

**“COMPARATIVE STUDY OF TREE SPECIES
COMPOSITION AND DIVERSITY
PATTERN IN OPEN AND CLOSED CANOPY
DRY DECIDUOUS FORESTS”**

M.Sc. (Forestry) THESIS

BY

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**DEPARTMENT OF FORESTRY
COLLEGE OF AGRICULTURE
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Thesis

Submitted to the

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VED PRAKASH PANDEY

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CERTIFICATE – I

This is to certify that the thesis entitled “**Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests**” submitted in partial fulfilment of the requirements for the degree of “Master of Science in Forestry of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Shri VED PRAKASH PANDEY** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

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LIST OF ABBREVIATIONS

<i>Abbreviations</i>	<i>Description</i>
%	Percent
&	And
<	Less Than
=	equal to
>	More Than
°C	degree centigrade
AGB	Above ground biomass
BGB	Below ground biomass
C.G.	Chhattisgarh
CBH	Circumference at breast height
cm	centimeter
D.B.H.	Diameter at breast height
EPCO	Environment Planning and Coordination Organization
<i>et. al</i>	And Others/co-workers
FAO	Food and Agricultural Organization
Fig.	Figure
FSI	Forest Survey of India
G.B.H.	Girth at Breast Height
GIS	Geographical Information System
ha	hectare
ha ⁻¹	per hectare
ht	Height
i.e.	That is
IVI	Importance Value Index
kg ha ⁻¹	kilogram per hectare
m	metre
MAB	Man and Biosphere
MoEF	Ministry of Environment and Forests
R.B.A	Relative Basal Area
R.F.	Relative Frequency
R.D.	Relative Density
t ha ⁻¹	ton per hectare
<i>viz.</i>	for example

CHAPTER-I

INTRODUCTIUON

India has a large network of protected areas including wildlife sanctuaries and biosphere reserves, which include diverse eco-regions and habitats. The theoretical basis and practical guidelines for ecological management of nature reserves is an important example of a sound framework for landscape ecology. Its central feature is recognition of the dynamic role of man in creating diversity stability through centuries of continuous land utilization with similar methods and gradual interventions in the form of agricultural, pastoral and other modifications in these man induced seminatural landscapes. Anthropogenic (human-oriented) pressure can cause uncontrolled influences that bring changes in forest floral and faunal diversity, habitat, landscape, soil degradation and may often lead to considerable alterations in the environmental conditions. In India, the forest cover is below 20% of the geographical area and much of it is under anthropogenic stress (Singh, S.P. 2002).

Biodiversity provides to humankind enormous direct economic benefits and array of indirect essential services through natural ecosystems, and plays an important role in modulating ecosystem functioning and stability (Singh, 2002). Biodiversity is not distributed uniformly on the earth, and could comprise 5 to more than 50 million species. Disruption of forest structure by natural and anthropogenic disturbance alters species richness and other ecosystem properties. Disturbance of an ecosystem has implications for the maintenance

and restoration of biodiversity at all hierarchical levels (Mc Naughton 1989; Walker 1989; Pickett and Parker 1994, Kumar and Ram 2005). The human influences on biodiversity and ecosystem functioning have largely taken the form of rapid, large and frequent changes in land and resource use, increased frequency of biotic invasions, reduction in species number, creation of stresses and the potential for changes in the climate system. Such changes have a direct impact through habitat destruction and over exploitation of resources such as overgrazing and an indirect impact through their effect on the composition of the atmosphere and the climate, both of which directly affect biodiversity (Heywood 1995). Humans have extensively altered the global environment, changing global biogeochemical cycles, transforming land and enhancing the mobility of biota. Many species have been eliminated from areas dominated by human influences (Chapin III *et al.* 2000). Gauthier *et al.* (2000) described that the vegetation dynamics of forest systems are controlled by numerous factors such as the available pool of species, the physical characteristics of land, soil fertility, climate and disturbance regime characteristics. Zapfack *et al.* (2002) reported the relatively the greater importance of secondary forests as a refuge area for primary forest species that may function as a starting point for possible regeneration of original biodiversity.

Deforestation of tropical forest has become a global concern in recent years. During past several years, large complex of natural habitat have been converted into agricultural, industrial or urbanized landscapes, leading to severe loss of the original habitat. Natural landscapes in particular, forests have been under severe pressure because of human population increase and associated

economic development. Human impacts on the biotic richness and ecological roles of forests have included clearing, burning and logging. This occurs naturally through such agents as fire, landslides, wind throw and insect attack. In managed forests timber harvesting and related activities have been the dominant disturbance agents. This has widened the gap between demand and supply of forest products and endangered the biodiversity and sustainable development, thereby adversely affecting ecological restoration (Bargali *et al.*, 2007).

Rate of deforestation is quite alarming in tropics and it is about 15 to 17 million ha/year (FAO, 1995). In India, of the 86 per cent of the tropical forest area, 54 per cent is dry deciduous (Kaul and Sharma, 1971), which is largely threatened by lopping, burning, overgrazing and cultivation (Jha and Singh, 1990). Due to these anthropogenic pressure dry deciduous forests in most part of the central India has been converted into dry deciduous scrub and dry grasslands, which are progressively species poor (Champion and Seth, 1968). In India, habitat destruction, overexploitation, pollution and species introduction are identified as a major cause of diversity loss (UNEP, 2001). The disturbance created by these factors determines forest dynamics and diversity at the local and regional scales (Burslem and Whitmore, 1999; Hubbell *et al.*, 1999); this disturbance has been considered as an important factor structuring communities (Sumina, 1994). Political and scientific concerns have been raised as we are experiencing an increase in species extinction rates caused by anthropogenic activities (Enrich and Wilson, 1991).

Tropical forest is one of the richest and complex terrestrial ecosystems, approximately 50 per cent of the world living terrestrial carbon sinks. According to Sharma *et al.*, (1990), tropical forest i.e., moist and dry forests account for approximately 60 per cent of global forests. According to the Holdridge system of life zone classification, dry tropical and sub-tropical forests and woodlands occur in frost-free areas where the mean annual biotemperature is higher than 17⁰C, mean annual rainfall is 250-2000 mm and the annual ratio of potential evapotranspiration (PET) to precipitation (P) exceeds unity. About 40% of the earth's tropical and subtropical land mass is dominated by open or closed canopy forests. Of this, 42% is dry forests, 33% is moist forest and only 25% are wet and rain forests (Holdridge 1967).

