. 2.765 t ha⁻¹.

Total tree carbon stock recorded was 163.232 t ha⁻¹. Total sapling carbon stock recorded was 12.151 t ha⁻¹. Total seedling carbon stock recorded was 1.44 t ha⁻¹. Total shrub carbon stock recorded was 2.562 t ha⁻¹. Total tree carbon sequestration recorded was 599.44 t ha⁻¹. Total sapling carbon sequestration recorded was 44.59 t ha⁻¹. Total seedling carbon sequestration recorded was 5.30 t ha⁻¹. Total shrub carbon sequestration recorded was 9.40 t ha⁻¹.

LIST OF ABBREVIATIONS

Abbreviations	Description
%	Per Cent
&	And
<	Less Than
=	Equal To
>	More Than
°C	Degree Centigrade
A	Abundance
A/F	Abundance/Frequency
BA	Basal Area
GBH	Girth At Breast Height
cm	Centimeter
Cd	Simpson's Index
D	Density
DBH	Diameter At Breast Height
et al	And Others/Co-Workers
Fig.	Figure
ha	Hectare
ha ⁻¹	Per Hectare
t ha ⁻¹	Metric Tonnes Per Hectare
ht	Height
i.e.	That Is
viz.	Namely
e.g.	For Example
m ha	Million Hectare
Kg ha ⁻¹	Kilogram Per Hectare
m	Meter
G	Gram
AGB	Above Ground Biomass

BGB	Below Ground Biomass
H'	Shannon Index
C	Carbon
CO ₂	Carbon Dioxide
R.B.A.	Relative Basal Area
R.D.	Relative Density
R.F.	Relative Frequency
IVI	Importance Value Index
FSI	Forest Survey Of India
No.	Number
FAO	Food And Agricultural Organization
IPCC	Inter-Governmental Panel On Climate Change
msl	Mean Sea Level
Mt	Metric Tonne
SOC	Soil Organic Carbon
d	Species Richness
E	Equitability
Cd	Concentration Of Dominance
P	Phosphorus
K	Potassium
N	Nitrogen
m ²	Square Meter
GHG	Green House Gases
CDM	Clean Development Mechanism



Introduction



CHAPTER-I

INTRODUCTION

*We are the **first generation** to feel the effect of climate change and the **last generation** who can do something about it.”*

Barack Obama,
Former USA President

Forests impact climate change in a global scenario by regulating the concentration of carbon dioxide levels in the atmosphere. They can act as “carbon sinks” by fixation of CO₂ from the atmosphere by the process of photosynthesis as well as “carbon sources” by releasing CO₂ into the atmosphere through decomposition of plant debris, forest fire, and respiratory metabolic activities besides which it releases oxygen which is essential for life. Currently there is 416.46 ppm carbon dioxide (CO₂) present in earth’s atmosphere which is still increasing causing climate change where as the forest acting as a carbon sink plays a major role to curtail it. Forests are the natural storehouses of biomass and carbon (Anon., 2005; Thokchom & Yadava, 2017).

Moreover, forests are most important in case of adapting climate-change, abatement, and mitigation. The significant role of forests in terms of carbon storage and sequestration has been observed as more vital in the present climatic condition and therefore it is considered as the center-stage of climate change mitigation strategies (Kishwan *et. al.*, 2009). Entire world forest having 861 ± 66 Pg C, and the percentage stored in living biomass, dead wood, litter, and mineral soil is 42, 8, 5, and 44% respectively (Pan *et. al.*, 2011), and forest vegetation is a store house of 359 billion tons of carbon(C) (Allen *et. al.*, 2010) which is twice that of from atmosphere (Lal, 2005). In current situation a major portion of carbon (two third of what there is in terrestrial ecosystem) stored in soil. (Scharlemann *et. al.*, 2014). Mahi in 1999 found out that the most diverse forest ecosystem in the world (Tropical forests) sequestering 3,040 g C/m²/year. For formulating a perfect strategy to mitigate climate change and global warming we need to understand the relationship between biodiversity and C storage in these ecosystem.

Phytosociology, also known as phytocoenology or simply plant sociology is the study of group of species of plant that are usually found together, with an aim to empirically describe the vegetative environment of a given territory. Delimiting and charaterizing

vegetation type, which is based on complete floristic (species) composition, is its principal goal. Floristically similar concrete stands (phytocoenoses), represented by plot records are combined into abstract vegetation types. Phytosociological classification (syntaxonomy), varies from plant taxonomy, as it places vegetation units into a hierarchical system based on varying degrees of floristic similarity (Richardson *et. al*, 2017).

In this world the most diversity is found in tropical and subtropical forest and variety of natural resources that they have helps to sustain the livelihood of local communities (Pradhan & Rahaman 2015). Vegetation in an area could be widely affected by the land use patterns and disturbance dominions (Kyayesimira & Leju, 2015). Many research paper have shown, however, that tropical forests are degrading as a result of anthropogenic pressure, and that quick attention and right strategy are required to maintain overall biodiversity, productivity, and sustainability. Various kinds of natural disturbances limit the scope of new species introduction in the existing forest stand (Jhariya, 2017; Jhariya & Yadav, 2016). Increase in greed for timber and NTFPs leads to disappearing most of these forests at an alarming rate (Murphy and Lugo, 1986a; Hare *et. al.*, 1997; Raghubanshi and Tripathi, 2009). According to the argument presented by Murphy and Lugo (1986b), the most disturbed and least protected ecosystems on the earth are the seasonally dry deciduous forests. These factors are causing significant environmental destruction and, as a result, are destroying the region's natural vegetation and habitat. and in other words there is a net annual increase in agricultural area of about million ha from more than 6 million ha where as there is a net annual loss of forest land of about 7 million ha (Anon., 2016).

Regarding the other aspect that mitigating CO₂, it is now one of the major environmental threats in front of a world leader. Due to the increase in anthropogenic activity and continuously reducing carbon sink, seems like a bed under the burden. With a rapid increase in greenhouse gases (mostly CO₂) the global temperature is also raising day by day. After the industrial revolution, this growth was remarkable. If we don't think about this now then the situation will go beyond our limitations. Increasing population and increasing rate of migration towards the urban put the urban environment under a great threat. The number of vehicles and personal equipment like AC in each household are being increased and contribute towards global warming. Recent data published by IUCN reported that the rate of extinction of wild species is increasing day by day due to climate change. If we don't think about it and do not take necessary remedies, the time will come when we shall be the only species in the world.

Ovington, (1962) and Brown *et. al.*, (1999) have argued that in order to for the better knowledge of the structure and the function of the ecosystem and for evaluating the status and quantification of biomass is an important focus on forest ecosystem trends as well as a wide range of environmental gradients. It is necessary to have a thorough idea about several major ecological processes like energy flow, water, and nutrient cycling in forest ecosystems and biomass provides primary data necessary for understanding these things (Chaturvedi & Singh, 1987; Tiwari, 1994). Inside the domain of biomass we can include all both above and below-ground and both living and nonliving organic material e.g., trees, crops, grasses, tree litter, roots, etc. (IPCC, 2003; Anon., 2005). Biomass leads a major role in the assessment of the annual increment of the forest and helps to determine proper management of the natural resource in a sustainable manner. In layman language carbon sequestration can be defined as the long term storage of carbon, that has immediate potential to become carbon dioxide gas, in soil, plant, ocean and geological formation which can be happen both naturally and artificially (anthropogenic activities). To address one on the major challenge i.e. climate change, which is increasing at a alarming rate in present scenario because of high CO₂ concentration we need to shift our focus towards the various methods of carbon capture and storage i.e. changing of land use practices & forests, geo-engineering techniques etc.(Selin, 2019).

India has been ranked fourth in the entire globe in terms of CO₂ emissions (Muntean *et. al.*, 2018). India, on the other hand, has a forest cover of 7,12,249 km² (21.54 percent) and significant C storage potential, with a total C stock of 7,124.6 million tonnes (Anon., 2019). Whereas, the total forest cover of Jharkhand is 23,553 km² which accounts for 29.55% of the total geographical area of the state (Anon., 2017) and play a key role in the carbon cycle both in terms of carbon flux and the volume of carbon stored; Although the state forest cover is more than the national average, for healthy/ hygienic environment there must be the minimally one-third area covered with the permanent greenery of the total geographical area of the state or global basis as per National Forest Policy, 1988. Further according to the Forest Survey of India, the total carbon stock of Jharkhand is 222.881 million tonnes (817.234 million tonnes of CO₂ equivalent) whereas, the total forest carbon of the country is 7082.063 million tonnes (Anon., 2017) and these figures could include natural forests, with tree plantations of mostly exotic species.

In another perspective in the race of development, our India lacks a lot. To cope up with the developed world, we need more construction and more infrastructure development for which we need to sacrifice the environment a little higher. But in the 21st century where

India is going to lead the world, we cannot stop this rapid developmental activity rather than doing it sustainably. For example, recently coal India Ltd announced to boost up their production capacity to 200 percentage and the Central government planned to establish a lignite-based thermal power plant in Tamil Nadu with 500MW capacity. These are some examples that prove that GOI also investing in a non-renewable energy sector that pollutes the environment. Hand to hand we need to boost our carbon sink that can absorb the excess CO₂ meant for development. And to achieve this objective especially in cities herbs are going to play a vital role.

GOI is also working on what we are debating here. For example, GOI has an aim to produce 175 GW of renewable energy from renewable sources by the year 2022 among which 100 GW from solar (40GW from rooftop solar), 60 GW from wind, etc. The mission towards the achievement of a goal is very slow but something is better than nothing. Various international forums like IPCC, the Paris climate agreement, UNEP put pressure on member countries to have control over their emissions. The government of various countries is trying to do their best but we can contribute to this mission by planting a plant especially various herbs as an urban household. By planting more and adopting more we can reduce the pressure on the environment and help to sink down the hazardous gases that lead to low respiratory disease. Either by changing our lifestyle or by creating a mini carbon sink we can mitigate carbon dioxide from the atmosphere.

Presently there are some studies are available on phytosociology, but studies on CO₂ sequestration in tropical dry deciduous forests of Ranchi Division need to be investigated for their management. By getting the data regarding carbon sequestration others could know the importance of untouched forests in the present situation (global warming). Keeping these facts in mind, the present study entitled **“SPECIES COMPOSITION, BIOMASS, CARBON STOCK AND CARBON SEQUESTRATION IN TROPICAL DRY DECIDUOUS FOREST OF KANKE RANGE, RANCHI DIVISION, JHARKHAND ”** with following objectives.

- To determine the species composition and diversity of the Patratu valley forest.
- To estimate the biomass and carbon stock of the Patratu valley forest.
- To estimate the carbon sequestration in the Patratu valley forest.



Review of Literature



CHAPTER-II

REVIEW OF LITERATURE

This chapter attempts to summarise previous research on vegetation composition, species diversity, biomass, and carbon storage patterns in tropical dry deciduous forests. With the goal of logically interpreting the study's findings, an extensive literature review was conducted, as well as work done relevant to the current investigation. However, due to a scarcity of literature on a few topics, similar studies conducted in other forest ecosystems are also cited. The following headings summarise a broad review of the literature.

- Species composition and diversity in different tropical forests.
- Biomass and carbon stock pattern in different forests.
- Carbon sequestration in different forests.

Species composition and diversity in different tropical forests.

Kumar *et. al.* (2021) investigated the carbon stock potential of *Pinus roxburghii* forests in the Indian Himalayas, discovering that the highest tree density ($575 \pm 90.14 \text{ ind. ha}^{-1}$) was found at altitudes greater than 1801 masl and the lowest at altitudes between 1001 and 1400 masl. Kandikhal had the highest ($96 \pm 18.36 \text{ t ha}^{-1}$) above-ground carbon stock, with bole, branch, and foliage contributing 89.93 ± 19.47 , 5.17 ± 1.04 , and $0.90 \pm 0.14 \text{ t ha}^{-1}$, respectively, while Gumkhal had the lowest ($26.68 \pm 9.48 \text{ t ha}^{-1}$), with contributions from the same component of 20.72 ± 7.84 , 4.50 ± 1.58 , and $1.47 \pm 0.11 \text{ t ha}^{-1}$, respectively. As per the research results, altitude does have a significant effect on the density, height, basal area, and volume of *Pinus roxburghii*, but not evenly.

Gogoi *et. al.* (2021) He compared the long-term impact of PF (Plantation forests) on species composition, plant diversity, biomass, and carbon storage potential to that of NF (natural forest). In the PF, they listed approximately 57 trees, 22 shrubs, and 23 herb species, and in the NF, they listed approximately 54 trees, 17 shrubs, and 8 herb species. PF had higher values for species richness and biodiversity indices, whereas NF had higher values for species dominance and evenness. Finally, they concluded that PF can be an useful ecosystem management tool for achieving biodiversity environmental targets.

Coban *et. al.* (2021) has studied the composition of woody plants in Istanbul and they have found that the botanical garden had the highest diversity next to which there is the garden. Furthermore, they specified that residential areas are shown to be important in terms of shrub (52%) and evergreen species (58%) among which 71% are exotic. They warned about the invasive plants whose ratio is high in parks and played a major role in keeping highways green.

Ao *et. al.* (2021) studied the diversity in Nagaland along an altitudinal gradient of 247 to 1478 m and a total of 777 individuals (118 sp, 84 genera, and 43 families) were recorded. Fagaceae was the most dominant family. The tree density and basal area range from 313 to 330 and 22.95 to 38.03 respectively. The forest community shows high equitability and low dominance. The forest has high species diversity (Shannon index 2.95 to 3.88 and Simpson dominance index 0.03 to 0.09).

Nero (2021) investigated a reclaimed and degraded mine site in Ghana and compared it to a natural forest. The restored site had 31 species (13 families) compared to 61 species in the natural stand (29 families). Furthermore, species richness, abundance, and diversity were found to be higher in the natural stand than in the restored site, but the mid-story and low stories have a high similarity in composition (Jaccard's index = 0.817). Shade-tolerant spp. dominated the understory (mostly herbs and shrubs). Finally, he came to the conclusion that mixed-species reclamation does not always result with in rapid restoration of indigenous climax species on mine spoils.

Bhandari *et. al.* (2021) investigated the condition of trees outside the forest (TOF), which are important an ingredient of living in the countryside. (fodder, fruit, firewood). They counted 623 individual trees (38 species, 21 families). The amount of land, the number of livestock, the distance from one's home to the forest, well-being status, and other factors were found to influence diversity the most in indigenous people's farmland. Finally, they concluded that TOF makes a significant contribution to the national carbon budget and that TOF should be considered in nationally determined contributions and performance-based payment in forestry systems (REDD+).

Mane *et. al.* (2019) examined the floral diversity, composition, and recruitment of tropical evergreen and semi-evergreen forests on Baratang Island in the Andaman and Nicobar Islands' Karst Land. They discovered a difference in species diversity ($F = 320.06$; $p < 0.001$) and composition ($P =$

0.001; $A = 0.031$) between trees and recruitment classes, with the diversity increasing with the age of the vegetation classes (trees > saplings > seedlings). Finally, they concluded that tree diversity increases as seedling and sapling diversity increases.

Jhariya *et. al.* (2018) studied a teak plantation forest ecosystem of Sarguja in Chhattisgarh to find out vegetation diversity, biomass and carbon stock at various sites and compare the data with the natural forest. They have found that teak stand having less diversity in the tree (6 tree species) as well as in understory also (20 herb species and 3 shrubs) as compared to what they found in natural forest i.e. 17 tree species and 23 species of understory (18 herbs and 5 shrubs). The population dynamics of the various vegetation stratum in the concerned sites also showed significant variation. The density of seedlings, saplings, and herbs was found to be highest in the natural stand, while tree and shrub density was greater in the teak stand. The seedling, sapling, shrub, and forest floor biomass are highest in natural forests. However, Carbon stock had a similar trend as that of biomass accumulation both in natural forest and teak stand.

Baboo *et. al.* (2017) conducted research on anthropogenic disturbances and discovered that such differences can alter species composition, limit regeneration, and reduce species diversity. They chose four locations in the Boramdeo Wildlife Sanctuary in central India and discovered temporal dynamism in species composition. Furthermore, they discovered an opposite relation between seedling species diversity and conservation-focused species populations. The inverse relationships between the number of pole species and stems, as well as the averaged tree canopy size, disturbance scores, and seedling species amount.

Behera *et. al.* (2017) studied various patches in Indian tropical deciduous forests along Himalayan foothills that include dry mixed (DM), Sal mixed (SM), and teak plantation (TP). The major findings are, a total of 22, 22, and 6 tree species were found in DM, SM, and TP PFT (plant functional types), respectively. Further more they have revealed that DM having the highest Shannon's index (2.46) and TP having maximum Simpon's index (0.85).

Naidu *et. al.* (2016) investigated that the species diversity and density of trees in the Andhra Pradesh region's Eastern Ghats, which are mostly covered by Tropical Deciduous Forests. Stem density, basal area, diversity, and species composition are the primary areas of investigation. There are a total of 2,227 people as a result of this (44 families, 98 genera, and 129 species). IVI values are highest in families such as Combretaceae, Euphorbiaceae, and Anacardiaceae. Because the biodiversity of these forests is currently threatened by anthropogenic and upcoming mining activities, immediate action is required.

Pradhan *et. al.* (2015) conducted a phytosociological study of Birbhum District's dry deciduous forest in West Bengal, India. The importance value index (IVI) of 486 tree individuals from 20 different species has been calculated. *Shorea robusta* is the dominant tree species in three forest areas, with the highest IVI value, followed by *Madhuca longifolia* and *Buchanania lanzan*. The Shannon- Weiner index (H') in Illambazar forest ranged from 0.11 to 0.48, 0.08 to 0.50 in Chorchor forest, and 0.18 to 0.95 in Ganpur forest.

Wittmann *et. al.* (2006) had research on the gradient of diversity in white water forest across basins of Amazon. They recorded almost 900 tree species that are flood-tolerant which indicates that the basin has the most species-rich flood plain forest worldwide. Species distribution and diversity varied as a result of flood level gradient, succession in natural forest, and geographical distance between sites. They also concluded that the diversity shows an increasing trend towards the western sites and towards the equatorial Amazonia.

Hermly and Verheyen (2007) reviewed the past land-use effects on forest diversity. According to the research, ancient forests are home to a significant portion of our forest flora. The ancient forest plant species (AFS) were not colonizers i.e. their distribution and abundance are limited by distance and time. Furthermore, they suggested that recent forests are suitable for adopting AFS. They have also cited a shred of clear evidence that for distribution of AFS the dispersal limitation is more important. Ancient forests at the equatorial climate and tropical climate had the most diversity making them highly important for nature conservation.