Biodiversity is important for human survival and economic well-being and for the function and stability of ecosystem (Singh, 2002). Prior to forest management operations, biodiversity are used to determine the nature and distribution resources of the region being managed. Such diversity inventories are integrated with the timber resources inventories in order that forest management operations can be planned (Rennolls and Laumonier, 2000). In these inventories, quantification of tree species diversity is an important aspect as it provides resources and habitat for many species (Cannon *et al.*, 1998). Being a dominant life form, trees are easy to locate precisely and count (Condit *et al.*, 1996) and are relatively better known, taxonomically (Gentry, 1992).

There is an alarming threat to life supporting systems on planet earth due to rapid declining of diversity and complexity of living organisms. The problem is serious, especially in tropical regions, where the biologists identify the 14 hot

spots (endangered zones) out of 25 in the world. Biodiversity is intimately interconnected with the long-term health and vigour of the biosphere as an indicator of global environment but also as a regulator of ecosystem functioning. Therefore, conservation of biodiversity at different levels is necessary. Presently there is a dearth of information on quantitative and qualitative pattern of closed and open canopy forest communities of tropical deciduous forests in Chhattisgarh.

In view of this, the present study entitled “**Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests**” was carried out with the following major objectives:-

1. To analyses the species composition of open verses closed canopy forest.
2. To analyses the diversity pattern of open verses closed canopy forest.
3. Compression of species composition and diversity pattern in open and closed canopy forests.

CHAPTER-II

REVIEW OF LITERATURE

India is recognized as one of the world's top 12 mega diversity nation (Myers, 1988). The richness in biodiversity is due to immense variety of climate and altitudinal conditions coupled with varied ecological habitats. The country has over 1, 15,000 species of plants and animals. Among flora, the country can boast of 45,000, which accounts for 15 per cent of the known world plants. Of the 15,000 species of flowering plants, 35 per cent are endemic and located in 26 endemic centers. Among the monocotyledons, out of 588 genera occurring in the country, 22 are strictly endemic.

In this chapter, an attempt has been made to review the work done on tree species composition and diversity patterns in Dry Deciduous Forests and other forests. The literature is broadly reviewed under the following major aspects.

- 2.1. To analyses the species composition and diversity pattern in open and closed canopy forests
- 2.2. Compression of species composition and diversity pattern in open and closed forests.

Singh *et al* (2006) defines vegetation structure as the organization in space of the individuals that form a stand (and by extension of a vegetation type or plant association) and he stated that primary elements of structure are growth form, stratification and coverage. The structural attributes of plant community

can be expressed both in qualitative and quantitative characters. The qualitative characters are physiognomy, phenology, stratification, abundance, dispersion, sociability, vitality and life form whereas quantitative characters include density, frequency, dominance and basal area (Odum, 1983). These quantitative primary variables are used for deriving secondary variables and Importance Value Index (IVI) of a species in a given community.

Champion & Seth (1968) identified five major forest groups in India viz. tropical, subtropical, montane temperate, sub alpine and alpine vegetation, which are further divided into forest types and sub types based on the ecological and bioclimatic characteristics. These vegetation types have a characteristic physiognomy, density, phenology, stratification etc. However, the structural heterogeneity needs further characterization in terms of community pattern, species diversity and density. According to Champion and Seth (1968) the forests of Chhattisgarh have been broadly categorized under tropical moist deciduous forest, tropical dry deciduous forest and montane sub tropical forest that have been further divided into sub categories and are grouped into 3 groups.

I. In group 3. Tropical Moist Deciduous Forests:

- (1) 3B/C1c slightly moist teak forests
- (2) 3C/C2e moist peninsular Sal forests
- (3) 3C/C3 moist mixed deciduous forest

II. In group 5. Tropical Dry Deciduous Forests:

- (1) 5B/C1c dry peninsular Sal forest

- (2) SB/C2 northern dry mixed deciduous forest.

III. In group 8. Montane Subtropical Forests:

- (1) 8A/C3 Central Indian sub tropical Hill Forest.

Chhattisgarh is second densely forested state of the country after Assam as it has 46 per cent of forest cover of its total area, which is more than 33 per cent of forest cover as recommended by National Forest policy. The state is well known in the country for its Sal forests, which occupy nearly 36 per cent of total forest cover. Teak forests are also abundant but mainly in western and southern parts of the state (Kumar *et al.*, 2003).

The ecological importance of species and their organization as plant communities assessed in terms of dominant, co-dominant and suppressed vegetation based on the phyto-sociological analysis (Mishra, 1968, Odum, 1983). The patch scale characterization of a vegetation type in terms of its floristic composition, density, dominance, diversity and identification of predominant, co dominant and suppressed communities are generally made by conventional sample plot/quadrat methods (Mishra, 1968, Whittaker, 1978). The conventional techniques of phyto-sociological analysis help in better understanding of community only at stand level. Several studies used correlation and regression relationship between species composition and structural attributes, including basal area and biomass (Franklin, 1986, Peterson *et al.*, 1986), diameter at breast height (Cohen and Spies, 1992; Oza *et al.*, 1989) height and density (Danson and curran, 1993, Cohen and Spies, 1992, Walsh, 1987) and leaf area index (Spanner *et al.*, 1990, Peterson, *et al.*, 1986).

Singh and Singh (1991) studied composition and diversity index in mixed dry deciduous forests of Vindhyan region. The basal cover of vegetation varied from 3.8 to 10.4 m² ha⁻¹ for trees and 3.1 to 7.8 m² ha⁻¹ for shrubs. Shannon and Weiner index and concentration of dominance ranged between 1.93 to 2.18 and 0.18 to 0.38, respectively. The beta diversity was 3.1. The structural and functional processes have to be quantified for thoroughly understanding the vegetation dynamics. The structural analysis of vegetation entail the floristic composition, stand density, basal area, vertical stratification and community types. While, the diversity provides information on species richness, distribution pattern and rate of change in species composition. Both structure and diversity of vegetation have strong functional role in controlling ecosystem process like biomass, production, cycling of water and nutrients (Gower *et al.*, 1992).

Longhi *et al.* (1999) studied the floristic composition, tree community structure and dendrometric characteristic of a fragment of the deciduous seasonal forest in Rio Grande do sul, Brazil, located eighteen 200 m² sample plots, and analyzed it. They found that 56 plant species belonging to 46 genera and 28 families with CBH (circumference at breast height) < or > 15cm. The tree height varied from 3.5 m in the understory to 22 m for the emergent trees. Most trees were in low competition as demonstrated by an h/d (ht/dia) relation < 1. The frequency distribution of circumference was 42.25% of the individuals with CBH 15-25 and only 4.25% with CBH > 65 cm.

The species inventories at defined sites and in minimum diameter classes give a reliable instrument to indicate the diversity level of a study site (Wattenberg and Breckle, 1995). Tree species diversity is an important aspect of forest ecosystem diversity (Reynolds and Laumonier, 2000). Plant diversity inventories in tropical forests have been concentrated on tree species than the other life forms, because tree species diversity is an important aspect of forest ecosystem diversity and fundamental to total tropical forest biodiversity. They provide resources and habitat structure for almost all other species.

Pande (2001) studied the structure of the tropical dry deciduous teak (*Tectona grandis*) forest of Satpura plateau (India) with special emphasis on regeneration and disturbance and identified three communities: (1) *Tectona grandis*- *Lagerstroemia parviflora*- *Sterculia urens* (site I); (2) *T. grandis*- *Lannea coromandelica*- *Diospyros melanoxylon*- *Butea monosperma*- *Miliusa tomentosa* (site II); and (3) *T. grandis*- *Chloroxylon swietenia*- *Lagerstroemia parviflora*- *Diospyros melanoxylon* (site III). Respective mean stand densities were 6.9, 9.5 and 16.3 trees/100 m², 19.99, 25.25 and 38.87 shrubs/100 m², and 25 600, 13 816 and 19 980 herbs/100 m². Site II showed the highest species richness followed by I and III. Based on the above population structure, it may be concluded that site III, the least disturbed, can be a suitable site for *Tectona grandis* regeneration and its associate species.

Quantitative floristic sampling also provides the necessary context for planning and interpreting long-term ecological research (Phillips *et al.*, 2003). The long-term permanent plot and permanent tagged individuals of trees provide a unique opportunity to investigate the dynamics of individual species

and total forest in space and time (Ayyappan and Parthasarathy, 1999). Such large-scale permanent plot studies are also important for conservation and management of tropical forests (Field and Vazquezynes, 1993). Recently the number of permanent plots has increased rapidly in various tropical forests of the world (Hubbell and Foster, 1983; Manokaran *et al.*, 1990; Sukumar *et al.*, 1992; Condit, 1995; Aiba and Kitayama, 1999; Ayyappan and Parthasarathy, 2001; Nebel *et al.*, 2001; Sagar and Singh, 2003).

Shi and Singh (2002) assessed the status of the world's remaining closed forest population distribution and protected areas in global biodiversity hot spots. According to them world's remaining closed forest are about 2.87 billion hectares, which occupies about 21.9 per cent of the land area of the world. The high human population pressure in the spot exists in 10.7 per cent of closed forests. The four spots with the most elevated risk as assessed by human population pressure were in the Western Ghats, Sri Lanka, Polynesia and Micronesia, Philippines and Caribbean hot spots. Arunachalam (2002) studied the species diversity in two different forest types of Western Ghats, India and found 16 tree species, 6 shrubs and 8 herbaceous species in wet evergreen 'Kittlemange kudige' forest, while the dry deciduous 'Thaniparai' forest had 18 tree species, 7 shrubs and 10 herbaceous species. The species richness index was greater for trees (2.32), followed by ground vegetation (1.50) and shrubs (0.98) in the evergreen forest. Both the Shannon-Weiner and Hill's diversity indices showed similar trend in both the sites. Simpson's index was low for tree species (0.08) and high for shrubs (0.18-0.19), while the Pielou's evenness index was greater for tree species and lower for the herbaceous species. Both

the forests have been preserved by the local people due to religious beliefs and have exploration potential of biological diversity provided suitable management packages for sustainable use of the resources.

Saha (2003) studied the patterns in woody species diversity, richness and partitioning of diversity in forest communities of tropical deciduous forest biome and observed that the regressive succession model hypothesizes tropical savanna-woodlands to be a degraded stage of primary deciduous forests. At the plot scale (0.1ha) secondary deciduous forests and savanna-woodlands had similar species diversity, a pattern not consistent with the regressive model of deciduous forest succession and mature deciduous forests had greater species diversity and richness ($p < 0.05$). Species richness at the community scale was greatest in secondary deciduous forest as expected from species area relationship. The communities shared 28 woody species but the species composition was significantly different between the communities. It suggests that conservation of tropical deciduous forests based on regressive succession model is problematic.

Sagar and Singh (2003) studied the forest inventory data collected during the year 1998 to 2000 from fifteen permanent plots having the size of 1 ha along a disturbance gradient in dry tropical forest region of India. The study indicate that the dry tropical forest is characterized by a patchy distribution of species and individuals with mixed species composition and different combinations of the dominant and co- dominant species representing the sites. The total number of stems, indices of species richness, evenness and α -diversity decreased with disturbance. A strong influence of number of species per

individual on β -diversity suggests that for resisting change in the floristic composition due to disturbance, a site must have low species individual ratio.