Dieler *et. al.* (2017) has reviewed regarding managerial practice effect on plant diversity in the temperate zone of Europe. The result revealed that there is no significant effect on species richness and diversity and no notable impact of time since the abandonment of management but there are some effects on the structural attributes. Management practices have put a negative effect on deadwood quantity, several microhabitats, and tree size diversity but they did not found any effect on basal areas and the number of leaving trees. On the other hand, forest productivity has increased by regular moderate thinning.

Silk (2004) studied the composition and diversity in the tropical rain forest of Indonesia which is affected by drought caused by El Nino (the climatic pattern that describes the unusual warming of the surface of the water in the eastern equatorial pacific ocean) in 1997/98. The particular draught caused tree mortality of 11.2, 18.1, and 22.7% in undisturbed, old logged, and recently logged forests (high mortality of pioneer Macaranga trees i.e. 65.4 %), respectively. Canopy opening was higher in comparison to non draught year (6, 8.6, 10.4% vs 3.7, 3.8, and 3.7 %respectively). A major factor contributing to mortality are successional status, tree size, and tree location.

Simonson *et. al.* (2012) investigated various aspects of plant species diversity and composition in relation to vegetation structure and landscape in a Mediterranean oak forest. They compared the Lidar data set to the field data to test the system's efficacy in assessing the vertical structure of vegetation, diversity of plant species, and community type, and the data were significantly correlated ($r=0.85$). Finally they concluded that Lidar can be widely used for habitat mapping and habitat condition assessment, but survey design (the density of lidar points, the geospatial accuracy of ground truthing, and the timing of ground truthing in relation to the acquisition of lidar data) should be carefully considered.

Biomass and carbon stock pattern in different forests

Mir *et. al.* (2021) had research on Biomass and carbon (C) stock from the community-managed montane evergreen forests of Meghalaya, northeast India. According to their study, the ABG (above-ground biomass) varied between $75.3 \pm 17.1 \text{ Mg ha}^{-1}$ in village forest to $273 \pm 55.5 \text{ Mg ha}^{-1}$ in Sacred forest and belowground biomass (BGB) has varied between 59.53 ± 8.4 to $19.9 \pm 4.3 \text{ Mg ha}^{-1}$ respectively. In the study sites the above-ground carbon stock has a range of 129 ± 26.3 , to $39 \pm 5.7 \text{ Mg C ha}^{-1}$ and the belowground carbon stock, the concentrations ranged from 6 to 34 Mg C ha^{-1} . The AGB accumulation had shown greater accumulation in intermediate diameter classes (26 – 45.9 cm). Lastly, they concluded that the human disturbance had a significant impact on the community forests' species richness, stand characteristics, biomass, and C stock.

Kumar *et. al.* (2021) studied the Carbon stock potential of *Pinus roxburghii* forests of the Indian Himalaya. According to them, the highest below-ground carbon was found in Kandikhal i.e. $28.58 \pm 4.81 \text{ t ha}^{-1}$ which is at an altitudinal range of 1001-1400 masl and the lowest in Gumkhal ($9.19 \pm 2.87 \text{ t ha}^{-1}$) between 1401 and 1800 masl. Again the summer season enhances the amount of production of litter, then comes winter and the rainy season.

Biradar and KS (2021) studied the biomass and carbon stock in sacred groves present in the Karnataka part of the western ghat. The result revealed that the highest rainfall area has maximum biomass i.e. 170.78 Mg and carbon stock i.e. 80.26 Mg as compared to the area receiving low rainfall 163.55 Mg and 76.87 Mg , respectively. The research also indicated that human disturbances resulting higher biomass and carbon stock.

Ahirwal *et. al.* (2021) put their eyes on IHR (Indian Himalayan Region) to investigate the role of different environmental variables in predicting carbon stock in biomass and soils in the forest, plantation, agroforest, and herbaceous biodiversity. The natural forests accounts for highest biomass i.e. $138.5 \pm 87.3 \text{ Mg C ha}^{-1}$ and plantation forests exhibited the highest SOC stock ($168.8 \pm 74.4 \text{ Mg C ha}^{-1}$) in the top 1-m of soils. A significant correlation was difficult to achieve between various environmental variables i.e. altitude, latitude, precipitation, and temperature with the carbon stock.

Khadanga and Jaykumar (2020) have studied tree biomass and carbon stock in Mahendragiri hills with the aim of establishing a relationship between elevation gradient and disturbance regime and stem density, biomass, and carbon stock. MHF 1 (Mahendragiri Hill Forest) having the biomass of 129.05 Mg ha⁻¹ as compared to 255.87 Mg ha⁻¹ in MHF 2; the total carbon stock followed the same pattern. Elevation, species richness, diversity, and stem density have an insufficient significant influence on biomass which has largely been impacted by disturbance and reported a positive correlation with tree diameter.

Kothandaraman *et. al.* (2020) investigated ecosystem-level carbon storage and its relationships to diversity in three major forest types: tropical dry deciduous (TDD I and TDD II), tropical semi-evergreen (TSE I and TSE II), and tropical evergreen forests (TEF I, TEF II and TEF III). The research was carried out in the Kanyakumari Wildlife Sanctuary in the Western Ghats. They discovered that the average C stock in these forests was 336.8 Mg C ha⁻¹ in woody vegetation, understorey, litter, deadwood, and soil, with 231.3, 3.0, 2.4, 15.2, and 84.9 Mg C ha⁻¹ in woody vegetation, understorey, litter, deadwood, and soil, respectively. The live vegetation, detritus, and soil contributed 65.5 percent, 5.5 percent, and 29 percent of the total ecosystem-level C stock, respectively, and were distributed in forest types in the following order: TEF III > TEF II > TEF I > TSE I > TDD II > TSE II > TDD I. Plant diversity, structural characteristics, and environmental factors were all related to C stocks in a positive way, accounting for 6.7, 77.2, and 16 percent of the variance, respectively.

Ouedraogo *et. al.* (2020) conducted research on above-ground biomass (AGB) and carbon stock in *Balanites aegyptiaca* and predicted that branch biomass accounted for 64 percent of the AGB in the two climatic zones and increased with dbh, but there was no significant difference in carbon content. Except for leaf biomass, the distribution of biomass varied across climatic zones. Although dbh (diameter at breast height) and D₂₀ (basal diameter at 20 cm height) are used as independent variables for predicting AGB, including height in the equations did not significantly improve the statistical fits for *B. aegyptiaca*.

Mahmood *et. al.* (2020) have launched an initiative to develop multi-species biomass models for Bangladesh's hill zone, which will aid in determining the carbon concentration in tree components such as leaves, branches, bark, and stem. The results showed that the best model of leaf, branches, and bark had lower adjusted R² values ranging from 0.3152 to 0.8043 and model efficiency ranging from 0.436 to 0.643, so they rejected using these models

to calculate biomass. Furthermore, they demonstrated that the best fit model for estimating stem and total aboveground biomass (TAGB) has a higher model efficiency of 0.948 and 0.837, respectively, and they recommended estimating tree biomass in Bangladesh hills. According to the study, the two most commonly used pantropical biomass models had lower model efficiency (0.667 to 0.697) than our derived TAGB model.

Salinas-Melgoza *et al.* (2018) conducted experiments on topographic variables like slope and elevation that have spatial variations in aboveground biomass within landscapes revealed that biotic interference, particularly that caused by human activities like cattle grazing and shifting cultivation, plays a significant role in determining biomass, though these effects may be moderated by accessibility. They also looked into the possibility of predicting above-ground biomass in a rural landscape. They also modelled linear and non-linear relationships, with linear models revealing that elevation, slope, topographic wetness index, and tangential curvature could explain up to 21% of above-ground biomass, while non-linear models revealed threshold values. It was also discovered that increasing the distance between roads has a continuous and positive effect on above-ground biomass, as well as a piecewise relationship that improves understanding of the intensity of human activities. These findings could pave the way for the creation of above-ground biomass baselines at the landscape level using freely available topographic map data.

Subashree *et al.* (2017), worked on biomass and carbon stock in two savannahs ecosystems of Kanyakumari Wildlife Sanctuary, Western Ghats, India. There is a remarkable variation in the both sites of Savannah regarding biomass and carbon accumulation patterns. They had pointed out one site showed higher woody biomass carbon than another site; however, in the case of soil carbon, the result has been found just reverse. Woody biomass sequestered the biggest carbon pool, followed by soil and understory biomass. They also noticed differences due to differences in terrain characteristics, edaphic factors, the frequency of fires, and so on. At last they emphasized the importance of savannahs vegetation and its role in stocking considerable amounts of carbon in their different carbon pools.

Salunkhe *et al.* (2016) used a nondestructive method to estimate tree biomass in Tropical Dry Deciduous Forest and Tropical Mixed Deciduous Forest established at seven sites in Madhya Pradesh, central India. They discovered a positive correlation between basal

area and above-ground biomass for all sites and forest types. Dry Deciduous Forest had higher density, basal area, and biomass than Mixed Deciduous Forest in general.

At Katghora forest division in Bilaspur circle of Korba district, Chhattisgarh, Pawar *et. al.* (2014) investigated biomass and carbon storage in relation to anthropogenic disturbances using three sites: least, moderately, and highly disturbed. They also reported that the carbon storage pattern by girth class followed a similar distribution trend as the biomass. It has the smallest proportion in the small girth category and the most storage in the larger girth category. According to the studies, disturbances have a significant impact on species regeneration, density, vegetation diversity, biomass accumulation, and carbon storage pattern. As a result, the increase in anthropogenic disturbances is degrading the forest's wealth and quality. Conservation measures are required to control disturbances and to allow the forest ecosystem to recover naturally.

Waikhom *et. al.* (2018) investigated the aboveground biomass and carbon stock in Manipur's largest sacred grove, enumerating aboveground biomass (962.94 to 1130.79 Mg/ha), carbon stock (481.47 to 565.40 Mg C ha⁻¹) tree density (1240 to 1320 stems ha⁻¹) and basal area (79.43 to 90.64 m² ha⁻¹). The diameter class 30-40cm made the greatest contribution to aboveground biomass (22.50-33.73 percent). The study site's aboveground biomass and carbon stock were found to be higher than in many tropical and temperate forests, indicating the importance of spiritual forest conservation in carbon sequestration.

Behera *et. al.* (2017) investigated dry mixed (DM), Sal mixed (SM), and teak plantations (TP) in an Indian tropical deciduous forest along the Himalayan foothills. The main findings are that AGB (Mg ha⁻¹) ranged from 290.82 to 455.99 across all PFTs (plant functional types). AGBC (Mg ha⁻¹) in DM ranged from 207.52 to 220.34, SM from 215.58 to 228.87, and TP from 125.94 to 141.18. AGB discovered a strong positive relationship between tree density and cover. Investigate the reason for higher AGB, which is humidity and air temperature (major microclimatic variables).

Salunkhe *et. al.* (2018) presented a systematic review and thorough account of studies conducted in India's various forest types, as well as a review of the above-ground biomass and carbon stock of the Indian forest ecosystem. They concluded that there is a positive relationship between tree species, breast height diameter, and biomass/carbon stock. In

addition, invasive species, small and medium-sized growing trees, mixed forest, agroforestry, and agrosilviculture all play important roles in atmospheric carbon assimilation.

Sarangale *et. al.* (2018) quantified the above-and below-ground carbon pools in a tree-based intercropping system as well as in conventional agricultural systems. The maximum total biomass, total carbon stock, and total carbon sequestration potential in pure *E. tereticornis* plantation were 1311.82 t ha⁻¹, 654.91 t ha⁻¹, and 130.98 t C ha⁻¹ yr⁻¹, respectively, followed by mixed (*P. deltoides* and *T. grandis*) plantations (210.29 t ha⁻¹, 109.11 t ha⁻¹, and 21.83 t C ha⁻¹yr⁻¹) and poplar (181.01 t ha⁻¹, 97.29 t ha⁻¹ and 18.59 t C ha⁻¹ yr⁻¹). The lowest values of the above parameters were observed in a land-use system based solely on agriculture.

Mohanraj *et. al.* (2011) conducted a comprehensive study on existing carbon stock in above-ground biomass, litter, debris, and soils (up to 30 cm) in Kolli forests, Eastern Ghats, and discovered that despite several conservation efforts at both the governmental and non-governmental levels, the efficacy of tropical forest sinks in India continues to deteriorate. Organic carbon levels ranged from 1.71 to 12.59. Soil carbon stock, surface litter carbon stock, coarse wood debris carbon stock, and total above-ground biomass carbon stock were estimated to be 5.54, 0.034, 0.001, and 4.49 Tg C, respectively.

Using field measurements, Xia *et. al.* (2014) estimate the spatial and temporal patterns of global grassland biomass and investigate the forces that drive them. From 1982 to 2006, the average global carbon stock in grassland aboveground live biomass was 1.05 Pg C, and it increased at a rate of 2.43 Tg C yr⁻¹. Temperature and precipitation have a significant impact and a positive relationship with the temporal change of global biomass.

Neupane *et. al.* (2014) quantified vegetation carbon stocks to assess the ecosystem's carbon sequestration potential. The study chose two community forests (CFs) in Nepal's Gorkha district to measure carbon stocks. Because of the greater density of the larger-sized trees, they discovered that the carbon pool of Laxmi Mahila CF was lower than that of Jalbire Mahila CF. Sal (*Shorea robusta*) made the greatest contribution to the carbon pool in both CFs, and the greatest amount (largest fraction) of carbon pool was found in 'stem' among different parts of vegetation (branches, leaves, stem, and undergrowth) in all plant species of both CFs.

Carbon sequestration in different forests

Deb *et. al.* (2021) looked into the role of community-managed forests in carbon sequestration. The findings demonstrated that management agents can play an important role in improving tree diversity, soil properties, and carbon stock in community forests. They studied JCM (Jamatia community forests) and HCF (Halam community forests), and JCF has higher tree diversity (2.741), higher soil organic matter (with higher N & P content), and higher carbon stock (342.9 Mg C ha⁻¹) than HCF due to better management (2.176, 158.7 Mg C ha⁻¹ respectively).

Hu *et. al.* (2021) conducted research on the carbon sequestration benefit of GFGP (Grain for Green Program) in southern China's hilly red soil region (HRSR). They discovered that total carbon sequestration increased at a rate of 15.43 percent between 2000 and 2015, making it the most significant change with the shortest implementation time. Each carbon pool's carbon sequestration (aboveground biomass, belowground biomass, soil, and dead organic matter) also showed an upward trend. They concluded that unused land converted to forest land is the most effective LUCC (land-use/land-cover change) for carbon sequestration.

Arehart *et. al.* (2021) have updated their post on "buildings as a carbon sink." They have also studied the need for characterization of current and future carbon storage in the global building stock, and significant studies and research work remains to be done to validate the theory of buildings as carbon sinks to mitigate the effects of climate change. According to reports, the cumulative effect of carbon stored in durable construction products and buildings is far less than the emissions from fossil fuel use in a single year (ranging from negligible to 175 percent). Again, there is an issue with carbon storage in the built environment being offset by net forest carbon losses, but the benefits of substitution are sometimes overlapping. Furthermore, the use of bio-based construction materials has the potential to accelerate global decarbonization progress.

Kovas *et. al.* (2021) investigated the role of afforestation in carbon sequestration in the lower Mississippi River basin in the United States. They discovered that the average cost of sequestering a tonne of carbon rises from \$13 (\$3.55 per tonne CO₂eq) at the lowest subsidy to \$36 (\$9.84 per tonne CO₂eq) at the highest subsidy. Soybeans, as the dominant

crop on the landscape, have the lowest cost, while rice or corn have the highest. Changes in afforestation type, from fast-growing softwoods to slow-growing hardwoods, result in significantly lower carbon sequestration costs.

Holtmann *et. al.* have studied carbon sequestration in mixed deciduous forests and derive the relation between tree size and species composition. The medium-sized trees having stem diameter between 30–60 cm account for the largest share i.e. 66% of total productivity at the study site, followed by small (0–30 cm) contributes 8.3% and large trees (>60 cm) contributes 25.5%. They also indicated that forest productivity is influenced more by vertical stand structure and shading than that of species composition.

In Portugal, Nunes *et. al.* (2021) investigated the overall impact of an invasive species on carbon sequestration. The invasive species they considered was *Acacia dealbata* Link, which has a negative impact on biodiversity and the economy because of its competition with *Pinus pinaster* Aiton and *Eucalyptus globulus* Labill. They have, however, investigated the opportunities for carbon capture and sequestration in the medium and long-term contexts of providing ecosystem services and mitigating climate change. Its heliophilous nature aids in determining growth, as this species' growth capacity is rapidly conditioned by the position of each tree within a stand, and it is unable to maintain that capacity in the medium and long term.

Jorgensen *et. al.* (2021) proposed some management practices to increase carbon sequestration in *Pinus sylvestris* forests. According to the research, thinning increased total C stock by 50% on average. The practices of applying fertilizer to thinned stands increased stocks similarly regardless of whether removed biomass was included (11%) or excluded (12%). Furthermore, fertilization combined with no thinning had a synergistic effect on C stocks, resulting in a 79 percent increase (35 percent when removed timber was included in the C stock). Fertilization had a greater positive effect on C stocks at higher latitudes. Fertilization also reduced soil respiration rates, which helps to reduce carbon loss in the form of CO₂ indirectly.

Huang *et. al.* (2020) examined a bibliography of 1284 academic works on forest carbon sequestration. The results show that forest carbon sequestration is becoming the

authors' favorite subject, as the number of publications in forest carbon sequestration research has increased rapidly and research in this field is in its "growth stage," and the most popular journals and subjects are "Forest Ecology and Management" and Forestry, respectively. The most productive authors are from the United States, China, and Canada, and the most popular keywords are temperate forest, forest management, uncertainty analysis, forest floor, REDD, and so on. More often than not, this research provides a better understanding of emerging development trends in this field.

Buotte *et. al.* (2019) studied preserving forests with the co-benefits of carbon sequestration and biodiversity. They have found that 1485 Tg C (5450 Tg CO₂ equivalent) will be the potential of a forest (having high productivity and low vulnerability) which is up to 20% of the global mitigation potential of all temperate and boreal forest. Additionally, they have concluded that high tree species richness and a high proportion of critical habitat for endangered vertebrate species positively correlate with the amount of biodiversity present and it will promote ecosystem resilience to climate change. They have mainly worked regarding a model and ecological criteria that can be used to prioritize landscape preservation and mitigate GHG.

Ontl *et. al.* (2019) prescribed some management procedures that would help to sequester carbon more and more. In another word, there should be a continuation of the supply of resources to managing forest carbon under changing climatic conditions. They have also prepared a road management plan for the carbon management concept that would help to reduce risk.