Pande (2005) studied the ecological status of vegetation in Satpura plateau, M. P. Total density for tree layer ranged between 46.93-387.5 tree ha⁻¹, for shrub layer 114 to 714.95 and 15905 to 102078 plants ha⁻¹ for herb layer. Whereas, the range for dominance was 9570 to 217333 cm² ha⁻¹ for trees, 2912 to 32462 cm² ha⁻¹ for shrub and 1304 to 218468 cm² ha⁻¹ for herbs. Negi and Nautiyal (2005) studied the phytosociological characteristics of Thalke Dhar Reserve forest of Central Himalayas. A total of 53 species (13 species of tree, 24 species of shrubs and 16 species of herbs) were recorded. The tree density was 1010-1230 trees ha⁻¹ in different compartment. Total basal cover of tree species ranged from 49.39 to 64.74 m² ha⁻¹ across the compartment. Density of sapling ranged between 690-770 saplings ha⁻¹. The value of diversity ranges from 2.156 to 2.323, 2.53 to 2.67, 2.39 to 3.20 and 3.32 to 3.94 for trees, saplings, seedlings and shrubs, respectively. Beta diversity was 1.42, 1.32, 1.16 and 1.30 for trees, saplings, seedlings and shrub layer, respectively.

Tropical forests indicate higher diversity as calculated by Knight (1975) for young stand (H' =5.06) and for old stand (H' =5.4). Sukumaran (2005) studied the floristic composition of sacred grooves and reported 329 plants species from 251 genera belonging to 110 families in which 108 belonging to angiosperms and 2 to gymnosperms. Forest was rich with 139 species of trees, 95 species of shrubs, 79 species of herbs and 16 species of lianas and climbers. 54 species are listed rare, endemic and threatened.

Cavalho *et al.* (2005) studied the distribution of tree and shrub species along a gradient of soils and topography in a strip of riparian forest of the Sao Francisco River in Tres Marias, MG, Brazil. The community of trees and shrubs, topography and soils of a fragment of tropical semi-deciduous and tropical deciduous forests was carried out to determine alleged correlations between the variation in physiognomic structure and species composition and variation in soil water regime and chemical fertility. The survey registered 1449 individuals belonging to 117 species, 83 genera, and 33 families, as well as three soil subgroups and five drainage classes.

Verghese and Menon (1998) conducted studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India. The stand density, species density and basal area of these forests were 535 trees ha⁻¹, 12 species per 0.1 ha and 26.57 m² ha⁻¹, respectively. Shannon index of these forests was 1.89, while evenness index was 0.73. *Terminalia paniculata*, *Pterocarpus marsupium* and *Careya arborea* were found as dominant plant association. Pande (2005) analyzed vegetation in nine forest villages in M. P. where highest tree diversity was recorded (1.19) at highly disturbed site and concentration of dominance showed reverse trend to diversity index and concluded that disturbances adversely affect the regeneration and composition of different tree species at different sites.

The values of concentration of dominance for tropical forest lies within the range of 0.21 to 0.92 (Bisht, 1989, Parthasarathy *et al.*, 1992: Visalkashi, 1995). In several temperate forests the values of total basal cover and density were 0.15-0.6 m² 100 m⁻² and 3.2-20.8 trees 100 m⁻², respectively (Saxena and

Singh, 1982, Ralhan *et al.*, 1982, Singh *et al.*, 1997, Kumar and Ram, 2005). The same ranges from 0.11-0.68 m² 100 m⁻² and from 5.5-18 trees 100 m⁻² for tropical forests (Visalakshi 1995, Parthasarathy *et al.*, 1992). Many workers have reported the diversity values in temperate forests ranged between 1.16 to 3.4 (Singh and Singh, 1987).

Kadavul (1999) studied the species richness, density and population structure of all trees inventories in four 1 ha plots of semi evergreen forests of Kalrayan hills, Western Ghats. A total of 2064 stems (mean 516 ha⁻¹) covering 89 species (74 genera and 39 families) were recorded. The species richness varied from 42 to 47 species ha⁻¹, Shannon index from 2.31 to 2.87 and stand density from 367 to 667 stems ha⁻¹, mean stand basal area was 33.6 m² ha⁻¹. *Nothopegia heyana* and *Celtis Philippines* were dominant and contributing 50 per cent of total density. Species richness and density decreased with tree girth.

Visalakshi (1995) analyzed the vegetation in two tropical forests with reserve forest (RF) and sacred grove (SG) in tropical dry evergreen forests of Coramandel coast of south India. The mean stand density of all woody species > 20 cm gbh in two stands was 280 stems ha⁻¹ and basal area 11.0 m² ha⁻¹ in RF. In SG stand density was 1130 stems ha⁻¹ and basal area 36.9 m² ha⁻¹. The Shannon- Wiener index for RF and SG site was 2.19 and 1.78, respectively.

Conserving forest biodiversity at the ecosystem level helps to support service such as maintaining the balance of atmospheric gases, recycling nutrients, regulating climate, maintaining hydrological cycles and creating soil. While scientists are still developing their understanding of the relationships among taxonomic diversity, productivity, stability and adaptability of

ecosystem, new research indicated that species diversity enhance the productive capacity of many forest ecosystems and their ability to adapt to changing conditions (Visalakshi, 1995).

Singh, S.P. (2002) has stated that most plans for conservation have focused on biodiversity, ignoring the importance of ecosystem services. Recent exercises on the prioritization of creatures and places deserving most attention for conservation and on developing national biodiversity conservation plans in several Asian countries, may further increase its imbalance.

Devi and Yadava (2006) studied the floristic diversity of dipterocarpus tuberculatus dominated forest of Manipur. A total of 123 species belonging to 48 families were recorded. the quantitative features such as density and importance value index of species varied greatly. In their study the diversity index of shrubs and herbs were found to be higher than the tree species. The concentration of dominance was recorded highest in the tree species.

Singh et al., (2006) have studied the biodiversity and importance of lesser-known woody species of moist deciduous forest of Achanakmar-Amarkantak biosphere reserve having the density and basal cover of 1203 stems ha^{-1} and $36.33\text{m}^2 \text{ha}^{-1}$. Patra *et al.* (2007) studied the open and closed, sal and miscellaneous forests of west Chindwara forest division, where they have noted that density and dominance of trees are invariably higher in closed forests, whereas, shrubs and herbs are higher in open forests except shrubs for miscellaneous closed forests. Miscellaneous open forests showed highest species richness followed by miscellaneous closed, sal closed and sal open for

tree species, diversity index values were highest for miscellaneous open followed by miscellaneous closed, sal open and sal closed forests.

Change in the habitat variables such as nature of substrate can affect species diversity. Natural or anthropogenic disturbances can reduce low population densities of plant species even further and isolate populations of commonly found species by habitat destruction (De 2007). Anitha *et al.* (2007) studied the effect of anthropogenic disturbances on tree community structure and regeneration in Anaikatty hills, Western Ghats, the study was conducted in the reserve forests of anaikatty hills and the adjoined Salim Ali Centre for Ornithology and Natural history (SACON) campus. Three habitats namely undisturbed, moderately disturbed and highly disturbed stands were identified on the basis of various signs of disturbances such as lopping cattle grazing, nearness to human habitation, collection of non-wood forest produces etc.

Khurana and Kalpana (2008) have studied the phyto-diversity in the natural forest of Hastinapur forests and concluded that high value of biodiversity in an area indicates high level of biological disturbances. Kanade *et.al.* (2008) have studied the vegetation composition and woody species diversity at Chandoli National park of northern Western Ghats and stated that lack of uniform methodology has always been a concern for drawing meaningful insights into outlining structural complexities leading to conservation strategies.

CHAPTER - III

MATERIALS AND METHODS

The study on “**Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests**” was carried out at Barnawapara Wildlife sanctuary of North Raipur Forest Division in Raipur district (Chhattisgarh) during the year 2007–2008. The details of the study site, climate, geology, soils, forest flora, fauna and other features of land along with the methodologies adopted are described below:

3.1 Study Site

The study was conducted in Barnawapara wildlife Sanctuary (North Raipur Division) situated in North-Eastern corner of Raipur district. The geographical location and physiographic features of study area are given below:

3.1.1 Geographical location and physiography

The study area is located between 21⁰20'0" to 21⁰25'47" North latitudes and 82⁰21'17" to 82⁰26'27" East longitudes. It is situated about 17 km away from Patwa on Raipur-Sambalpur NH No. 6. The location of study area, important places and road network are depicted in Figs. 3.1 and 3.2.

The general topography of area is undulating due to formation of rockout crops. The area adjoining Nawapara forest village has a number of hillocks scattered all over the area. The slopes of hillocks are moderate to steep. Tilsa pathar is the highest with an approximate altitude of 463 m above m.s.l.

The stream and nalas flowing in the area have steep bank rich in alluvial soil and sustain a rich variety of vegetation.

Dry deciduous forest, grasslands, agriculture lands and human habitations surround the study area. Most of the villages in study area are categorized as forest villages and majorities of them are accessible through Kaccha roads, which is motorable only in dry season. Road network is absent in few hilly tracts, which are inaccessible due to steep slopes and dense forest.

3.1.2 Climate

The climate of study area is dry humid tropical consists of three seasons *viz.* rainy, winter and summer. The rainy season commences from about mid June to September. The winter season, which commences from the beginning of November, lasts till the end of February. The summer commences from the beginning of March. It is quite prolonged and severe and lasts till monsoon sets in. The climatic data is shown in Fig 3.3.

3.1.3 Rainfall

The average annual rainfall in the study area ranges from 1200-1350 mm. About 80 percent of the annual rainfall in the study area is received from south west monsoon during June to August. The highest amount of rainfall occurs in July. Number of rainy days varies from 90-100 days.

3.1.4 Temperature

The mean monthly maximum temperature ranges from 27.3⁰C in January to 41.8⁰C in May and mean monthly minimum temperature ranges from

12.7⁰C in December to 27.3⁰C in May. The mean annual maximum and minimum temperature of study area are 33.1⁰C and 20.5⁰C, respectively.

3.1.5 Humidity

Relative humidity of study area increase with the onset of south-west monsoon and it generally becomes more than 80% in July. In the post monsoon and winter seasons the relative humidity lies between 50-65% in the morning (6:00 to 12:00 hrs.) and 30-40% in the afternoon (12:00 to 16:00 hrs.). Relative humidity is lowest during summer and drops below 30 percent in the afternoon in April and May.

3.1.6 Geology

The area is having three distinct geological formations *viz.* Chhattisgarh Super Group, Late Precambrian and Early Precambrians. Lithologically the area is divided into seven groups namely Raipur Shale and Limestone, Khairagarh Sandstone, Gunderdehi Shale, Cuddapahas Charmur Limestone, Chandrapur Sand Stone Grit, Dharwar Rocks, Granite and Genesis.

3.1.7 Soils

Physicochemical properties of study site are studied by Kumar and Singh (2008) which is summarized in Table 3.1. Soil of study was sandy loam in nature. Proportions of sand silt and clay in soil were 41 %, 30% and 34%, respectively. Bulk density was 0.93 g cm⁻³. Water holding capacity of soil was 61.01%. Soil of the study area contained 0.94% organic carbon; 184.1 kg ha⁻¹ available nitrogen where as total nitrogen in soil was 0.16%. Soil holds 16.34 kg ha⁻¹ available phosphorus and 280.5 kg ha⁻¹ available K. The nitrate and

ammonium nitrogen in soil were 5.56 microgram per gram and 4.44 microgram per gram.

Table 3.1: Physico-chemical properties of soil (<20 cm depth)

Properties	
Physical properties	
Texture	Sandy loam
Mechanical composition	
Sand (%)	41.0
Silt (%)	30.0
Clay (%)	34.0
Bulk density (g cm ⁻³)	0.93
Chemical properties	
% organic carbon	1.75
Available N (kg ha ⁻¹)	184.1
Total N (%)	0.16
Available P (kg ha ⁻¹)	16.34
Available K (kg ha ⁻¹)	280.5
NO ₃ -N (µg g ⁻¹)	5.56
NH ₄ -N(µg g ⁻¹)	4.44
Water holding capacity (%)	61.01

3.1.8 Forest types

Different types of forest vegetation occur in the study area. Northern and eastern directions are covered with luxuriant forests, whereas Teak plantations occupy a major area in southern direction. In western direction, a large area is covered by degraded and mixed forest and also with bamboo brakes occasionally found as patches in this direction. According to Champion and Seth (1968), the forests of the study area are classified into four major forest types viz., (1) Southern Tropical Dry Deciduous Teak Forest (5A/C_{1b}), (2) Northern Tropical Dry Peninsular Deciduous Sal Forest (5B/C_{1c}), (3) Northern

Tropical Mixed Deciduous Sal Forest (5B/C₂) and (4) Dry Bamboo Brakes (5/E₉).