Kolo *et. al.* (2020) told that Ecosystem services (ES), aside from timber production, are hardly considered during forest management decisions. timber production, carbon storage, and groundwater recharge. They examined how the optimal species composition and harvest schedule change while the 3 ES (timber production, carbon storage, and groundwater recharge) are taken into consideration & they found that the ES has an impact on composition and schedule. Among the 3 the carbon storage puts minimal effect.

Babbar *et. al.* (2021) examined carbon sequestration in the Sariska Tiger reserve and they have found that 1.351 Tg (\$214.57) carbon has already been lost from 2000 to 2018 and another 0.107 Tg of carbon is expected to lose in the future. They also recommended

quantifying the biomass which is necessary to understand the productivity of forests, carbon sink, and source dynamics. The major cause of loss was the extraction of fuel wood by local communities illegally. Finally, they have recommended restoration/reforestation and afforestation (enhancing and conserving carbon pool in vegetation) as the most practical carbon loss mitigation strategy.

Hernandez and Sheehan (2020) made a comparison of electrochemical carbon dioxide conversion and reforestation. In the current scenario, interest in new technology for carbon capture, utilization, and storage (CCUS) has increased in order to reduce anthropogenic greenhouse gas emissions. They also compare the efficiency of model photovoltaic-driven carbon dioxide conversion technologies that generate liquid alcohols to that of planting an equivalent forest. They also tested how much higher the rate of direct CO₂ conversion (around 0.5 percent) using artificial photosynthetic technology provided an overall system-level thermal efficiency. This research can be expanded by examining additional factors such as (i) indirect CO₂ emissions reduction, (ii) techno-economic analysis, (iii) upstream and downstream CO₂ emissions, and (iv) life cycle analysis of energy generation and equipment production, among others.

Gogoi *et. al.* (2021) investigated the long-term impact of PF (Plantation forests) on species composition, plant diversity, biomass, and carbon storage potential, comparing these values to NF values (natural forest). Total biomass C in PF was estimated to be 165 Mg C ha⁻¹ and 197 Mg C ha⁻¹ in NF equivalent age. The dominant tree species in the PF are *Bombax ceiba*, *Dalbergia sissoo*, *Samanea saman*, *Tetrameles nodiflora*, and *Gmelina arborea*, which contribute 56 percent of the total biomass C. The NF ecosystem carbon pool is larger and has a higher potential for carbon dioxide sequestration (959 Mg CO₂ ha⁻¹) than the PF (818 Mg CO₂ ha⁻¹). Finally, they concluded that PF can be a preferable ecosystem management tool for achieving the goals of providing climate services such as carbon sequestration.

Richard and Stokes (2004) examined the cost of carbon sequestration over a 12-year period. For several decades, it may be possible to sequester 250 to 500 million tonnes of carbon per year in the United States (\$10-150 per tonne of carbon), and up to 2,000 million tonnes per year globally. The secondary benefits of agricultural land conversion to forests may be as great as the cost, which influences the contribution of carbon sequestration to greenhouse mitigation strategies.

Leighty *et. al.* (2006) investigated carbon sequestration in Alaska forests and discovered 2.8 0.5 Pg C, or 8% of total carbon in the forests of the conterminous United States. They also calculated that net carbon loss from the Tongass due to forest management was estimated to be 6.4–17.2 Tg C for the period 1900–95, and net carbon flux in the Tongass ranged from 0.33 Tg C Yr⁻¹ to 2.3 Tg C annual emission for the period 1995–2095. Finally, estimated net fluxes range from 0.19 Tg C Yr⁻¹ sequestration to 1.6 Tg C Yr⁻¹ emission.

Oren *et. al.* (2001) conducted an experiment in a matured pine forest and discovered that when nutrients were added, there was a significant synergistic gain from increased CO₂ and nutrients. This gain was twice as low at the moderate site as it was at the poor site (threefold higher than the expected additive effect). As a result, fertility can mitigate the response of wood carbon sequestration to increased atmospheric CO₂. Finally, future assessments of carbon sequestration must take into account the constraints imposed by soil fertility as well as interactions with nitrogen deposition.

Hoen and Solaerg (1994) investigated 253 different stand treatments. (1) continued growth, (2) young growth release thinning, (3) thinning, (4) fertilization, (5) dear felling, (6) clear-felling with seed tree retention, and (7) planting or natural regeneration The study demonstrates that changing the forest management on Buskerud's productive forest area has a significant potential for increasing the present value of the flow of net CO₂ fixations (NPVCO₂). When compared to the NPVCO₂ obtained when the net present value of the timber cash flow (NPVNOK) for the area is maximised (BASE problem), an increase in NPVCO₂ of 8.4% -17.9% can be obtained. The possibility of increasing the NPVCO₂ is determined by the real rate of discount. The corresponding decrease in NPVNOK ranges between 8.1 and 14.9 percent.



*Materials
and
Methods*



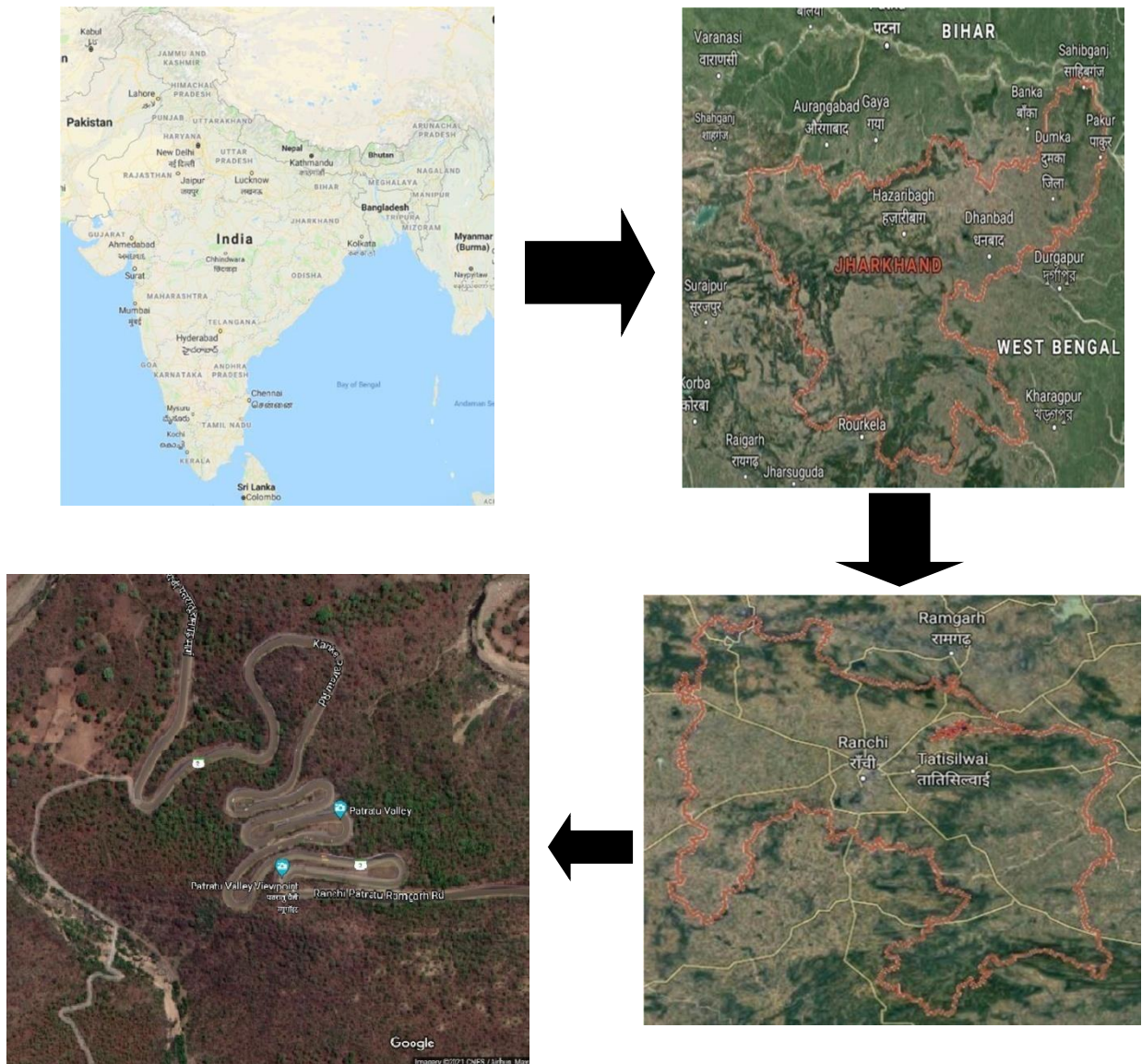
CHAPTER-III

MATERIALS AND METHODS

The details of experimental materials and methods used and techniques followed during the course of the present investigation are described below:

Geographical location and Physiography

The study site was located in Patratu valley Forest, Pithoria Beat, Ranchi West Range Kanke, Ranchi Division. The entire area is situated on hilly forest tract, which comes under Tropical Dry Deciduous Forest. The Patratu valley forest is located at a distance of about 26 KM from Birsa Agricultural University Campus on Ranchi-Pithoria-Road.. The Survey area lies at an elevation of around 405 m (1328.74 ft) from mean sea level.



[Fig.1. Location map of Patratu valley forest, Kanke Range]

Climate

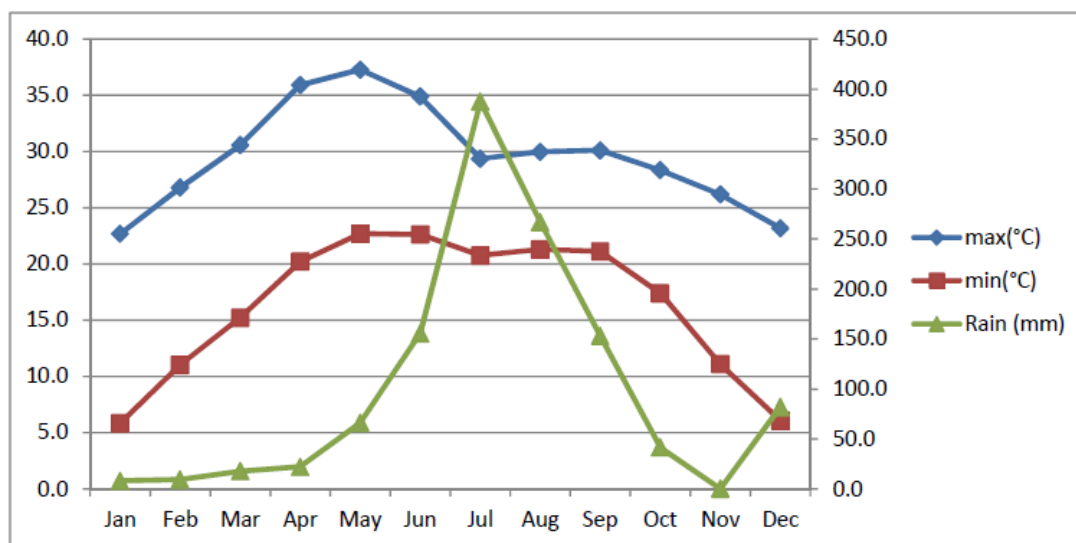
The region in the Ranchi district fall under the zone of tropical climate which experiences hot summer month from March to end of June and also receives a sufficient amount of rainfall during South West monsoon from mid June to September. In month of November to end of February (winter season) it experience cold and dry weather.

Temperature

As this region falls under tropical climate, temperature varies from 20^o C-42^oC in summer month and 0^oC - 25^oC in winter month. Month of may counts under the hottest month of the year and in this month mean maximum suits up to 36^oC. mean daily maximum temperature and man daily minimum temperature experienced at 22^oC and 7^oC respectively.

Rainfall

The study site receives its maximum rainfall during the month of June to September i.e. 1100mm out of total average of 1413.6 mm (56”).



[Fig.2. Ombrothermic diagram of Tropical deciduous forest of Ranchi East Division (Jan 2014- Jun 2019)]

Humidity

The average humidity is about 63%, which is increase and decrease in summer and winter accordingly.

Soils

The study site having the soil of mostly residual type, stony and gravelly soil (mixture of cobbles, pebbles and gravels) Some patches contain alluvial soil with coarse sand and gravel (with silt and clay). Topography determines the soil thickness.

Forest types

Sal (*Shorea robusta L.*) is the dominating species in the tropical region of Jharkhand. This corresponds to the Northern Dry Sal bearing forests 5B/C1 type (*Champion & Seth, 1968*).

Technical programme:

Sampling:

The study on above ground carbon sequestration in Tropical dry deciduous forest will be conducted after reconnaissance survey of Patratu valley Forest, Ranchi division.

Method:

For characterization of vegetation the simple random sampling procedure was adopted. The phyto-sociological analysis of the forest was carried out by randomly placing 10 quadrates of 10x10 m². In each quadrate, GBH (girth at breast height) of individual (≥ 30 cm girth) trees and saplings (individuals >10 cm - ≤ 30 cm girth) was measured. In centre of each 10x10m² quadrate, a 2x2m² area was marked for enumeration of seedlings (individuals <10 cm girth). Stem girth of adult and sapling was measured at 1.37m from the ground and for seedling at collar region. Shrubs will be measured in the 10 x 10m² quadrate at base. As the research work was conducted in summer months (20th – 30th April 2021), the contribution of herbaceous vegetation towards carbon sequestered can be neglected for the time being.

Phytosociological analysis

The vegetational data was quantitatively analyzed for density, frequency, abundance (Curtis and McIntosh, 1950).

$$\text{Density (tree/ha)} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates studied}}$$

$$\text{Frequency (\%)} = \frac{\text{Number of sampling units in which species occurred}}{\text{Total number of sampling units studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individual of the species in all sampling units}}{\text{Number of sampling units in which the species occurred}}$$

The relative density, relative frequency and relative basal area was calculated using following equations.

$$\text{Relative density (RD)} = \frac{\text{Density of the individual species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of the individual species}}{\text{Total frequency of all the species}} \times 100$$

$$\text{Relative basal area (RBA)} = \frac{\text{Basal area of the individual species}}{\text{Total abundance of all species}} \times 100$$

An importance value index was calculated as the sum total of relative frequency, relative density and relative basal area (Phillips, 2003).

$$\text{Importance value index (IVI)} = \text{RF} + \text{RD} + \text{RBA}$$

Species diversity analysis

Plant diversity in different quadrants was quantified by following diversity indices.

Shannon Index (Shannon and Weaver, 1963) was used for the species diversity

$$H' = - \sum p_i \log_2 p_i$$

Where,

p_i is the proportion of total stand basal area represented by the i^{th} species.

The working formula given by Smith (1974) was used here

$$H' = 3.3219 [\log_{10} N - (\sum N_i \log_{10} N_i / N)]$$

Where,

N_i is the total basal cover of species i

N is the total basal cover of all the species.

The factor 3.3219 is used to convert the index value to \log_2 .

Concentration of dominance (Cd) will be measured by Simpson's Index (Simpson, 1949)

$$Cd = \sum (N_i / N)^2$$

Where,

N_i and N are same as explained above and it varies between 0-1.

Equitability (e) was calculated as suggested by Pielou (1966)

$$e = H' / \ln S.$$

Where,

H' = Shannon index

S = the number of species.

Species richness (d) was calculated following Marglef, (1958).

$$d = S-1 / \ln N.$$

Where,

S = total number of species,

N = basal area of all species (m² ha⁻¹)

Biomass

Allometric equations was used for measuring tree and shrub biomass. These equations are developed by Sing and Mishra (1979) for dry deciduous forest species which is associated with tree circumference to biomass. Computation protocol as described by Singh and Singh (1991) was followed. The above ground herbaceous biomass was measured at its peak growth stage.

The relationship between girth of a tree and dry weight of a component is given by equation:

$$\text{Log } Y = a + b \log X$$

Where,

Y = dry weight (kg) of component (Bole, Branch, Leaf and Root)

X = girth (cm) at 1.37 m height

a and b = allometric constants

Carbon Storage

Carbon concentration was calculated by assuming that the carbon content is 50% of the total biomass (Brown and Lugo 1982, Cannell 1995, Dixon *et. al.* 1994, Ravindranath *et. al.* 1997, Richter *et. al.* 1995, Schroeder 1992). Carbon storage in different part of the vegetation was calculated by the, using carbon concentration values for vegetation pools of

dry tropics as 43.5% in bole, 45.67% in branch, 46.67% in leaf and 35.73% in root (Pawar *et al.* 2014 and Jhariya, 2017).

$$W_{\text{carbon}} = 0.5 * Y$$

Carbon Sequestration

To determine the value of carbon sequestration we need to find out the weight of carbon dioxide that can be produce with the carbon present in the biomass. To find the amount of CO₂ we need to multiply 3.67 with the value of carbon storage. (Tooichi, 2018).

$$W_{\text{carbon-dioxide}} = 3.67 * W_{\text{carbon}}$$



Plate-1: A view of Tropical Dry Deciduous Forest of Kanke Range Ranchi Division



Results and Discussion



CHAPTER IV

RESULTS AND DISCUSSIONS

The results on “SPECIES COMPOSITION, BIOMASS, CARBON STOCK AND CARBON SEQUESTRATION IN TROPICAL DRY DECIDUOUS FOREST OF KANKE RANGE, RANCHI DIVISION, JHARKHAND” are discussed in this chapter. The findings are presented under four major headings i.e. Determination of species composition and diversity, Biomass, Carbon stock, and Carbon sequestration. Results on different aspects in each part are described below.

1) DETERMINATION OF SPECIES COMPOSITION AND DIVERSITY

Species Composition

The species composition was studied as tree, sapling, seedling and shrub layers. The frequency (%), density (stems ha⁻¹), basal area (m² ha⁻¹) and IVI are calculated for tree, sapling, seedling, and shrub layer respectively.

Tree Layer

According to the study conducted there are a total of 1670 trees ha⁻¹ which include 19 species and 14 families. Among the species, most no. of trees are under the Dipterocarpaceae family i.e. 800 individuals followed by Ebenaceae (230), Rubiaceae (120), and Combretaceae (110). As per the outcome of data analysis tabulated in Table no. 4.1 the *Shorea robusta* with IVI value 129.87 dominated the ecosystem followed by *Diospyros melanoxylon* (39.32) and *Adina cordifolia* (27.11). The lowest IVI value was found to be 2.76, 2.79 & 3.73 which are associated with species like *Terminalia catappa*, *Bridelia retusa* & *Dellenia indica* respectively. The highest density was found to be associated with *Shorea robusta* & other major species having significant stem ha⁻¹ value are *Diospyros melanoxylon* & *Adina cordifolia*. *Bridelia retusa*, and *Terminalia catappa* represent the lowest density. Regarding Basal area the top three places have been acquired by *Shorea robusta*, *Diospyros melanoxylon*, and *Adina cordifolia* respectively and *Bridelia retusa* is at the bottom. The total tree density and basal area was recorded 1670 tree ha⁻¹ and 44.08 m² ha⁻¹, respectively.