3.2 Experimental details

3.2.1 Sampling/ Ground Inventory

The Comparative study of Tree species composition and diversity pattern in open and closed canopy Dry Deciduous was conducted after repeated reconnaissance survey of Barnawapara wild life sanctuary. Total three sites were selected, out of which two sites viz. site-1 (Patpara) and site-2 (Near Bandhi Nala) for open canopy forest and one site (Karidogari) for closed canopy forest from Barnawapara wildlife Sanctuary.

3.2.2 Method

The stratified random sampling procedure was adopted for characterization of forest. The phyto-sociological analysis in each forest was carried by randomly laying quadrats of 10 x 10 m² in size. Randomly 10 quadrats were laid down in each forest. In each quadrat, for tree species the individuals >31.5 cm G.B.H. were categorized as trees, <31.5 but >10 cm as saplings and <10 cm as seedlings. Stem girth of each adult individual tree was measured at 1.37 m (G.B.H.) from the ground level. Thus all individuals were enumerated by species and the girth of all the individuals was measured. Within each quadrat sub-quadrats of 5×5 m and 2×2m were used for the measurement of saplings and seedlings, respectively.

3.2.3 Phyto-sociological analysis

The vegetation data in each forest site was quantitatively analyzed for frequency, density and abundance by using following expressions (Curtis and Mc Intosh, 1950).

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

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

$$\text{Abundance (stems /ha)} = \frac{\text{Total number of individual of the species in all quadrats}}{\text{Number of quadrats in which the species occurred}}$$

Distribution Patterns

The ratio of abundance to frequency indicates regular distribution if below 0.025, random distribution between 0.025 to 0.05 and contagious distribution if >0.05 (Curtis and Cottam, 1956)

Basal area of trees was calculated as cross sectional area of stem at breast height i.e. at 1.37 m from the ground level. The relative density, relative frequency, relative basal area, relative abundance was calculated using

following equations.

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

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

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

$$\text{Relative abundance (RA)} = \frac{\text{Abundance of the individual species}}{\text{Total abundance of all species}} \times 100$$

The Importance Value Index (IVI) was determined as the sum total of relative frequency, relative density and relative dominance (Phillips, 1959).

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

3.2.4 Plant diversity analysis

Plant diversity in different forest fragments was quantified by following diversity indices.

- a) **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 was the total basal cover of species i and N was the total basal area of all the species. The factor 3.3219 was used to convert the index value to \log_2 .

b) **Concentration of dominance** was measured by Simpson's Index (Simpson, 1949)

$$Cd = (Ni / N)^2$$

Ni and N were same as explained above and it varies between 0-1.

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

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

H' = Shannon index and S = the number of species.

d) **Species richness** was calculated by the following equation (Marglef, 1958).

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

Where,

S = total number of species,

N = basal area of all species ($m^2 ha^{-1}$)

e) **Beta diversity**; Beta diversity is often been used to indicate habitat variation with regarded to species composition and was calculated as (Whittaker, 1977)

$$bd = Sc / \bar{S}$$

Where,

Sc = total number of species in all sites and \bar{S} = average species per site.

CHAPTER-IV

RESULTS AND DISCUSSION

The results on “**Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests**” are discussed in this chapter. The findings are presented in three parts to facilitate the interpretation of results in accordance with topics.

4.1 Species composition of open verses closed canopy forests

4.2 Diversity pattern of open verses closed canopy forests

4.3 Comparison of species composition and diversity pattern in open and closed canopy forests.

Results on different aspects in each part are described below :

4.1 Species composition

4.1.1 Tree Layers

In the present study a total of 650 and 750 trees ha⁻¹ in the open canopy forest sites and 1520 trees ha⁻¹ in closed canopy forest site representing 22 species and 16 families were encountered. The most diverse families were Euphorbiaceae (3), Combretaceae (2), Anacardiaceae (2), Caesalpiniaceae (2), The Euphorbiaceae family represented highest individual 66 followed by Combretaceae (66), Lythraceae (29), Ebenaceae (24). Results of Species composition analysis in tree layers of different forest sites are given in the table 4.1 to 4.2.

4.1.1.1 Open canopy forests

The study was conducted in two sites, i.e, site-1 (located at Patpara) and site-2 (located near Bandhi Nala).

Site -1.

In the open forest site-1, a total of 650 trees ha⁻¹ representing 10 species and 9 families were encountered. The Combretaceae family was represented by 37 individuals followed by Lythraceae (08), Anacardiaceae (06). It is evident from the data presented in the table 4.1 that *Terminalia alata* was the most dominant tree followed by *Bridelia retusa* and *Lagerstroemia parviflora*. Highest density was recorded in *Terminalia alata* followed by, *Lagerstroemia parviflora*, *Buchanania lanzan* and *Bridelia retusa*. Lowest density was recorded in case of *Grewia tiliaefolia*, *Cassia fistula*, and *Mitragyna parviflora*. Highest basal area was observed in *Terminalia alata* followed by, *Bridelia retusa*, *Lagerstroemia parviflora* and *Buchanania lanzan*. Lowest basal area was observed in *Cassia fistula*, *Grewia tiliaefolia* and *Mitragyna parviflora*. Basal area and density of individual tree species varied from 0.013 m² ha⁻¹ to 44.03 m² ha⁻¹ and 10 to 370 stems ha⁻¹, respectively. *Terminalia alata* showed highest value of IVI (185.14) followed by *Bridelia retusa* (25.83) and *Lagerstroemia parviflora* (25.75). The total basal area of Patpara (site-1) was recorded 48.28 m² ha⁻¹. Abundance to frequency ratio indicated that all of the species showed contagious and random distribution.