Table 4.1 VEGETATIONAL COMPOSITION OF TREE LAYER

Sl.No	Species	F(%)	D (stems ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
1	<i>Lagerstroemia parviflora</i> Roxb	30	80	1.40	13.85
2	<i>Diospyros melanoxylon</i> Roxb.	80	230	4.35	39.32
3	<i>Shorea robusta</i> Roth.	100	800	27.50	129.87
4	<i>Adina cordifolia</i> (Roxb.)	60	120	3.60	27.11
5	<i>Terminalia catappa</i> (L.)	10	10	0.09	2.76
6	<i>Phyllanthus emblica</i> (L.)	20	40	0.41	7.25
7	<i>Terminalia tomentosa</i> (Roxb.)	30	80	1.92	15.03
8	<i>Bridelia retusa</i> (L.) A. Juss	10	10	0.10	2.79
9	<i>Syzygium cumini</i> (Linn.) Skeels.	10	20	0.32	3.89
10	<i>Butea monosperma</i> (Lamk) Taub	20	30	0.63	7.15
11	<i>Scheichera olosa</i> (Lour.) Oken	20	20	0.23	5.64
12	<i>Gmelina arborea</i> Linn.	10	20	0.26	3.75
13	<i>Madhuca indica</i> J.F. Gmel.	30	60	0.97	11.67
14	<i>Millettia pinnata</i> (L.) Panigrahi	10	30	0.47	4.82
15	<i>Terminalia arjuna</i> (Roxb.)	10	20	0.26	3.74
16	<i>Mangifera indica</i> Linn.	10	20	0.52	4.35
17	<i>Azadirachta indica</i> A. Juss	20	40	0.60	7.68
18	<i>Limonia acidissima</i> (L.)	20	20	0.20	5.56
19	<i>Dillenia indica</i> (L.)	10	20	0.25	3.73
Total		510	1670	44.08	

Sapling Layer

According to the study conducted there is a total of 1280 saplings ha⁻¹ which include 16 species and 13 families. Among the species, most no. of saplings are under the Dipterocarpaceae family i.e. 510 individuals followed by Ebenaceae, and Combretaceae. As per the outcome of data analysis tabulated in Table no. 4.2 the *Shorea robusta* with IVI value 102.18 dominated the ecosystem followed by *Diospyros melanoxylon* (48.72) and *Terminalia catappa* (26.29). The lowest IVI value was found to be 4.14, 4.35 & 4.92 which are associated with species like *Terminalia tomentosa*, *Azadirachta indica* & *Bauhinia variegata* respectively. The highest density was found to be associated with *Shorea robusta* & other major species having significant stem ha⁻¹ value are *Diospyros melanoxylon* & *Terminalia catappa*. *Terminalia tomentosa*, *Azadirachta indica*, and *Butea monosperma* represent the lowest density. Regarding Basal area the top three places have been acquired by *Shorea robusta*, *Diospyros melanoxylon*, and *Terminalia catappa* respectively and *Terminalia tomentosa* is at the bottom. The total sapling density and basal area was recorded 1280 sapling ha⁻¹ and 4.83 m² ha⁻¹, respectively.

Table 4.2 VEGETATIONAL COMPOSITION OF SAPLING LAYER

Sl.No	Species	F(%)	D (stems ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
1	<i>Diospyros melanoxylon</i> Roxb.	80	200	0.70	48.72
2	<i>Adina cordifolia</i> (Roxb.)	40	70	0.19	18.62
3	<i>Shorea robusta</i> Roth.	90	510	2.00	102.18
4	<i>Terminalia catappa</i> (L.)	30	120	0.48	26.29
5	<i>Phyllanthus emblica</i> (L.)	20	50	0.15	11.66
6	<i>Terminalia tomentosa</i> (Roxb.)	10	10	0.05	4.14
7	<i>Limonia acidissima</i> (L.)	20	40	0.20	11.88
8	<i>Lagerstroemia parviflora</i> Roxb	30	60	0.32	18.19
9	<i>Scheichera olosa</i> (Lour.) Oken	20	40	0.11	10.05
10	<i>Azadirachta indica</i> A. Juss	10	10	0.06	4.35
11	<i>Wrightia antidysenterica</i> (L.) R.Br	10	30	0.09	6.53
12	<i>Madhuca indica</i> J.F. Gmel.	10	20	0.10	5.96
13	<i>Bauhinia variegata</i> (L.) Benth	10	20	0.05	4.92
14	<i>Dillenia indica</i> (L.)	30	60	0.14	14.56
15	<i>Streblus asper</i> Lour.	10	20	0.11	6.17
16	<i>Butea monosperma</i> (Lamk) Taub	10	20	0.09	5.75
Total		430	1280	4.83	

Seedling Layer

According to the study conducted there is a total of 13640 seedlings ha⁻¹ which include 15 species and 13 families. Among the species, most no. of seedlings are under the Dipterocarpaceae family i.e. 4550 individuals followed by Ebenaceae, and Phyllanthaceae. As per the outcome of data analysis tabulated in Table no. 4.3 the *Shorea robusta* with IVI value 91.68 dominated the ecosystem followed by *Syzygium cumini* (45.60) and *Diospyros melanoxylon* (44.71). The lowest IVI value was found to be 4.02, 4.97 & 5.14 which are associated with species like *Syzygium cumini*, *Alstonia scholaris*, & *Scheichera olosa* respectively. The highest density was found to be associated with *Shorea robusta* & other major species having significant stem ha⁻¹ value are *Diospyros melanoxylon* & *Phyllanthus emblica*. *Syzygium cumini*, and *Scheichera olosa* represent the lowest density. Regarding Basal area the top three places have been acquired by *Shorea robusta*, *Phyllanthus emblica* and *Wrightia antidysenterica* respectively and *Syzygium cumini* is at the bottom. The total seedlings density and basal area was recorded 13640 seedlings ha⁻¹ and 1.11 m² ha⁻¹, respectively.

Table 4.3 VEGETATIONAL COMPOSITION OF SEEDLING LAYER

Sl.No	Species	F(%)	D (stems ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
1	<i>Shorea robusta</i> Roth.	100	4550	0.34	91.68
2	<i>Adina cordifolia</i> (Roxb.)	10	250	0.01	5.51
3	<i>Phyllanthus emblica</i> (L.)	50	2120	0.18	45.60
4	<i>Dillenia indica</i> (L.)	30	1200	0.08	24.32
5	<i>Diospyros melanoxylon</i> Roxb.	60	2600	0.10	44.71
6	<i>Lagerstroemia parviflora</i> Roxb.	20	600	0.02	11.75
7	<i>Bridelia retusa</i> (L.) A. Juss	10	250	0.05	8.65
8	<i>Wrightia antidysenterica</i> (L.) R. Br	10	250	0.13	16.29
9	<i>Limonia acidissima</i> (L.)	10	250	0.07	10.90
10	<i>Syzygium cumini</i> (Linn.) Skeels.	10	120	0.004	4.02
11	<i>Azadirachta indica</i> A. Juss	10	250	0.03	7.31
12	<i>Alstonia scholaris</i> (L.) R. Br	10	250	0.00	4.97
13	<i>Scheichera olosa</i> (Lour.) Oken	10	200	0.01	5.14
14	<i>Butea monosperma</i> (Lamk) Taub	10	500	0.05	10.94
15	<i>Streblus asper</i> Lour.	10	250	0.04	8.20
Total		360	13640	1.11	

Shrub Layer

According to the study conducted there are a total of 9330 shrub ha⁻¹ which include 06 species and 05 families. Among the species, most no. of shrubs are under the Lygodiaceae family i.e. 6590 individuals followed by Lamiaceae. As per the outcome of data analysis tabulated in Table no. 4.4 the *Lygodium japonicum* with IVI value 97.06 dominated the ecosystem followed by *Woodfordia fruticosa* (80.35) and *Clerodendrum infortunatum* (40.95). The lowest IVI value was found to be 8.59 & 33.01 which are associated with species like *Vitex negundo*, & *Agave sisalana* respectively. The highest density was found to be associated with *Lygodium japonicum* & other major species having significant stem ha⁻¹ value are *Clerodendrum infortunatum* & *Lantana camara*. *Agave sisalana*, and *Vitex negundo* represent the lowest density. Regarding Basal area the top three places have been acquired by *Woodfordia fruticosa*, and *Agave sisalana* respectively and *Lygodium japonicum* is at the bottom. The total shrub density and basal area was recorded 9330 shrub ha⁻¹ and 1.86 m² ha⁻¹, respectively.

Table4.4 VEGETATIONAL COMPOSITION OF SHRUB LAYER

Sl.No	Species shrub	F(%)	D (stems ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
1	<i>Lantana camara</i> (L.)	90	680	0.17	40.04
2	<i>Lygodium japonicum</i> (Thunb.) Sw.	100	6590	0.002	97.06
3	<i>Woodfordia fruticosa</i> (L.) Kurz.	50	480	1.16	80.35
4	<i>Vitex negundo</i> (L.)	20	260	0.01	8.59
5	<i>Clerodendrum infortunatum</i> (L.)	90	1250	0.07	40.95
6	<i>Agave sisalana</i> (Perrine)	30	70	0.45	33.01
Total		380	9330	1.86	

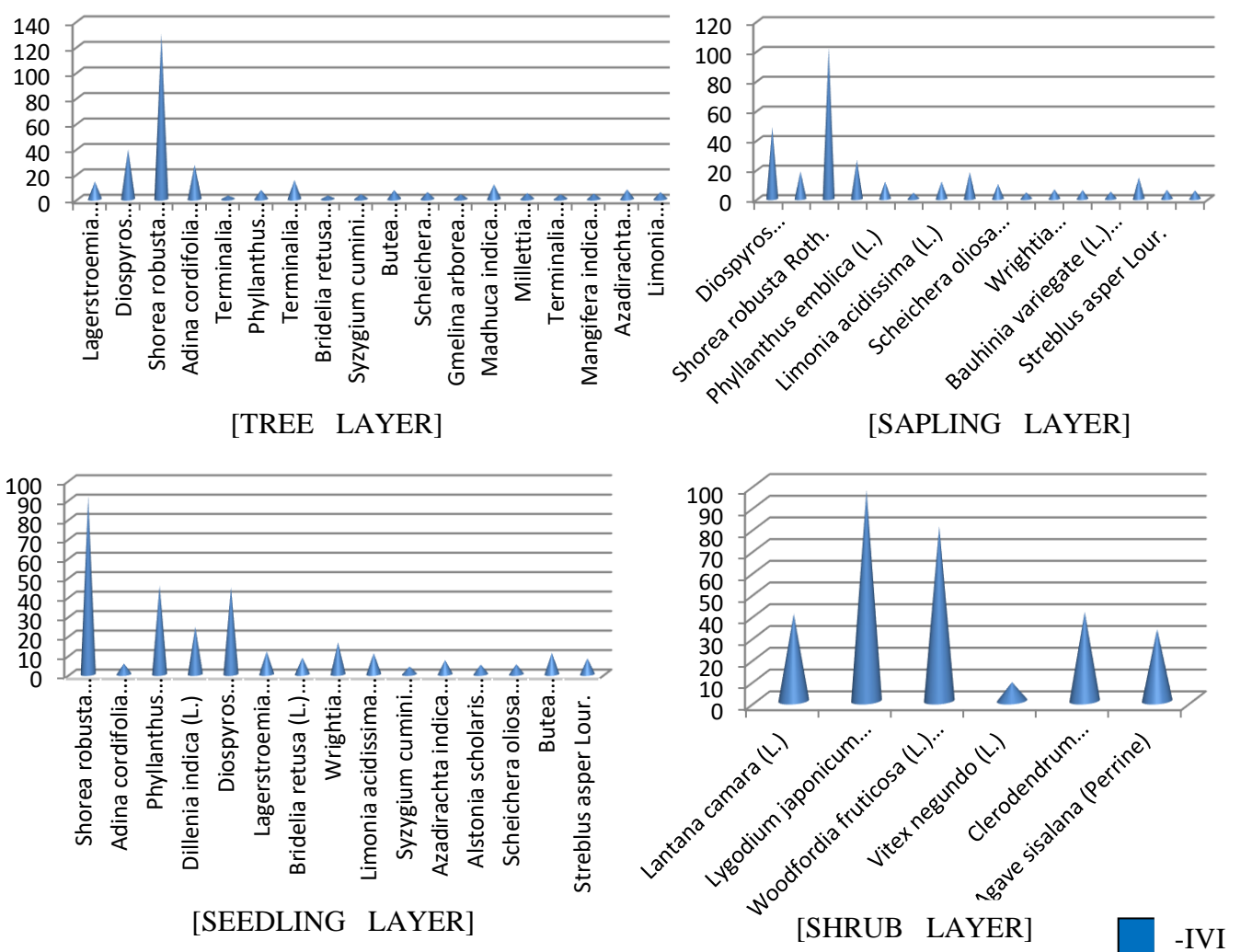
The tree basal area cover was found to be 44.01 m² ha⁻¹, which is supported by the value 33.5-46.8 m² ha⁻¹ (Raj, 2019). The sapling and seedling basal area were found to be 4.83 m² ha⁻¹, and 1.11 m² ha⁻¹, which were compared with 0.86 - 5.07 and 0.28 - 0.96 respectively by Yadav (2016). The shrub basal area cover was 1.86 m² ha⁻¹ in Patratu valley forest.

The tree having the density 1670 ha⁻¹ in the present study. The sapling density was found to be 1280 in Patratu valley, which is higher than 30-610 and seedling density (13640) is supported by the value 7750-39500, as studied by Pawar *et. al.*

(2014). The Shrub density in the studied area is 9330 which was compared with 4500 shrubs ha⁻¹. (Jharia & Yadav, 2016).

The most dominant and abundant species among the three layer of vegetation (tree, sapling and seedling) was Sal with highest IVI values 129.87, 102.18, and 91.68 respectively. This data is backed by Kumar & Saikia (2018) with value of 167.29 in Sal dominated forest of Ranchi and by Raj (2019) with value 115.3-135.2 in Sal dominating tropical dry deciduous forest. Most abundant shrub is *Lygodium japonicum* with IVI value 97.06, as supported by Watkins & Catherine (2009).

The present study showed increasing density and decreasing basal area as reported by Kumar & Saikia (2018). The decline in basal area may be due to lack of silvicultural management, dammar extraction, insect attack and small timbers. The enhancement in stem density may be due to strong social security and enforcement of forest policies.



[Graph No.: 01- Comparison of IVI values of different species]

Table 4.5 Comparison of Vegetational Composition of Tropical Dry Deciduous Forest of Ranchi West Division With Other Forests

Location	Layers	Density (stems ha ⁻¹)	Basal area (m ² ha ⁻¹)	Source
Sal Dominate Tropical Deciduous Forest, C. G.	Tree	--	33.5-46.8	Raj (2019)
	Sapling seedling	12250-14500	0.31- 0.35 --	
Tropical Moist Deciduous Forests of Ranchi, Jharkhand	Tree	397	262.50	Kumar & Saikia (2018)
	Shrub	11,047	--	
	Herb	232,553	--	
Central Himalayan	Tree	560-1100	27.24- 80.04	Arya <i>et. al.</i> (2017)
	Sapling	50-110	--	
	Seedling	60-390	--	
Tropical Deciduous Forest Achanakmar- Amarkantak Biosphere Reserve	Tree	260-810	9.96- 41.60	Yadav (2016)
	Sapling	7500-35000	0.86- 5.07	
	Seedling	25000-92500	0.28-0.96	
Tropical Forest, Odisha	Over story	728.474	28.453	Mishra <i>et. al.</i> (2018)
Sarguja Forest, C. G.	Shrub	4500	5.43	Jharia & Yadav (2016)
	Herb	8,32,000	--	
Sal Dominat Forest, Central Himalayan	Tree	650	--	Kapkoti <i>et. al.</i> (2016)
	Sapling	36		
	Seedling	400		
Sal- Teak Mixed Forest, Central Himalayan	Tree	911	--	
	Sapling Seedling	1303 6656		
Tropical Dry Mixed Deciduous Forest, Myanmar	Tree	1061	27.52	Aye <i>et. al.</i> (2014)
Southern Tropical Moist Deciduous Forests	Tree	132	23.32	Jayakumar & Nair (2013)
Subtropical Dry Deciduous Forest	Tree	288	14.32	Sharma & Kant (2014)
	Shrub	376	--	
Himalayan Subtropical Pine Forest	Tree	498	37.75	
	Shrub	163	--	
Dry Tropics	Tree	100-510	14.67-26.67	Pawar <i>et. al.</i> (2014)
	Sapling	30-610	0.06-1.24	
	Seedling	7750-39500	--	
Tropical Dry Deciduous Forest	Tree	1670	44.08	Present Study
	Sapling	1280	4.83	
	Seedling	13640	1.113	
	Shrub	9330	1.86	

Species Diversity

Species diversity, the number of species in a community, is ecologically important. Since, it seems to increase as more stable community. The valuations of species in different layers are summarized in the Table 4.6.

Shannon index (H')

The Shannon index values recorded were 1.98 for tree layer, 2.09 for sapling layer, 2.06 for seedling layer and 0.99 for shrub layer in study area.

Concentration of dominance (Cd)

The values recorded for Concentration of dominance in different vegetational layers were 0.262 for tree layer, 0.2 for sapling layer, 0.185 for seedling layer and 0.52 for shrub layer found in study area.

Equitability (e)

Equitability (e) values were 0.67 for tree layer, 0.75 for sapling layer, 0.76 for seedling layer and 0.55 for shrub layer found in study area.

Species Richness (d)

In study site species richness values were 2.42 for tree layer, 2.09 for sapling layer, 1.47 for seedling layer and 0.54 for shrub layer in study area.

Table 4.6 DIVERSITY INDICES OF TROPICAL DRY DECIDUOUS FOREST OF RANCHI EAST DIVISION

Parameters	Tree	Sapling	Seedling	Shrub
Shannon index (H')	1.98	2.09	2.06	0.99
Conc. of Dominance (cd)	0.262	0.2	0.18	0.52
Equitability (e)	0.676	0.75	0.76	0.55
Species Richness (d)	2.42	2.09	1.47	0.54

Maximum diversity as found in sapling layer with Shannon index (2.09) followed by seedling (2.06), tree (1.98) and shrub (0.99). The Concentration of dominance were found highest in shrub layer (0.52) followed by trees (0.262), saplings (0.2), and seedlings (0.18). Highest evenness was found in seedling layer with equitability 0.76 followed by saplings (0.75), trees (0.676) and shrubs (0.55). The species richness was found highest in tree layer (2.42) followed by saplings (2.09), seedlings (1.47) and shrubs (0.54).