Site -2

In the open forest site-2 a total of 750 trees ha⁻¹ representing 16 species and 14 families were encountered. The Euphorbiaceae family was represented by 22 individuals followed by Combretaceae (21) and Leguminosae (9). It is evident from the data presented in the Table 4.1 that *Terminalia alata* was the most dominant tree species followed by *Cleistanthus collinus* and *Butea monosperma*. Highest density was recorded in *Terminalia alata* followed by *Butea monosperma*, *Lagerstroemia parviflora* and *Bridelia retusa*. Lowest density was recorded in case of *Anogeissus latifolia*, *Emblica officinalis*, *Diospyros melanoxylon* and *Mitragyna parviflora*. Highest value for basal area was observed in *Terminalia alata* followed by *Cleistanthus collinus* and *Butea monosperma*. Lowest basal area was observed in *Emblica officinalis*, *Diospyros melanoxylon* and *Anogeissus latifolia*. Basal area and density of individual tree species varied from 0.021 m²ha⁻¹ to 32.62 m² ha⁻¹ and 10 to 200 stems ha⁻¹, respectively. *Terminalia alata* showed highest value of IVI (98.45) followed by *Cleistanthus collinus* (43.39), and *Butea monosperma* (29.13). The total basal area of site-2 recorded 47.269 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and few species showed regular distribution.

4.1.1.3 Closed canopy forest

The forest was located at Karidongari area, in which a total of 1520 trees ha⁻¹ representing 18 species and 13 families were encountered. The Euphorbiaceae family was represented by 21 individuals followed by Ebenaceae (20) and Lythraceae (15), It is evident from the data presented in the

table 4.2 that *Bridelia retusa* was the most dominant tree layer followed by *Diospyros melanoxylon*, *Shorea robusta* and *Lagerstroemia parviflora*. Highest density was represented by *Bridelia retusa* followed by *Cassia fistula*, *Diospyros melanoxylon* and *Lagerstroemia parviflora* where as *Mitragyna parviflora*, *Bauhinia variegata*, and *Embllica officinalis* showed the lowest values for density. Highest value for basal area was observed in *Diospyros melanoxylon* followed by *Bridelia retusa* and *Shorea robusta*. Lowest basal area was observed in *Embllica officinalis*, *Butea monosperma* and *Cassia fistula*. Basal area and density of individual tree species varied from 0.005 m² ha⁻¹ to 11.28 m² ha⁻¹ and 20 to 270 stems ha⁻¹, respectively. *Bridelia retusa* showed highest value of IVI (51.38) followed by *Diospyros melanoxylon* (45.95), and *Shorea robusta* (34.98)). The total basal area of this site was recorded 50.351 m² ha⁻¹. Abundance to frequency ration indicated that most of the species were distributed randomly distribution followed by contagious distribution pattern.

4.1.2 Sapling layer

In the present study, a total of 1570 saplings (490 saplings in each open canopy forest sites and 590 saplings in closed forest site) in all the sites representing 16 species and 14 families were encountered. The most diverse families were Euphorbiaceae (2), Anacardiaceae (2). The Euphorbiaceae family represented (43) highest individuals followed by Lythraceae (25) Combretaceae (24), Ebenaceae (13). Results on species composition of in sapling layers are given in the table 4.3 to 4.4.

4.1.2.1 Open canopy forests

Site-1

In this site a total of 490 sapling ha⁻¹ representing 8 species and 7 families were encountered. The Lythraceae family was represented by 14 individuals followed by Combretaceae (11), Anacardiaceae (9) and Euphorbiaceae (7). It is evident from the data presented in the table 4.3 that *Terminalia alata* was the most dominant tree species followed by *Cleistanthus collinus* and *Lagerstroemia parviflora* and *Diospyros melanoxylon*. Highest density was recorded in *Terminalia alata* followed by *Cleistanthus collinus*, *Lagerstroemia parviflora* and *Diospyros melanoxylon*. Lowest density was recorded in case of *Buchanania lanzan*, *Cassia fistula* and *Butea monosperma*. Highest basal area was observed in *Terminalia alata* followed by *Cleistanthus collinus*, *Lagerstroemia parviflora* and *Diospyros melanoxylon*. Lowest basal area was observed in *Buchanania lanzan*, *Cassia fistula*, *Butea monosperma* and *Grewia tiliaefolia*. Basal area and density of individual tree species varied from 0.0058 m² ha⁻¹ to 1.017 m² ha⁻¹ and 10 to 140 stems ha⁻¹, respectively. *Terminalia alata* (90.60) showed highest value of IVI followed by *Cleistanthus collinus* (62.54), and *Lagerstroemia parviflora* (55.16). The total basal area of site-1 was recorded 2.3779 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed random and few species showed contagious distribution and none of the species were regularly distributed.

Site -2

In site-2 a total of 490 saplings ha⁻¹ representing 11 species and 10 families were encountered. The Combretaceae family was represented by 10

individuals followed by Stiaginaceae (8), Euphorbiaceae (7) and Tiliaceae (7). It is evident from the data presented in the table 4.3 that *Cleistanthus collinus* was the most dominant sapling layer followed by *Bridelia retusa* and *Lagerstroemia parviflora* and *Grewia tiliaefolia*. Highest density was recorded for *Cleistanthus collinus* followed by *Bridelia retusa*, *Lagerstroemia parviflora* and *Grewia tiliaefolia*. Lowest density was recorded in case of *Buchanania lanzan*, *Schleichera oleosa*, *Butea monosperma* and *Mitragyna parviflora*. Highest value for basal area was observed in *Cleistanthus collinus* followed by *Bridelia retusa* and *Grewia tiliaefolia* whereas lowest basal area was observed in *Buchanania lanzan*, *Schleichera oleosa*, *Butea monosperma*. Basal area and density of individual tree species varied from 0.0062 m² ha⁻¹ to 0.532 m² ha⁻¹ and 10 to 100 stems ha⁻¹, respectively. *Cleistanthus collinus* showed highest value of IVI (67.72) followed by *Bridelia retusa* (53.46) and *Lagerstroemia parviflora* (43.75). The total basal area of open forest was recorded and 1.769 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and only few species showed regular distribution.