TABLE 4.7 COMPARISON OF DIVERSITY INDICES OF TROPICAL DRY DECIDUOUS FOREST OF RANCHI WEST DIVISION WITH OTHER FORESTS

Location	Layers	H'	cd	E	d	sources
Sal Dominating Tropical Deciduous Forest	Tree	1.61-1.86	0.18-0.58	0.6-0.82	1.71-2.23	Raj (2019)
	Sapling	1.42-1.68	0.28-0.79	0.67-0.96	0.89-1.48	
	Seedling	1.46-1.75	0.21-0.62	0.48-0.71	1.2-1.67	
Sal Forest in Kumaun Region	Tree	0.313	0.894			Kapkoti <i>et. al.</i> (2016)
	Sapling	0.871	0.674			
	Seedling	0.722	0.722			
Central Himalaya	Tree	0.93-2.18	0.1-0.44	0.49-0.87	0.16-0.54	Arya <i>et. al.</i> (2017)
	Sapling	0.5-1.84	0.16-0.55	0.72-0.92	0.11-0.6	
	Seedling	0.2-2.02	0.13-0.54	0.18-0.97	0.12-0.92	
Tropical Moist Deciduous Forests of Ranchi, Jharkhand	Tree	2.25	0.32	0.49	10.28	Kumar & Saikia (2018)
	Shrub	2.72	1.1	0.76	4.88	
	Herb	2.98	0.08	0.78	5.85	
Tropical Deciduous Forest		1.09-2.3	0.25-0.65	0.49-1.2	5.0-12.1	Yadav (2016)
Southern Tropical Moist Deciduous Forests	Tree	2.79				Jayakumar & Nair (2013)
	Sapling	2.48				
	Seedling	2.62				
Sarguja Forest	Herb	4.606	0.045	1.397	1.917	Sinha <i>et. al.</i> (2015)
Tropical Dry Mixed Deciduous Forest, Myanmar	Tree	1.45-3.61	0.5-0.96	0.38-0.84		Aye <i>et. al.</i> (2014)
Eastern Ghats, Odisha	Tree	1.29-2.19	0.62-0.87	0.68-0.92		Sahu <i>et. al.</i> (2019)
Eastern Ghats, Andhra Pradesh		3.76-3.96	0.96-0.97	0.6-0.78	10.0-11.2	Naidu & Kumar (2016)

Subtropical Forest Siwaliks	Tree	3.38	0.96	0.84	16.46	Sharma & Kant (2014)
	Shrub	2.68	0.89	0.75	10.27	
Dry Tropics	Tree	2.32-2.83	0.2-0.24	1.13-1.29	1.08-1.91	Pawar <i>et.</i>
	Sapling	0.91-2.65	0.18-0.55	1.06-1.31	0.29-1.29	
	Seedling	1.5-2.68	0.2-0.55	0.72-1.37	0.33-0.23	
Tropical Deciduous Forest Horhap Beat, Ranchi East Division	Tree	2.43-2.97	0.24-0.33	0.92-0.99	1.79-2.53	Panda. <i>et.</i> <i>al.</i> (2020)
	Sapling	3.07-3.08	0.19-0.21	1.0	2.11-2.43	
	Seedling	2.21-2.26	0.37-0.4	0.84-0.86	1.19-1.21	
	Shrub	1.53-1.65	0.46-0.48	0.85-0.86	0.56-0.67	
	Herb	3.30-3.39	0.13-0.14	1.0	1.27-1.6	
Tropical Deciduous Forest Patratu Forest Ranchi West Division	Tree	1.98	0.262	0.676	2.42	Present study
	Sapling	2.09	0.2	0.75	2.09	
	Seedling	2.06	0.18	0.76	1.47	
	Shrub	0.99	0.52	0.55	0.54	

BIOMASS

The total biomass in different vegetational layers i.e. tree, sapling, seedling, and shrub layer in study sites are given in the Table 4.8 to 4.12.

Tree Layer

Concerning the study conducted in Patrattu valley forest, the total tree biomass of 326.646 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 120.75 t ha⁻¹, 153.64 t ha⁻¹, 13.76 t ha⁻¹ & 38.5 t ha⁻¹ which is 36.96%, 47.03%, 4.21%, & 11.78% of the total biomass respectively. The species called *Shorea robusta* has contributed the highest to the biomass i.e. 221.4 t ha⁻¹ which is 67.8% of the total. The other major species which contribute to the biomass are *Lagerstroemia parviflora* (34 t ha⁻¹) & *Diospyros melanoxylon* (22.46 t ha⁻¹) which constituted 10.4 and 6.8 % of the total biomass respectively. However, *Terminalia catappa* contributes lowest to the ecosystem when biomass is concern i.e. 0.56 t ha⁻¹. The total above-ground biomass recorded was 288.14 t ha⁻¹ and below-ground biomass was 33.504 t ha⁻¹.

Table 4.8 TOTAL TREE BIOMASS (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lagerstroemia parviflora</i> Roxb	13.654	12.842	2.013	5.491	34.000
2	<i>Diospyros melanoxylon</i> Roxb.	9.999	8.454	0.941	3.066	22.460
3	<i>Shorea robusta</i> Roth.	77.003	112.383	8.303	23.734	221.400
4	<i>Adina cordifolia</i> (Roxb.)	4.466	4.384	0.556	1.373	10.780
5	<i>Terminalia catappa</i> (L.)	0.253	0.198	0.034	0.078	0.564
6	<i>Phyllanthus emblica</i> (L.)	0.751	0.706	0.112	0.261	1.830
7	<i>Terminalia tomentosa</i> (Roxb.)	3.699	3.984	0.445	1.140	9.266
8	<i>Bridelia retusa</i> (L.) A. Juss	0.168	0.132	0.023	0.052	0.374
9	<i>Syzygium cumini</i> (Linn.) Skeels.	0.771	0.793	0.094	0.237	1.896
10	<i>Butea monosperma</i> (Lamk) Taub	1.076	1.118	0.131	0.331	2.656
11	<i>Scheichera olosa</i> (Lour.) Oken	0.756	0.709	0.096	0.233	1.794
12	<i>Gmelina arborea</i> Linn.	0.569	0.534	0.072	0.175	1.350
13	<i>Madhuca indica</i> J.F. Gmel.	2.173	2.149	0.269	0.669	5.260
14	<i>Millettia pinnata</i> (L.) Panigrahi	1.049	1.032	0.131	0.323	2.534
15	<i>Terminalia arjuna</i> (Roxb.)	0.557	0.513	0.071	0.171	1.312
16	<i>Mangifera indica</i> Linn.	1.269	1.472	0.148	0.391	3.280
17	<i>Azadirachta indica</i> A. Juss	1.606	1.414	0.208	0.494	3.722
18	<i>Limonia acidissima</i> (L.)	0.395	0.309	0.053	0.121	0.878
19	<i>Dillenia indica</i> (L.)	0.538	0.518	0.068	0.166	1.290
Total		120.755	153.643	13.767	38.504	326.646

Sapling Layer

Concerning the study conducted in Patrattu valley forest, the total sapling biomass of 24.301 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 11.453 t ha⁻¹, 6.9 t ha⁻¹, 1.54 t ha⁻¹ & 4.38 t ha⁻¹ which is 47.12%, 28.39%, 6.33% and 18.02 %, of the total biomass respectively. The species called *Shorea robusta* has contributed the highest to the biomass i.e. 11.38 t ha⁻¹ which is 40.6% of the total. The other major species which contribute to the biomass are *Diospyros melanoxylon* (3.6 t ha⁻¹) & *Terminalia catappa* (2.01 t ha⁻¹) which constituted 12.08 and 7.17 % of the total biomass respectively. However, *Madhuca indica* contributes lowest to the ecosystem when biomass is concern i.e. 0.100 t ha⁻¹. The total above-ground biomass recorded was 19.92 t ha⁻¹ and below-ground biomass was 4.38 t ha⁻¹.

Table 4.9 TOTAL SAPLING BIOMASS (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Diospyros melanoxylon</i> Roxb.	1.695	1.025	0.228	0.648	3.596
2	<i>Adina cordifolia</i> (Roxb.)	0.748	0.452	0.101	0.286	1.587
3	<i>Shorea robusta</i> Roth.	5.363	3.244	0.721	2.051	11.380
4	<i>Terminalia catappa</i> (L.)	0.989	0.598	0.133	0.378	2.098
5	<i>Phyllanthus emblica</i> (L.)	0.357	0.216	0.048	0.137	0.758
6	<i>Terminalia tomentosa</i> (Roxb.)	0.109	0.066	0.015	0.042	0.231
7	<i>Limonia acidissima</i> (L.)	0.107	0.065	0.014	0.041	0.227
8	<i>Lagerstroemia parviflora</i> Roxb	0.411	0.248	0.055	0.157	0.871
9	<i>Scheichera olosa</i> (Lour.) Oken	0.369	0.223	0.050	0.141	0.782
10	<i>Azadirachta indica</i> A. Juss	0.135	0.082	0.018	0.052	0.287
11	<i>Wrightia antidysenterica</i> (L.) R.Br	0.186	0.112	0.025	0.071	0.394
12	<i>Madhuca indica</i> J.F. Gmel.	0.047	0.029	0.006	0.018	0.100
13	<i>Bauhinia variegata</i> (L.) Benth	0.089	0.054	0.012	0.034	0.189
14	<i>Dillenia indica</i> (L.)	0.369	0.224	0.050	0.141	0.784
15	<i>Streblus asper</i> Lour.	0.235	0.142	0.032	0.090	0.499
16	<i>Butea monosperma</i> (Lamk) Taub	0.244	0.148	0.033	0.093	0.518
	Total	11.453	6.928	1.541	4.379	24.301

Seedling Layer

Concerning the study conducted in Patrattu valley forest, the total seedling biomass of 2.887 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 1.506 t ha⁻¹, 0.329 t ha⁻¹, 0.361 t ha⁻¹ & 0.691 t ha⁻¹ which is 52.29, 11.39, 12.50 and 23.93%, of the total biomass respectively. The species called *Diospyros melanoxylon* has contributed the highest to the biomass i.e. 0.7 t ha⁻¹ which is 24.30 % of the total. The other major species which contribute to the biomass are *Shorea robusta* (0.521 t ha⁻¹) & *Phyllanthus emblica* (0.5 t ha⁻¹) which constituted 18.04 and 17.36 % of the total biomass respectively. However, *Scheichera olosa* contributes lowest to the ecosystem when biomass is concern i.e. 0.012 t ha⁻¹. The total above-ground biomass recorded was 2.196 t ha⁻¹ and below-ground biomass was 0.691 t ha⁻¹.

Table 4.10 TOTAL SEEDLING BIOMASS (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Shorea robusta</i> Roth.	0.297	0.045	0.069	0.110	0.521
2	<i>Adina cordifolia</i> (Roxb.)	0.014	0.002	0.003	0.005	0.024
3	<i>Phyllanthus emblica</i> (L.)	0.200	0.064	0.086	0.151	0.500
4	<i>Dillenia indica</i> (L.)	0.066	0.009	0.016	0.024	0.115
5	<i>Diospyros melanoxylon</i> Roxb.	0.367	0.061	0.080	0.193	0.700
6	<i>Lagerstroemia parviflora</i> Roxb.	0.010	0.003	0.002	0.002	0.017
7	<i>Bridelia retusa</i> (L.) A. Juss	0.091	0.025	0.017	0.034	0.168
8	<i>Wrightia antidysenterica</i> (L.) R. Br	0.169	0.048	0.031	0.063	0.311
9	<i>Limonia acidissima</i> (L.)	0.169	0.048	0.031	0.063	0.311
10	<i>Syzygium cumini</i> (Linn.) Skeels.	0.007	0.001	0.002	0.002	0.012
11	<i>Azadirachta indica</i> A. Juss	0.056	0.014	0.011	0.021	0.102
12	<i>Alstonia scholaris</i> (L.) R. Br	0.014	0.002	0.003	0.005	0.024
13	<i>Scheichera olosa</i> (Lour.) Oken	0.007	0.001	0.002	0.003	0.012
14	<i>Butea monosperma</i> (Lamk) Taub	0.027	0.004	0.007	0.010	0.048
15	<i>Streblus asper</i> Lour.	0.014	0.002	0.003	0.005	0.024
Total		1.506	0.329	0.361	0.691	2.887

Shrub Layer

Concerning the study conducted in Patrattu valley forest, the total shrub biomass of 5.12 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 2.37 t ha⁻¹, 1.32 t ha⁻¹, 0.55 t ha⁻¹ & 0.882 t ha⁻¹ which is 46.21, 25.76, 10.73 and 17.17%, of the total biomass respectively. The species called *Woodfordia fruticosa* has contributed the highest to the biomass i.e. 2.765 t ha⁻¹ which is 53.96 % of the total. The other major species which contribute to the biomass are *Agave sisalana* (1.411 t ha⁻¹) & *Lantana camara* (0.5 t ha⁻¹) which constituted 27.53 and 10.69 % of the total biomass respectively. However, *Clerodendrum infortunatum* contributes lowest to the ecosystem when biomass is concern i.e. 0.052 t ha⁻¹. The total above-ground biomass recorded was 4.24 t ha⁻¹ and below-ground biomass was 0.882 t ha⁻¹.

Table 4.11 TOTAL SHRUB BIOMASS (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lantana camara</i> (L.)	0.216	0.138	0.093	0.101	0.548
2	<i>Lygodium japonicum</i> (Thunb.) Sw.	0.088	0.064	0.068	0.051	0.272
3	<i>Woodfordia fruticosa</i> (L.) Kurz.	1.306	0.721	0.262	0.476	2.765
4	<i>Vitex negundo</i> (L.)	0.025	0.018	0.019	0.014	0.076
5	<i>Clerodendrum infortunatum</i> (L.)	0.017	0.012	0.013	0.010	0.052
6	<i>Agave sisalana</i> (Perrine)	0.716	0.366	0.099	0.230	1.411
Total		2.368	1.320	0.555	0.882	5.124

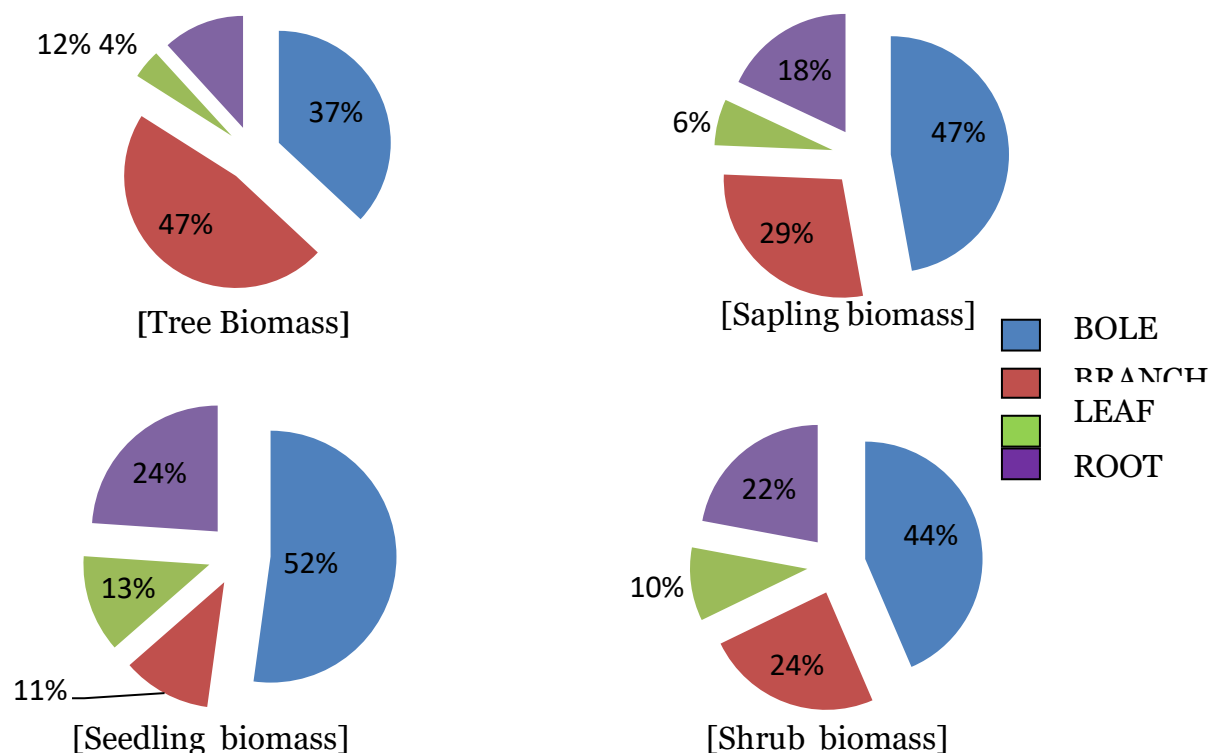
Total tree biomass was found to be 326.646 t ha⁻¹, which was supported by the value 103.3- 453.5 t ha⁻¹ (Joshi & Dhyani ,2018) and higher than Dry Tropics i.e. 127.7-227.7 t ha⁻¹ studied by Pawar *et. al.* (2014). However the total tree biomass was compared with Sal forest of Nepal studied by Neupen & Sharma (2014) 123- 305.9 t ha⁻¹.

Total sapling biomass was 24.301 t ha⁻¹, which was supported by the value 6.65- 28.62t ha⁻¹ in Eastern Himalaya (Bhutan by Tashi, 2016). However the total sapling biomass was much lower than 56.59 t ha⁻¹ in Tropical deciduous forest (Jharia & Yadav ,2018).

Total seedling biomass was found to be 2.887 t ha⁻¹, which was supported by the studies conducted in Tropical deciduous forest by Jharia & Yadav (2018) determined 7.66 t ha⁻¹.

Total shrub biomass was 5.124 t ha⁻¹, in present study which was found lower than 12.67 t ha⁻¹ studied by Salunkhe *et al.* (2014) in Tropical dry deciduous forest, M.P. and was found higher than 0.01-2.82 t ha⁻¹ studied by Rao & Rao (2015) in Tropical deciduous forests, Nallamalais. However the total shrub biomass was compared with 2.41- 7.64 t ha⁻¹ at Eastern Himalaya, Bhutan (Tashi, 2016).

Previous reports on biomass estimation of different forests are summarized in Table 4.11. Among the reference data, the highest biomass was estimated in the Tropical Forest, Congo by Ekoungoulou *et al.* (2018) and Tropical rain forest, Brazil by Cummings *et al.* (2002). Present study indicates a healthy biomass composition compared to other tropical dry deciduous forest areas.



[Graph No.02:Contribution of different parts towards biomass]

Table 4.12 COMPARISON OF FLORAL BIOMASS (t ha⁻¹) OF TROPICAL DRY DECIDUOUS FOREST OF RANCHI EAST DIVISION WITH OTHER FORESTS

Location	Layers	Above-ground	Below-ground	Total	Sources
Tropical North East Forest	Tree	124.6-255	--	--	Thochom & Yadava (2017)
Tropical Dry Deciduous Forest	Tree	83.2– 370.1	20.1 -83.4	103.3- 453.5	Joshi & Dhyani (2018)
Sal Forest in Nepal	Tree	117.2-299.6	5.8-6.3	123- 305.9	Neupen & Sharma (2014)
Tropical Dry Forest, East Godavari	Tree	58.04- 368.39	--	--	Srinivas&Sun darapandian (2018)
Tropical Deciduous Forests, Nallamalais	Tree	--	--	5.2- 299.3	Rao & Rao (2015)
	Shrub	--	--	0.01-2.82	
	Herb	--	--	0.2-6.0	
Dry Tropics, C. G.	Tree	111.2-199.4	16.5-28.3	127.7-227.7	Pawar <i>et. al.</i> (2014)
Semi Evergreen Forest	Tree	197.59±60.06	--	--	Giri <i>et. al.</i> (2018)
Tropical Deciduous Forest	Tree	211.99	29.45	241.44	Jharia & Yadav (2018)
	Sapling	46.46	10.13	56.59	
	Seedling	6.07	1.59	7.66	
	Shrub	12.89	2.61	15.50	
Tropical Wet Evergreen Forest	Tree	101.26-282.6	20.25-56.52	121.51-339.13	Gogoi <i>et. al.</i> (2017)
Tropical Dry Deciduous Forest, Haryana	Tree	37.93 - 63.73	11.12-17.81	49.05-81.54	Singh <i>et. al.</i> (2014)
Tropical Dry Deciduous	Herb	--	--	5.23	Salunkhe <i>et. al.</i> (2014)
	Shrub	--	--	12.67	

Forest, M.P.					
Tropical Forest of Cachar, Assam	Tree	32.47 -261.64	--	--	Borah <i>et. al.</i> (2013)
Eastern Himalaya, Bhutan	Tree	108.24- 407.2	--	--	Tashi <i>et. al.</i> (2016)
	Sapling	6.65- 28.62			
	Shrub	2.41- 7.64			
Tropical Rain Forest, Brazil	Open	288-346	--	--	Cummings <i>et. al.</i> (2002)
	Dense	298-533	--	--	
	Ecotone	298-422	--	--	
Tropical Forest, Congo	Tree	291.8- 559.7	68.5- 131	360.3- 690.7	Ekoungoulou <i>et. al.</i> (2018)
Savvana	--	12.88	--	--	Oliveira <i>et. al.</i> (2019)
Tropical Rain Forest, Australia	Tree	307– 909	--	--	Bradford&Murphy (2019)
Sundarbans, Bangladesh	Tree	154.8	84.2	239	Kamruzzaman (2017)
Conifer Forest Bhutan	Tree			191.58	Tshering (2019)
Tropical Deciduous Forest Horhap Beat, Ranchi East Division	Tree	254.8-333.3	42.2-53.6	297.04- 386.9	Panda. <i>et. al.</i> (2020)
	Sapling	18.06-19.86	4.24-4.37	22.30-24.23	
	Seedling	7.14- 5.617	2.09-1.63	7.24- 9.23	
	Shrub	2.33-4.42	0.48-0.92	2.8- 5.3	
	Herb	1.24- 2.46	0.25-0.49	1.5- 2.9	
Tropical Deciduous Forest Patratu Forest Ranchi West Division	Tree	288.14	38.504	326.646	Present study
	Sapling	22.973	5.05	28.023	
	Seedling	2.196	0.691	2.887	
	Shrub	4.242	0.882	5.124	

CARBON STOCK

The total carbon stock in different vegetational layers at study site are given in the Table 4.13 to 4.17.

Tree Layer

Concerning the study conducted in Patrattu valley forest, the total tree carbon stock of 163.232 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 60.377 t ha⁻¹, 76.822 t ha⁻¹, 6.88 t ha⁻¹ & 19.25 t ha⁻¹ which is 36.96%, 47.03%, 4.21%, & 11.78% of the total carbon stock respectively. The species called *Shorea robusta* has contributed the highest to the carbon stock i.e. 110.7 t ha⁻¹ which is 67.7% of the total. The other major species which contribute to the carbon stock are *Lagerstroemia parviflora* (17 t ha⁻¹) & *Diospyros melanoxylon* (11.23 t ha⁻¹) which constituted 10.4 and 6.8 % of the total carbon stock respectively. However, *Terminalia catappa* contributes lowest to the ecosystem when carbon stock is concern i.e. 0.282 t ha⁻¹.

Table 4.13 TOTAL TREE CARBON STOCK (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lagerstroemia parviflora</i> Roxb	6.827	6.421	1.006	2.746	17.000
2	<i>Diospyros melanoxylon</i> Roxb.	5.000	4.227	0.471	1.533	11.230
3	<i>Shorea robusta</i> Roth.	38.501	56.191	4.151	11.867	110.700
4	<i>Adina cordifolia</i> (Roxb.)	2.233	2.192	0.278	0.687	5.390
5	<i>Terminalia catappa</i> (L.)	0.127	0.099	0.017	0.039	0.282
6	<i>Phyllanthus emblica</i> (L.)	0.376	0.353	0.056	0.130	0.915
7	<i>Terminalia tomentosa</i> (Roxb.)	1.849	1.992	0.222	0.570	4.633
8	<i>Bridelia retusa</i> (L.) A. Juss	0.084	0.066	0.011	0.026	0.187
9	<i>Syzygium cumini</i> (Linn.) Skeels.	0.386	0.396	0.047	0.119	0.948
10	<i>Butea monosperma</i> (Lamk) Taub	0.538	0.559	0.065	0.165	1.328
11	<i>Scheichera oliosa</i> (Lour.) Oken	0.378	0.355	0.048	0.116	0.897
12	<i>Gmelina arborea</i> Linn.	0.285	0.267	0.036	0.087	0.675
13	<i>Madhuca indica</i> J.F. Gmel.	1.087	1.074	0.135	0.334	2.630
14	<i>Millettia pinnata</i> (L.) Panigrahi	0.525	0.516	0.065	0.161	1.267
15	<i>Terminalia arjuna</i> (Roxb.)	0.279	0.256	0.035	0.086	0.656
16	<i>Mangifera indica</i> Linn.	0.635	0.736	0.074	0.195	1.640
17	<i>Azadirachta indica</i> A. Juss	0.803	0.707	0.104	0.247	1.861
18	<i>Limonia acidissima</i> (L.)	0.197	0.154	0.027	0.061	0.439
19	<i>Dillenia indica</i> (L.)	0.269	0.259	0.034	0.083	0.645
Total		60.377	76.822	6.884	19.252	163.323

Sapling Layer

Concerning the study conducted in Patrattu valley forest, the total sapling carbon stock of 12.151 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 5.727 t ha⁻¹, 3.464 t ha⁻¹, 0.77 t ha⁻¹ & 2.19 t ha⁻¹ which is 47.12%, 28.39%, 6.33% and 18.02 %, of the total carbon stock respectively. The species called *Shorea robusta* has contributed the highest to the carbon stock i.e. 5.69 t ha⁻¹ which is 40.6% of the total. The other major species which contribute to the carbon stock are *Diospyros melanoxylon* (1.8 t ha⁻¹) & *Terminalia catappa* (1.05 t ha⁻¹) which constituted 12.08 and 7.17 % of the total carbon stock respectively. However, *Madhuca indica* contributes lowest to the ecosystem when carbon stock is concern i.e. 0.05 t ha⁻¹.

Table 4.14 TOTAL SAPLING CARBON STOCK (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Diospyros melanoxylon</i> Roxb.	0.847	0.513	0.114	0.324	1.798
2	<i>Adina cordifolia</i> (Roxb.)	0.374	0.226	0.050	0.143	0.794
3	<i>Shorea robusta</i> Roth.	2.682	1.622	0.361	1.025	5.690
4	<i>Terminalia catappa</i> (L.)	0.494	0.299	0.067	0.189	1.049
5	<i>Phyllanthus emblica</i> (L.)	0.179	0.108	0.024	0.068	0.379
6	<i>Terminalia tomentosa</i> (Roxb.)	0.054	0.033	0.007	0.021	0.116
7	<i>Limonia acidissima</i> (L.)	0.053	0.032	0.007	0.020	0.114
8	<i>Lagerstroemia parviflora</i> Roxb	0.205	0.124	0.028	0.078	0.436
9	<i>Scheichera olosa</i> (Lour.) Oken	0.184	0.111	0.025	0.070	0.391
10	<i>Azadirachta indica</i> A. Juss	0.068	0.041	0.009	0.026	0.144
11	<i>Wrightia antidysenterica</i> (L.) R.Br	0.093	0.056	0.012	0.035	0.197
12	<i>Madhuca indica</i> J.F. Gmel.	0.024	0.014	0.003	0.009	0.050
13	<i>Bauhinia variegata</i> (L.) Benth	0.045	0.027	0.006	0.017	0.095
14	<i>Dillenia indica</i> (L.)	0.185	0.112	0.025	0.071	0.392
15	<i>Streblus asper</i> Lour.	0.118	0.071	0.016	0.045	0.250
16	<i>Butea monosperma</i> (Lamk) Taub	0.122	0.074	0.016	0.047	0.259
	Total	5.727	3.464	0.770	2.190	12.151

Seedling Layer

Concerning the study conducted in Patrattu valley forest, the total seedling carbon stock of 1.44 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 0.75 t ha⁻¹, 0.165 t ha⁻¹, 0.18 t ha⁻¹ & 0.345 t ha⁻¹ which is 52.29, 11.39, 12.50 and 23.93%, of the total carbon stock respectively. The species called *Diospyros melanoxylon* has contributed the highest to the carbon stock i.e. 0.35 t ha⁻¹ which is 24.30 % of the total. The other major species which contribute to the carbon stock are *Shorea robusta* (0.261 t ha⁻¹) & *Phyllanthus emblica* (0.25 t ha⁻¹) which constituted 18.04 and 17.36 % of the total carbon stock respectively. However, *Scheichera olosa* contributes lowest to the ecosystem when carbon stock is concern i.e. 0.006 t ha⁻¹.

Table 4.15 TOTAL SEEDLING CARBON STOCK (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Shorea robusta</i> Roth.	0.148	0.023	0.035	0.055	0.261
2	<i>Adina cordifolia</i> (Roxb.)	0.007	0.001	0.002	0.003	0.012
3	<i>Phyllanthus emblica</i> (L.)	0.100	0.032	0.043	0.075	0.250
4	<i>Dillenia indica</i> (L.)	0.033	0.005	0.008	0.012	0.058
5	<i>Diospyros melanoxylon</i> Roxb.	0.184	0.030	0.040	0.096	0.350
6	<i>Lagerstroemia parviflora</i> Roxb.	0.005	0.001	0.001	0.001	0.008
7	<i>Bridelia retusa</i> (L.) A. Juss	0.046	0.013	0.008	0.017	0.084
8	<i>Wrightia antidysenterica</i> (L.) R. Br	0.084	0.024	0.015	0.031	0.155
9	<i>Limonia acidissima</i> (L.)	0.084	0.024	0.015	0.031	0.155
10	<i>Syzygium cumini</i> (Linn.) Skeels.	0.003	0.000	0.001	0.001	0.006
11	<i>Azadirachta indica</i> A. Juss	0.028	0.007	0.005	0.010	0.051
12	<i>Alstonia scholaris</i> (L.) R. Br	0.007	0.001	0.002	0.003	0.012
13	<i>Scheichera olosa</i> (Lour.) Oken	0.003	0.000	0.001	0.001	0.006
14	<i>Butea monosperma</i> (Lamk) Taub	0.014	0.002	0.003	0.005	0.024
15	<i>Streblus asper</i> Lour.	0.007	0.001	0.002	0.003	0.012
Total		0.753	0.165	0.180	0.345	1.443

Shrub Layer

Concerning the study conducted in Patrattu valley forest, the total shrub carbon stock of 2.562 t ha⁻¹ was recorded among which contribution of bole, branch, leaves & root was 1.184 t ha⁻¹, 0.66 t ha⁻¹, 0.277 t ha⁻¹ & 0.441 t ha⁻¹ which is 46.21, 25.76, 10.73 and 17.17%, of the total carbon stock respectively. The species called *Woodfordia fruticosa* has contributed the highest to the carbon stock i.e. 1.36 t ha⁻¹ which is 53.96 % of the total. The other major species which contribute to the carbon stock are *Agave sisalana* (0.706 t ha⁻¹) & *Lantana camara* (0.74 t ha⁻¹) which constituted 27.53 and 10.69 % of the total carbon stock respectively. However, *Clerodendrum infortunatum* contributes lowest to the ecosystem when carbon stock is concern i.e. 0.026 t ha⁻¹.

Table 4.16 TOTAL SHRUB CARBON STOCK (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lantana camara</i> (L.)	0.108	0.069	0.047	0.050	0.274
2	<i>Lygodium japonicum</i> (Thunb.) Sw.	0.044	0.032	0.034	0.026	0.136
3	<i>Woodfordia fruticosa</i> (L.) Kurz.	0.653	0.360	0.131	0.238	1.383
4	<i>Vitex negundo</i> (L.)	0.012	0.009	0.010	0.007	0.038
5	<i>Clerodendrum infortunatum</i> (L.)	0.008	0.006	0.007	0.005	0.026
6	<i>Agave sisalana</i> (Perrine)	0.358	0.183	0.049	0.115	0.706
	Total	1.184	0.660	0.277	0.441	2.562

The total carbon stock recorded in tree was 163.323 t ha⁻¹, which was compared with 48.97 - 214.97 t ha⁻¹ in Tropical dry deciduous forest (Joshi & Dhyani, 2018). The above ground tree carbon stock was reported to be 44.51- 218.84 t ha⁻¹ in Tropical Dry Forest, East Godavari (Srinivas & Sundarapandian, 2018).

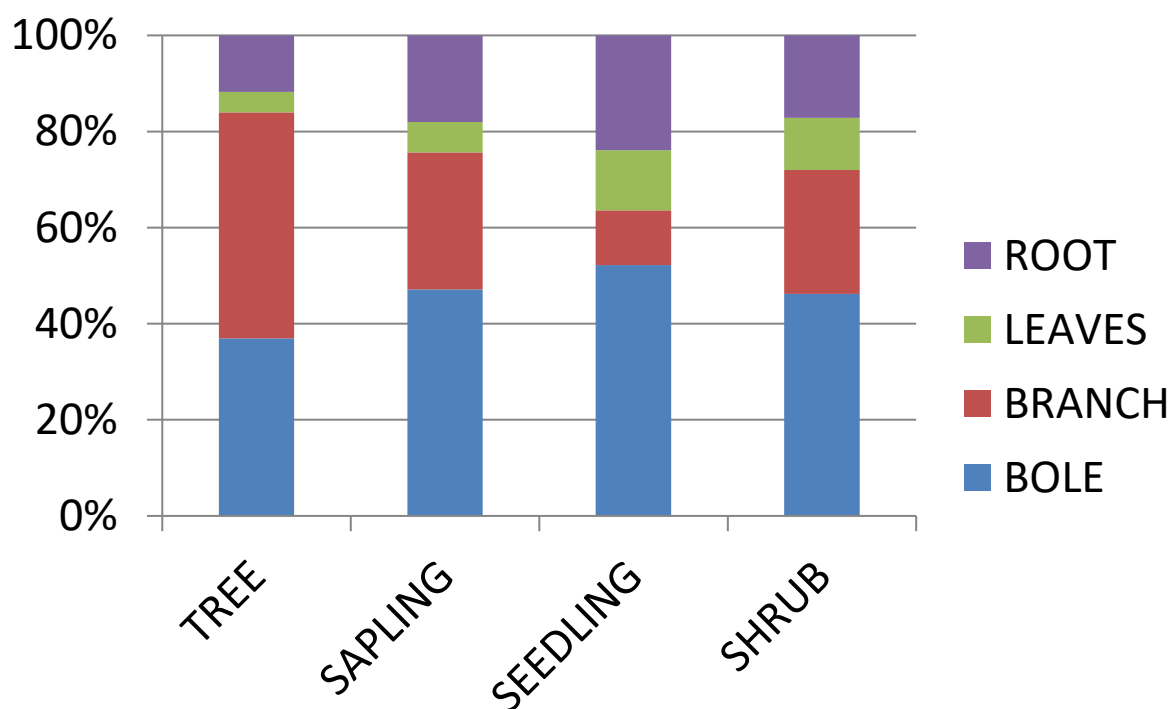
The total carbon stock recorded in sapling was 12.151 t ha⁻¹, which was supported by 2.73- 15.1 t ha⁻¹ estimated by Tashi *et. al.* (2017) in Eastern Himalaya, Bhutan.

The seedlings carbon stock was recorded 1.443 t ha⁻¹, was compared with 3.25 t ha⁻¹

determined by Jharia & Yadav (2018) in Tropical deciduous forest.

The shrub carbon stock was recorded 2.562 t ha⁻¹, was supported by 1.11- 3.21 t ha⁻¹ estimated by Tashi *et. al.* (2017) in Eastern Himalaya, Bhutan and was found lower than 6.68 t ha⁻¹ determined by Jharia & Yadav (2018) in Tropical deciduous forest.

The total carbon stock in tree, shrub and herb reported by Rao & Rao (2015) was 3.22-156.84 t ha⁻¹ in Tropical deciduous forests, Nallamalais.



[Graph No.03:Contribution of different parts towards carbon stock]

Table 4.17 COMPARISON OF FLORAL CARBON STOCK (t ha⁻¹) OF TROPICAL DRY DECIDUOUS FOREST OF RANCHI WEST DIVISION WITH OTHER FORESTS

Location	Layers	Above-ground	Below-ground	Total	Source
Tropical North East Forest	Tree	60.09-121.43	--	--	Thochoom & Yadava (2017)
Tropical Dry Deciduous Forest	Tree	--	--	48.97 - 214.97	Joshi & Dhyani (2018)
Sal Forest in Nepal	Tree	50.4-128.8	2.5-2.7	52.9- 131.54	Neupene & Sharma (2014)
Tropical Dry Forest, East Godavari	Tree	44.51-218.84	--	--	Srinivas Sundarapandian (2018)
Tropical Forest of Cachar, Assam	Tree	16.24 - 130.82	--	--	Borah <i>et. al.</i> (2013)
Tropical Deciduous Forests, Nallamalais	Tree Shrub Herb	--	--	3.22-156.84	Rao & Rao (2015)
Dry Tropics, C. G.	Tree	49.3- 88.5	5.8-10	55.1-98.5	Pawar <i>et. al.</i> (2014)
Semi Evergreen Forest	Tree	98.8±30.03	--	--	Giri <i>et. al.</i> (2018)
Tropical Deciduous Forest	Tree Sapling Seedling Shrub	95.22 20.66 2.68 5.75	10.52 3.62 0.57 0.93	105.74 24.28 3.25 6.68	Jharia & Yadav (2018)
Tropical Wet Evergreen	Tree	55.69-155.44	11.14-31.09	66.83- 186.53	Gogoi <i>et. al.</i> (2017)

Forest					
Tropical Dry Deciduous Forest, Haryana	Tree Shrub	19.77- 33.58 2.81- 5.54 0.9- 1.14	5.56- 8.90 1.42- 2.74 0.6- 0.69	25.33- 42.48 4.23- 8.28 1.5- 1.83	Singh <i>et. al.</i> (2014)
Eastern Himalaya, Bhutan	Tree Sapling Shrub	49.81- 190.5 2.73- 15.1 1.11- 3.21	-- -- --	-- -- --	Tashi <i>et. al.</i> (2016)
Conifer Forest Bhutan	Tree	--	--	95.79	Tshering (2019)
Moist Afromontane Forest, Ethiopia	Tree Litter Soc	243.8 0.03 --	45.97 -- 219.1	508.9	Dibaba <i>et. al.</i> (2019)
Savvana	--	5.91	--	--	Oliveira <i>et.al.</i> (2019)
Tropical Deciduous Forest Horhap Beat, Ranchi East Division	Tree Sapling Seedling Shrub Herb	114.1- 149.3 8.04- 8.84 2.49- 3.17 1.04-1.97 0.6-1.1	15.08- 9.15 1.52- 1.56 0.58- 0.74 0.17-0.33 0.12- 0.22	129.21-168.43 9.56- 10.4 3.07-3.91 1.21- 2.3 0.72- 1.32	Panda. <i>et. al.</i> (2020)
Tropical Deciduous Forest Patratu Forest Ranchi West Division	Tree Sapling Seedling Shrub	144.071 11.5 1.01 2.122	19.52 2.52 0.345 0.44	163.323 14.012 1.443 2.56	Present study

Carbon sequestration

The total Carbon sequestration in different vegetation layers in the study sites are given in the Table 4.18 to 4.22. Carbon sequestration of different layers was determined by multiplying the carbon storage value with 3.67.

Tree Layer

Concerning the study conducted in Patratu valley forest, the total carbon sequestration was found to be 599.44 t ha⁻¹ among which contribution of bole, branch, leaves & root was 221.58 t ha⁻¹, 281.94 t ha⁻¹, 25.26 t ha⁻¹, 70.66 t ha⁻¹ which is 36.96%, 47.03%, 4.21%, & 11.78% of the total carbon sequestration respectively. The species called *Shorea robusta* has contributed the highest to the carbon sequestration i.e. 406.31 t ha⁻¹ which is 67.7% of the total. The other major species which contribute to the carbon sequestration are *Lagerstroemia parviflora* (62.39 t ha⁻¹) & *Diospyros melanoxylon* (41.21 t ha⁻¹) which constituted 10.4 and 6.8 % of the total respectively. However, *Terminalia catappa* contributes lowest to the ecosystem when carbon sequestration is concern i.e. 1.03 t ha⁻¹.

Table 4.18 TOTAL TREE CARBON SEQUESTRATION (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lagerstroemia parviflora</i> Roxb	25.06	23.56	3.69	10.08	62.39
2	<i>Diospyros melanoxylon</i> Roxb.	18.35	15.51	1.73	5.63	41.21
3	<i>Shorea robusta</i> Roth.	141.30	206.22	15.24	43.55	406.31
4	<i>Adina cordifolia</i> (Roxb.)	8.20	8.05	1.02	2.52	19.78
5	<i>Terminalia catappa</i> (L.)	0.47	0.36	0.06	0.14	1.03
6	<i>Phyllanthus emblica</i> (L.)	1.38	1.30	0.21	0.48	3.36
7	<i>Terminalia tomentosa</i> (Roxb.)	6.79	7.31	0.82	2.09	17.01
8	<i>Bridelia retusa</i> (L.) A. Juss	0.31	0.24	0.04	0.09	0.69
9	<i>Syzygium cumini</i> (Linn.) Skeels.	1.42	1.45	0.17	0.44	3.48
10	<i>Butea monosperma</i> (Lamk) Taub	1.97	2.05	0.24	0.61	4.87
11	<i>Scheichera olosa</i> (Lour.) Oken	1.39	1.30	0.18	0.43	3.29
12	<i>Gmelina arborea</i> Linn.	1.04	0.98	0.13	0.32	2.48
13	<i>Madhuca indica</i> J.F. Gmel.	3.99	3.94	0.49	1.23	9.65
14	<i>Millettia pinnata</i> (L.) Panigrahi	1.93	1.89	0.24	0.59	4.65
15	<i>Terminalia arjuna</i> (Roxb.)	1.02	0.94	0.13	0.31	2.41
16	<i>Mangifera indica</i> Linn.	2.33	2.70	0.27	0.72	6.02
17	<i>Azadirachta indica</i> A. Juss	2.95	2.59	0.38	0.91	6.83
18	<i>Limonia acidissima</i> (L.)	0.72	0.57	0.10	0.22	1.61
19	<i>Dillenia indica</i> (L.)	0.99	0.95	0.12	0.30	2.37
	Total	221.58	281.94	25.26	70.66	599.44

Sapling Layer

Concerning the study conducted in Patrattu valley forest, the total sapling carbon sequestration was found to be 44.59 t ha⁻¹ among which contribution of bole, branch, leaves & root was 21.02 t ha⁻¹, 12.71 t ha⁻¹, 2.83 t ha⁻¹ and 8.04 t ha⁻¹ which is 47.12%, 28.5%, 6.31% and 18.02 %, of the total carbon sequestration respectively. The species called *Shorea robusta* has contributed the highest to the carbon sequestration i.e. 20.88 t ha⁻¹ which is 40.6% of the total. The other major species which contribute to the carbon sequestration rate are *Diospyros melanoxylon* (6.60 t ha⁻¹) & *Terminalia catappa* (3.85 t ha⁻¹) which constituted 12.08 and 7.17 % of the total carbon sequestration respectively. However, *Madhuca indica* contributes lowest to the ecosystem when weight of carbon sequestration is concern i.e. 0.18 t ha⁻¹.

Table 4.19 TOTAL SAPLING CARBON SEQUESTRATION (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Diospyros melanoxylon</i> Roxb.	3.11	1.88	0.42	1.19	6.60
2	<i>Adina cordifolia</i> (Roxb.)	1.37	0.83	0.18	0.52	2.91
3	<i>Shorea robusta</i> Roth.	9.84	5.95	1.32	3.76	20.88
4	<i>Terminalia catappa</i> (L.)	1.81	1.10	0.24	0.69	3.85
5	<i>Phyllanthus emblica</i> (L.)	0.66	0.40	0.09	0.25	1.39
6	<i>Terminalia tomentosa</i> (Roxb.)	0.20	0.12	0.03	0.08	0.42
7	<i>Limonia acidissima</i> (L.)	0.20	0.12	0.03	0.08	0.42
8	<i>Lagerstroemia parviflora</i> Roxb	0.75	0.46	0.10	0.29	1.60
9	<i>Scheuchera olosa</i> (Lour.) Oken	0.68	0.41	0.09	0.26	1.43
10	<i>Azadirachta indica</i> A. Juss	0.25	0.15	0.03	0.09	0.53
11	<i>Wrightia antidysenterica</i> (L.) R.Br	0.34	0.21	0.05	0.13	0.72
12	<i>Madhuca indica</i> J.F. Gmel.	0.09	0.05	0.01	0.03	0.18
13	<i>Bauhinia variegata</i> (L.) Benth	0.16	0.10	0.02	0.06	0.35
14	<i>Dillenia indica</i> (L.)	0.68	0.41	0.09	0.26	1.44
15	<i>Streblus asper</i> Lour.	0.43	0.26	0.06	0.17	0.92
16	<i>Butea monosperma</i> (Lamk) Taub	0.45	0.27	0.06	0.17	0.95
Total		21.02	12.71	2.83	8.04	44.59

Seedling Layer

Concerning the study conducted in Patrattu valley forest, the total weight of seedling carbon sequestration was found to be 5.30 t ha⁻¹ among which contribution of bole, branch, leaves & root was 2.76 t ha⁻¹, 0.60 t ha⁻¹, 0.66 t ha⁻¹ and 1.27 t ha⁻¹ which is 52.29, 11.39, 12.50 and 23.93%, of the total carbon sequestration respectively. The species called *Diospyros melanoxylon* has contributed the highest to the carbon sequestration i.e. 1.28 t ha⁻¹ which is 24.30 % of the total. The other major species which contribute to the carbon sequestration are *Shorea robusta* (0.96 t ha⁻¹) & *Phyllanthus emblica* (0.92 t ha⁻¹) which constituted 18.04 and 17.36 % of the total weight respectively. However, *Syzygium cumini* contributes lowest to the ecosystem when carbon sequestration is concern i.e. 0.02 t ha⁻¹.

Table 4.20 TOTAL SEEDLING CARBON SEQUESTRATION (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Shorea robusta</i> Roth.	0.54	0.08	0.13	0.20	0.96
2	<i>Adina cordifolia</i> (Roxb.)	0.03	0.001	0.01	0.01	0.04
3	<i>Phyllanthus emblica</i> (L.)	0.37	0.12	0.16	0.28	0.92
4	<i>Dillenia indica</i> (L.)	0.12	0.02	0.03	0.04	0.21
5	<i>Diospyros melanoxylon</i> Roxb.	0.67	0.11	0.15	0.35	1.28
6	<i>Lagerstroemia parviflora</i> Roxb.	0.02	0.00	0.00	0.00	0.03
7	<i>Bridelia retusa</i> (L.) A. Juss	0.17	0.05	0.03	0.06	0.31
8	<i>Wrightia antidysenterica</i> (L.) R. Br	0.31	0.09	0.06	0.12	0.57
9	<i>Limonia acidissima</i> (L.)	0.31	0.09	0.06	0.12	0.57
10	<i>Syzygium cumini</i> (Linn.) Skeels.	0.01	0.001	0.001	0.001	0.02
11	<i>Azadirachta indica</i> A. Juss	0.10	0.03	0.02	0.04	0.19
12	<i>Alstonia scholaris</i> (L.) R. Br	0.03	0.001	0.01	0.01	0.04
13	<i>Scheichera olosa</i> (Lour.) Oken	0.01	0.001	0.001	0.001	0.02
14	<i>Butea monosperma</i> (Lamk) Taub	0.05	0.01	0.01	0.02	0.09
15	<i>Streblus asper</i> Lour.	0.03	0.001	0.01	0.01	0.04
Total		2.76	0.60	0.66	1.27	5.30

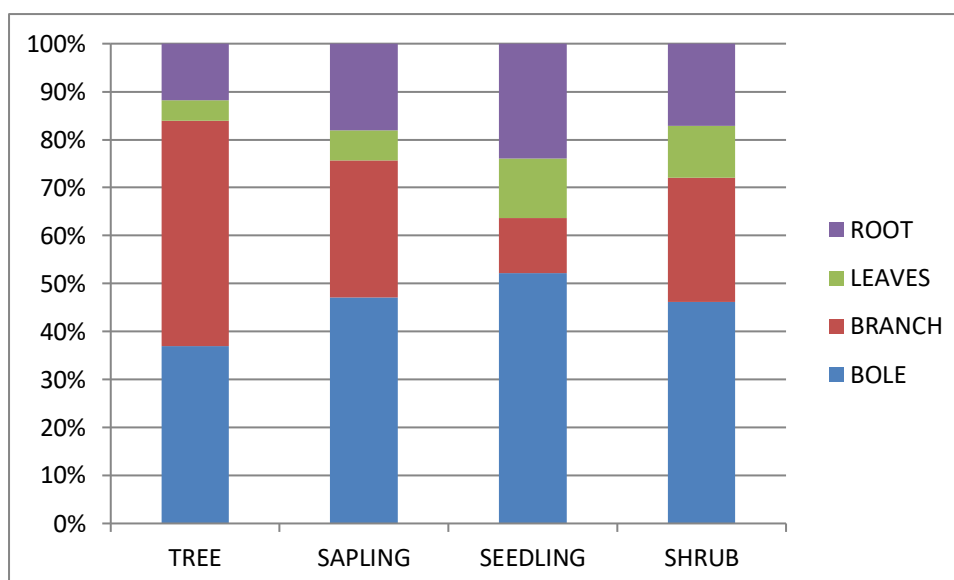
Shrub Layer

Concerning the study conducted in Patrattu valley forest, the total shrub carbon sequestration was found to be 9.40 t ha⁻¹ among which contribution of bole, branch, leaves & root was 4.34 t ha⁻¹, 2.42 t ha⁻¹, 1.02 t ha⁻¹ and 1.62 t ha⁻¹ which is 46.21, 25.76, 10.73 and 17.17%, of the total carbon sequestration respectively. The species called *Woodfordia fruticosa* has contributed the highest to the carbon sequestration i.e. 5.07 t ha⁻¹ which is 53.96 % of the total. The other major species which contribute to the carbon dioxide storage are *Agave sisalana* (2.59 t ha⁻¹) & *Lantana camara* (1.01 t ha⁻¹) which constituted 27.53 and 10.69 % of the total respectively. However, *Clerodendrum infortunatum* contributes lowest to the ecosystem when carbon sequestration is concern i.e. 0.10 t ha⁻¹.

Table 4.21 TOTAL SHRUB CARBON SEQUESTRATION (t ha⁻¹) AND THEIR RELATIVE DISTRIBUTION IN DIFFERENT PLANT PARTS

Sl.No.	Name of Species	Bole	Branch	Leaves	Roots	Total
1	<i>Lantana camara</i> (L.)	0.40	0.25	0.17	0.19	1.01
2	<i>Lygodium japonicum</i> (Thunb.) Sw.	0.16	0.12	0.13	0.09	0.50
3	<i>Woodfordia fruticosa</i> (L.) Kurz.	2.40	1.32	0.48	0.87	5.07
4	<i>Vitex negundo</i> (L.)	0.05	0.03	0.04	0.03	0.14
5	<i>Clerodendrum infortunatum</i> (L.)	0.03	0.02	0.02	0.02	0.10
6	<i>Agave sisalana</i> (Perrine)	1.31	0.67	0.18	0.42	2.59
	Total	4.34	2.42	1.02	1.62	9.40

Total carbon sequestration recorded in tree was 599.44 t ha⁻¹, which was compared with 182.8-699.13 t ha⁻¹ estimated by Tashi *et. at.* (2016) in Eastern Himalaya. Total above ground and below ground carbon sequestration was found to be 577.14 t ha⁻¹ and 81.59 t ha⁻¹ which can be compared with the value 456.2 t ha⁻¹ and 57.39 t ha⁻¹ respectively (Jharia & Yadav, 2018). The weight of shrub carbon sequestration was recorded 9.40 t ha⁻¹, was lower than 24.51 t ha⁻¹ estimated by Jharia and Yadav (2018) in Tropics of Chhatisgarh. The total carbon sequestration of the study site was recorded to be 658.73 t ha⁻¹ which was supported by the value 179.71- 788.94 t ha⁻¹ studied by Joshi & Dhyani (2018).



[Graph No.04:Contribution of different parts towards carbon sequestration]

Table 4.22 COMPARISON OF CARBON SEQUESTRATION (t ha⁻¹) OF TROPICAL DRY DECIDUOUS FOREST OF RANCHI WEST DIVISION WITH OTHER FORESTS

Location	Layers	Above-ground	Below-ground	Total	Source
Tropical North East Forest	Tree	220.53-445.64	-----	-----	Thoichom & Yadava (2017)
Tropical Dry Deciduous Forest	Tree	-----	-----	179.71-788.94	Joshi & Dhyani (2018)
Sal Forest in Nepal	Tree	184.96-472.7	9.175-9.91	194.14-482.75	Neupene & Sharma (2014)
Tropical Dry Forest, East Godavari	Tree	163.35-803.14	-----	-----	Srinivas & Sundarapandian (2018)
Tropical Forest of Cachar, Assam	Tree	59.60-480.11	-----	-----	Borah <i>et. al.</i> (2013)

Tropical Deciduous Forests, Nallamalais	Tree Shrub Herb	-----	-----	11.82- 575.60	Rao & Rao (2015)
Dry Tropics, C. G.	Tree	180.93-324.8	21.28-36.7	202.22- 361.5	Pawar <i>et. al.</i> (2014)
Semi Evergreen Forest	Tree	362.6-110.21	-----	-----	Giri <i>et. al.</i> (2018)
Tropical Deciduous Forest	Tree Sapling Seedling Shrub	349.45 75.82 9.835 21.10	38.60 13.28 2.092 3.41	388.066 89.11 11.93 24.51	Jharia & Yadav (2018)
Tropical Wet Evergreen Forest	Tree	40.88-570.46	40.88- 114.10	245.266- 684.56	Gogoi <i>et. al.</i> (2017)
Tropical Dry Deciduous Forest, Haryana	Tree Shrub	72.56-123.23 10.31-20.33 3.03-4.183	20.41-32.66 5.2-10.1 2.2-2.53	92.96-155.9 15.52-30.38 5.505-6.714	Singh <i>et. al.</i> (2014)
Eastern Himalaya, Bhutan	Tree Sapling Shrub	182.8-699.13 10-55.41 4.07-11.78	-----	-----	Tashi <i>et. al.</i> (2016)
Conifer Forest Bhutan	Tree	-----	-----	351.54	Tshering (2019)
Moist Afromontane Forest, Ethiopia	Tree Litter	893.93 0.11	168.56	1867.66	Dibaba <i>et. al.</i> (2019)
Savvana	--	21.68	-----	-----	Oliveira <i>et.al.</i> (2019)
Tropical Deciduous Forest Patratu Forest Ranchi West Division	Tree Sapling Seedling Shrub	528.78 36.55 4.02 7.78	70.66 8.04 1.27 1.62	599.44 44.59 5.30 9.40	Present study



Plate-2: Measuring Diameter of a Sal Seedling In The Study Site

Plate-3: Measuring Diameter of a Kendu Sapling in the Study Site



Plate-4: Measuring Diameter of a tree in the Study Site



Plate-5: A Sal coppice shoot

Plate-6: Drawing the quadrat for tree sampling





*Summary
and
Conclusion*



CHAPTER-V

SUMMARY AND CONCLUSION

Study on “Species composition, biomass, carbon stock and carbon sequestration in tropical dry deciduous forest of Kanke range, Ranchi division, Jharkhand” was carried out in Patratu forest situated in Eastern part of Ranchi district which is located between 23° 34’ 29’’N to 23° 34’ 31’’N latitude and 85° 16’17’’E to 85° 16’33’’E longitude during the year 2020-2021.

The species composition and diversity of different floral layer was conducted by putting 10 x 10 m² size quadrat (10 numbers) randomly on sample plots of Patratu forest. In each quadrat, GBH (Girth at Breast Height) of each individual were measured. Primary variables like density, frequency, and basal area, are useful for structural analysis. Furthermore the primary variables were analyze to determine secondary variables like relative frequency, relative density, relative basal, area and IVI.

The diversity parameters viz. Shannon index, Simpson’s index, equitability, and species richness were also calculated for tree, sapling, seedling, and shrub layer. Biomass for each layer was estimated using allometric equations based on the relationship between girth of a tree and dry weight of component. Carbon stock for each layer was also estimated by carbon conversion method. Dividing the value of carbon stock with the mean age of each layer carbon sequestration rate was calculated subsequently CO₂ sequestration rate was calculated separately and for the whole forest. The salient findings on Species composition, biomass, carbon stock and carbon sequestration in tropical dry deciduous forest of Kanke range, Ranchi division, Jharkhand are summarized below:

SPECIES COMPOSITION

Tree Layer

- A total of 1670 trees ha⁻¹ representing 19 species and 14 families were encountered in study site.
- Basal area and density of individual tree species varied from 0.09-27.05 m² ha⁻¹ and 10- 800 stems ha⁻¹.

- *Shorea robusta* was represented the highest density followed by *Diospyros melanoxylon* and *Adina cordifolia*.
- Highest basal area was observed in *Shorea robusta* followed by *Diospyros melanoxylon*, and *Adina cordifolia*.
- *Shorea robusta* showed highest value of IVI (129.87) followed by *Diospyros melanoxylon* (39.32) and *Adina cordifolia* (27.11).
- The total tree density and basal area was recorded 1670 tree ha⁻¹ and 44.08 m² ha⁻¹, respectively.

Sapling Layer

- A total of 1280 saplings ha⁻¹ representing 16 species and 13 families were encountered.
- Basal area and density of individual tree species varied from 0.05-2.00 m² ha⁻¹ and 10- 510 stems ha⁻¹.
- *Shorea robusta* was represented the highest density followed by *Diospyros melanoxylon* and *Terminalia catappa*.
- Highest basal area was observed in *Shorea robusta* followed by *Diospyros melanoxylon*, and *Terminalia catappa*.
- *Shorea robusta* showed highest value of IVI (102.18) followed by *Diospyros melanoxylon* (48.72) and *Terminalia catappa* (26.29).
- The total sapling density and basal area was recorded 1280 sapling ha⁻¹ and 4.83 m² ha⁻¹, respectively.

Seedling Layer

- A total of 13640 seedlings ha⁻¹ representing 15 species and 13 families were encountered.
- Basal area and density of individual tree species varied from 0.01-0.34 m² ha⁻¹ and 120- 4550 stems ha⁻¹.
- *Shorea robusta* was represented the highest density followed by *Diospyros melanoxylon* and *Phyllanthus emblica*.
- Highest basal area was observed in *Shorea robusta* followed by

Phyllanthus emblica, and *Wrightia antidysenterica*.

- *Shorea robusta* showed highest value of IVI (91.68) followed by *Syzygium cumini* (45.60) and *Diospyros melanoxylon* (44.71).
- The total seedlings density and basal area was recorded 13640 seedlings ha⁻¹ and 1.11 m² ha⁻¹, respectively.

Shrub Layer

- A total of 9330 shrubs ha⁻¹ representing 6 species and 5 families were encountered.
- The basal area and density of individual shrub species varied from 0.01-1.16 m² ha⁻¹ and 70- 6590 stems ha⁻¹.
- *Lygodium japonicum* was represented the highest density followed by *Clerodendrum infortunatum* and *Lantana camara*.
- Highest basal area was observed in *Woodfordia fruticosa* followed by *Agave sisalana* and *Lantana camara*.
- *Lygodium japonicum* showed highest value of IVI (97.06) followed by *Woodfordia fruticosa* (80.35) and *Lantana camara* (40.04).
- The total shrub density and basal area as recorded 9330 shrub ha⁻¹ and 1.86 m² ha⁻¹, respectively.

SPECIES DIVERSITY

- Shannon index was calculated to be 1.98 for trees, 2.09 for saplings, 2.06 for seedlings, and 0.99 for shrubs.
- The Concentration of dominance was calculated to be 0.262 for trees, 0.2 for saplings, 0.185 for seedlings, and 0.52 for shrubs.
- Equitability was calculated to be 0.67 for trees, 0.75 for saplings, 0.76 for seedlings, and 0.55 for shrubs.
- Species richness was calculated to be 2.42 for trees, 2.09 for saplings, 1.47 for seedlings, and 0.54 for shrubs.

BIOMASS

Tree Layer

- Total tree biomass recorded was 326.646 t ha⁻¹ of which 288.14 t ha⁻¹ was AGB and 33.504 t ha⁻¹ BGB.
- Highest biomass was constituted by branch (153.64 t ha⁻¹) followed by bole (120.75 t ha⁻¹) and root (38.5 t ha⁻¹).
- Lowest biomass was found by leaf i.e. 13.76 t ha⁻¹.
- The bole, branch, leaf and root biomass constituted 36.96%, 47.03%, 4.21%, & 11.78% respectively of the total biomass.
- Among the individual species *Shorea robusta* constituted the highest biomass i.e. 221.4 t ha⁻¹.

Sapling Layer

- Total sapling biomass recorded was 24.301 t ha⁻¹ of which 19.92 t ha⁻¹ was AGB and 4.38 t ha⁻¹ BGB.
- Highest biomass was constituted by bole (11.45 t ha⁻¹) followed by branch (6.9 t ha⁻¹) and root (4.38 t ha⁻¹).
- Lowest biomass was found by leaf i.e. 1.541 t ha⁻¹.
- The bole, branch, leaf and root biomass constituted 47.12%, 28.39%, 6.33% and 18.02% respectively of the total biomass.
- Among the individual species *Shorea robusta* constituted the highest biomass i.e. 11.38 t ha⁻¹.

Seedling Layer

- Total seedling biomass recorded was 2.887 t ha⁻¹ of which 2.196 t ha⁻¹ was AGB and 0.691 t ha⁻¹ BGB.
- Highest biomass was constituted by bole (1.506 t ha⁻¹) followed by root (0.691 t ha⁻¹) and leaf (0.361 t ha⁻¹).
- Lowest biomass was found by branch i.e. 0.329 t ha⁻¹.
- The bole, branch, leaf and root biomass constituted 52.29, 11.39, 12.50 and 23.93%,

respectively of the total biomass.

- Among the individual species *Shorea robusta* constituted the highest biomass i.e. 0.521 t ha⁻¹.

Shrub Layer

- Total shrub biomass recorded was 5.12 t ha⁻¹ of which 4.24 t ha⁻¹ was AGB and 0.882 t ha⁻¹ BGB.
- Highest biomass was constituted by bole (2.37 t ha⁻¹) followed by branch(1.32 t ha⁻¹) and root (0.882 t ha⁻¹).
- Lowest biomass was found by leaf i.e. 0.55 t ha⁻¹.
- The bole, branch, leaf and root biomass constituted 46.21, 25.76, 10.73 and 17.17%, respectively of the total biomass.
- Among the individual specie *Woodfordia fruticosa* constituted the highest biomass i.e. 2.765 t ha⁻¹.

. CARBON STOCK

Tree Layer

- Total tree carbon stock recorded was 163.232 t ha⁻¹.
- Highest carbon stock was constituted by branch (76.82 t ha⁻¹) followed by bole (60.377 t ha⁻¹) and root (19.25 t ha⁻¹).
- Lowest carbon stock was found by leaf i.e. 6.88 t ha⁻¹.
- The bole, branch, leaf and root carbon stock constituted 36.96%, 47.03%, 4.21%, & 11.78% respectively of the total carbon stock.
- Among the individual species *Shorea robusta* constituted the highest carbon stock i.e. 110.7 t ha⁻¹.

Sapling Layer

- Total sapling carbon stock recorded was 12.151 t ha⁻¹.
- Highest carbon stock was constituted by bole (5.727 t ha⁻¹) followed by branch (3.46 t ha⁻¹) and root (2.19 t ha⁻¹).
- Lowest carbon stock was found by leaf i.e. 0.77 t ha⁻¹.

- The bole, branch, leaf and root carbon stock 47.12%, 28.39%, 6.33% and 18.02% , respectively of the total carbon stock.
- Among the individual species *Shorea robusta* constituted the highest carbon stock i.e. 5.69 t ha⁻¹.

Seedling Layer

- Total seedling carbon stock recorded was 1.44 t ha⁻¹.
- Highest carbon stock was constituted by bole (0.75 t ha⁻¹) followed by root (0.345 t ha⁻¹) and leaf (0.18 t ha⁻¹).
- Lowest carbon stock was found by branch i.e. 0.18 t ha⁻¹.
- The bole, branch, leaf and root carbon stock constituted 52.29, 11.39, 12.50 and 23.93%, respectively of the total carbon stock.
- Among the individual species *Shorea robusta* constituted the highest carbon stock i.e. 0.35 t ha⁻¹.

Shrub Layer

- Total shrub carbon stock recorded was 2.562 t ha⁻¹.
- Highest carbon stock was constituted by bole (1.184 t ha⁻¹) followed by branch (0.66 t ha⁻¹) and root (0.44 t ha⁻¹).
- Lowest carbon stock was found by leaf i.e. 0.277 t ha⁻¹.
- The bole, branch, leaf and root carbon stock constituted 46.21, 25.76, 10.73 and 17.17%, respectively of the total carbon stock.
- Among the individual species *Woodfordia fruticosa* constituted the highest carbon stock i.e.1.36 t ha⁻¹.

CARBON SEQUESTRATION

Tree Layer

- Total tree carbon sequestration was 599.44 t ha⁻¹.
- Total carbon sequestration was constituted by branch (281.94 t ha⁻¹) followed by bole (221.58 t ha⁻¹) and root (70.66 t ha⁻¹).

- Lowest carbon sequestration was by leaf i.e. 25.26 t ha⁻¹.
- The bole, branch, leaf and root 36.96%, 47.03%, 4.21%, & 11.78% respectively to the total carbon sequestration.
- Among the individual species *Shorea robusta* constituted the highest towards carbon sequestration i.e. 406.31 t ha⁻¹.

Sapling Layer

- Total sapling carbon sequestration was 44.59 t ha⁻¹.
- Total carbon sequestration was constituted by bole (21.02 t ha⁻¹) followed by branch (12.71 t ha⁻¹) and root (8.04 t ha⁻¹).
- Lowest carbon sequestration was by leaf i.e. 2.83 t ha⁻¹.
- The bole, branch, leaf and root 36.96%, 47.03%, 4.21%, & 11.78% respectively to the total carbon sequestration.
- Among the individual species *Shorea robusta* constituted the highest towards carbon sequestration i.e. 20.88 t ha⁻¹.

Seedling Layer

- Total seedling carbon sequestration was 5.30 t ha⁻¹.
- Total carbon sequestration was constituted by bole (2.76 t ha⁻¹) followed by roots (1.27 t ha⁻¹) and leaves (0.66 t ha⁻¹).
- Lowest carbon sequestration was by branch i.e. 0.60 t ha⁻¹.
- The bole, branch, leaf and root 36.96%, 47.03%, 4.21%, & 11.78% respectively to the total carbon sequestration.
- Among the individual species *Diospyros melanoxylon* constituted the highest towards carbon sequestration i.e. 1.28 t ha⁻¹.

Shrub Layer

- Total shrub carbon sequestration was 9.40 t ha⁻¹.
- Total carbon sequestration was constituted by bole (4.34 t ha⁻¹) followed by branch (2.42 t ha⁻¹) and root (1.62 t ha⁻¹).

- Lowest carbon sequestration was by leaf i.e. 1.02 t ha⁻¹.
- The bole, branch, leaf and root 36.96%, 47.03%, 4.21%, & 11.78% respectively to the total carbon sequestration.
- Among the individual species *Woodfordia fruticosa* constituted the highest towards carbon sequestration i.e. 5.07 t ha⁻¹.

CONCLUSION

A total of 1670 trees ha⁻¹, 1280 sapling ha⁻¹, 13640 seedling ha⁻¹ and 9330 shrub ha⁻¹ has been found in study site. Highest diversity was found in case of *Shorea robusta* in tree, sapling and seedling layer and *Lygodium japonicum* shrub layer. Total biomass recorded was 358.95 t ha⁻¹ among which 326.65 t ha⁻¹ is from tree layer (major contributor), 24.301 t ha⁻¹ from sapling layer, 2.887 t ha⁻¹ from seedling layer & 5.124 t ha⁻¹ from shrub layer. Bole is a major contributor towards biomass in case of Sapling, Seedling, & Shrub layer but in Tree layer highest biomass was stored in branch. Total carbon stock found was 179.38t ha⁻¹ among which 163.232t ha⁻¹ is from tree (major contributor), 12.15 t ha⁻¹ from sapling layer, 1.44 t ha⁻¹ from seedling layer & 2.56 t ha⁻¹ from shrub layer. Bole is a major contributor towards biomass in case of Sapling, Seedling, & Shrub layer but in Tree layer highest biomass was stored in branch.. The study site has sequestered 658.34 t ha⁻¹ carbon as a whole.

Emissions of Carbon dioxide (CO₂) plays primary role to the increase in greenhouse gases (GHGs) level, which would cause reduction in rainfall, change in temperature pattern and behaviour of species. Although forest is a renewable natural resource but without proper management practices, depending upon the natural forest that would not fulfill the purpose to trap equal amount of carbon which release to the atmosphere. However, it is concluded that-

- Vegetation has a great role in carbon trapping and storing. Not only the trees and saplings, but also the seedlings shrubs and herbs, store a significant amount of carbon.
- Absorption of CO₂ in directly depends on the biomass production of floral species. Hence proper input management plays an important role in biomass

production.

- More the amount of carbon will store, there would be less the chance of global warming and climate change in that particular microclimate.
- *Shorea robusta* is the major dominating species with higher potential of biomass and carbon store.

The tropical dry deciduous forest is an economically important forest ecosystem and as a result, a large area of this forest had been disturbed through faulty land use practices like logging and agriculture resulting in a highly degraded land. It is not only modifying carbon storage in above ground biomass, below ground biomass and in soil layers but also reduce the growth pattern in the ecosystem. However, it is also concluded that social security of this region provides better species survival in terms of density of the vegetation and management of understorey is very much needful for promoting natural regeneration and future growth.

SUGGETION AND RECOMMENDATIONS

Based upon the study the following suggestions and recommendations are given below.

- Introduction of fast growing native species in the degraded lands is very much essential.
- Improve the plant growth by specific silvicultural practices is also suggested.
- Further study should be made on nutrient dynamics of these forests and the agro-ecosystem of adjoining areas with quantitative study on forest produce explored from these forests is needed.



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Appendix



APPENDIX

APPENDIX I

Allometric relationship between the log dry weight (kg) of different components (Y) on log girth (X, cm) for trees in natural forests (Based on Singh, K.P. and Misra, R. 1979). All equations are of the form $\text{Log } Y = a + b \text{ log } X$.

Species	component	Correlation coefficient r	intercept log a	slope b	Standard error of estimate (SEE)	Standard error of b (SE of b)
<i>Diospyros melanoxylon</i> (n=21)	Bole	0.9961	-2.3639	2.4012	0.0498	0.0486
	Branch	0.9941	-3.7528	3.1466	0.0805	0.0785
	Leaf	0.9678	-2.7088	1.9890	0.1217	0.1186
	Root	0.9923	-2.5205	2.2442	0.0659	0.0643
	Total	0.9988	-2.2359	2.5331	0.0289	0.0282
<i>Phyllanthus emblica</i> (n=21)	Bole	0.9970	-2.2675	2.3179	0.0436	0.0415
	Branch	0.9914	-3.1576	2.8571	0.0910	0.0867
	Leaf	0.9910	-2.2645	1.7667	0.0574	0.0547
	Root	0.9964	-2.1898	2.0283	0.0417	0.0397
	Total	0.9987	-2.0281	2.4227	0.0297	0.0283
<i>Lagerstroemia parviflora</i> (n=18)	Bole	0.9957	-2.2277	2.2908	0.0492	0.0534
	Branch	0.9898	-2.9451	2.6849	0.0888	0.0964
	Leaf	0.9853	-2.7657	2.0988	0.0840	0.0911
	Root	0.9920	-3.0475	2.5876	0.0758	0.0822
	Total	0.9965	-2.0908	2.4470	0.0472	0.0512
'Other species'(Total of all species) (n=200)	Bole	0.9874	-2.1725	2.2880	0.0842	0.0260
	Branch	0.9569	-3.2888	2.9420	0.2051	0.0635
	Leaf	0.9678	-2.6977	2.0403	0.1219	0.0377
	Root	0.9697	-2.6045	2.2913	0.1327	0.0410
	Total	0.9844	-2.0854	2.4750	0.1015	0.0314
Shrub spp. pool	Bole	0.9887	-2.9407	2.6827		
	Branch	0.9515	-3.0225	2.5422		
	Leaf	0.9574	-2.7795	1.9953		
	Root	0.9749	-3.0849	2.4481		

APPENDIX II

COORDINATES OF ALL THE QUADRATES WAS TAKEN IN THE STUDY SITES.

1. 23° 34' 31''N 85° 16'19''E
2. 23° 34' 29''N 85° 16'17''E
3. 23° 34' 34''N 85° 16'28''E
4. 23° 34' 32''N 85° 16'29''E
5. 23° 34' 32''N 85° 16'33''E
6. 23° 34' 30''N 85° 16'32''E
7. 23° 34' 31''N 85° 16'29''E
8. 23° 34' 36''N 85° 16'20''E
9. 23° 34' 31''N 85° 16'33''E
10. 23° 34' 29''N 85° 16'19''E