4.1.2.3 Closed canopy forest

In the closed canopy forest site a total of 590 saplings ha⁻¹ representing 14 species and 12 families were encountered. The Euphorbiaceae family was represented by 18 individuals followed by Lythraceae (7) and Tiliaceae (7). It is evident from the data presented in the table 4.4 that *Cleistanthus collinus* as the most dominant sapling layer followed by *Lagerstroemia parviflora* and *Terminalia alata*. Highest density was recorded in *Cleistanthus collinus*

followed by *Lagerstroemia parviflora*, *Terminalia alata* and *Diospyros melanoxylon*. Lowest density was recorded in case of *Holarrhena pubescens*, *Mitragyna parviflora*, *Buchanania lanzan*, *Cassia fistula* and *Grewia tiliaefolia*. Highest value for basal area was observed in *Cleistanthus collinus* followed by *Lagerstroemia parviflora*, *Terminalia alata* and *Diospyros melanoxylon*. Lowest basal area was recorded in *Mitragyna parviflora*, *Cassia fistula* and *Holarrhena pubescens*. Basal area and density of individual sapling varied from 0.0045 m² ha⁻¹ to 1.1434 m² ha⁻¹ and 10 to 140 stems ha⁻¹, respectively. *Cleistanthus collinus* showed highest value of IVI (88.22) followed by *Lagerstroemia parviflora* (42.21) and *Terminalia alata* (41.19). The total basal area of closed forest site was recorded 2.4576 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and few species showed the regular distribution at this site.

4.1.3 Seedling layer

In the present study a total of 1170 seedling ha⁻¹ in all the sites representing 13 species and 11 families were encountered. The most diverse family was Euphorbiaceae (3). Ebenaceae family represented (42) highest individual followed by Combretaceae (17), Euphorbiaceae (15). Results on species composition analysis in seedling layers are given in the table 4.5 to 4.6.

4.1.3.1 Open canopy forest

Site -1

In this site, a total of 420 seedling ha⁻¹ representing 7 species and 7 families were encountered. The Anacardiaceae family was represented by 14

individuals followed by Lythraceae (10), Combretaceae (6), and Euphorbiaceae (6). It is evident from the data presented in the table 4.5 that *Lagerstroemia parviflora* was the most dominant seedling layer followed by *Diospyros melanoxylon* and *Terminalia alata*. Highest density was recorded in *Terminalia alata* followed by *Diospyros melanoxylon*, *Lagerstroemia parviflora* and *Bridelia retusa*. Lowest density was recorded in case of *Butea monosperma*, *Emblica officinalis* and *Chloroxylon swietenia*. Highest basal area was observed in *Lagerstroemia parviflora*, *Diospyros melanoxylon* and *Terminalia alata*. Lowest basal area was observed in *Butea monosperma* and *Bridelia retusa*. Basal area and density of individual seedlings species varied from 0.000202 m² ha⁻¹ to 0.0000057 m² ha⁻¹ and 10 to 140 seedling ha⁻¹, respectively. *Lagerstroemia parviflora* showed highest value of IVI (94.85) followed by *Diospyros melanoxylon* (84.81) and *Terminalia alata* (68.08). The total basal area of seedlings was recorded 0.09632 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed random and contagious distribution and regular distribution was not shown by any species in this forest site.

Site -2

In the site-2, a total of 370 seedlings ha⁻¹ representing 6 species and 6 families were encountered. The Lythraceae family was represented by 21 individuals followed by Euphorbiaceae (6). It is evident from the data presented in the table 4.5 that *Diospyros melanoxylon* was the most dominant seedling layer followed by *Holarrhena pubescens* and *Emblica officinalis*. Highest density was recorded in *Diospyros melanoxylon* followed by and *Holarrhena pubescens*. Lowest density was recorded in case of *cassia fistula* and

Schleichera oleosa. Highest basal area was observed in *Holarrhena pubescences* followed by *Diospyros melanoxylon*. Lowest basal area was observed in *cassia fistula* and *Emblica officinalis*. Basal area and density of individual seedling species varied from 0.0024 m² ha⁻¹ to 0.0129 m² ha⁻¹ and 10 to 210 seedling ha⁻¹, respectively. *Diospyros melanoxylon* showed highest value of IVI (153.27) *Holarrhena pubescens* (83.06), *Emblica officinalis* (21.53). The basal area of this site was recorded 0.0268 m² ha⁻¹. Abundance to frequency ratio indicated that most of the species showed contagious distribution and few species showed random distribution pattern.

4.1.3.2 Closed canopy forest

In the closed forest site a total of 380 seedling ha⁻¹ representing 9 species and 8 families were encountered. The Lythraceae family was represented by 11 individuals followed by Euphorbiaceae (4) and Rubiaceae (4). It is evident from the data presented in the table 4.6 that *Shorea robusta* was the most dominant tree layer followed by *Diospyros melanoxylon* and *Cassia fistula*. Highest density was recorded in *Diospyros melanoxylon* followed by *Bridelia retusa*, and *Schleichera oleosa*. Lowest density was recorded in case of *Madhuca indica*. Highest basal area was observed in *Shorea robusta* followed by *Bridelia retusa*. Lowest basal area was observed in *Madhuca indica* and *Lagerstroemia parviflora*. Basal area and density of individual tree species varied from 0.0000314m² ha⁻¹ to 0.00697 m² ha⁻¹ and 20 to 110 seedling ha⁻¹, respectively. *Shorea robusta* showed highest value of IVI (91.90) followed by *Diospyros melanoxylon* (58.59), and *Cassia fistula* (29.29). The total basal area of closed forest site was recorded 0.00915 m² ha⁻¹. Abundance to frequency

ratio indicated that most of the species showed contagious distribution and only few species were randomly distributed.

In the present study the tree basal cover values for open forest site were lower (47.27-48.29 m² ha⁻¹) than that of closed forest site (50.351 m² ha⁻¹). These basal cover values were higher than the values reported for several dry tropical forest communities in Vindhyan region reported by Jha and Singh (1990) between 6.58 and 23.21 m² ha⁻¹ and from 3.80 to 10.36 m² ha⁻¹ by Singh and Singh (1991). Murphy and Lugo, (1986a) have reported the basal cover of 17 to 40 m² ha⁻¹ for dry tropical forest and 20 to 75 m² ha⁻¹ for wet forest. In the present study the density values of open canopy forest were 650 and 750 trees ha⁻¹ and this value for the closed canopy forest was 1520 tree ha⁻¹. Compared to the present study the density of Dipterocarps forest in Thailand of dry forest was 554 to 789 (Visaratana *et al.*, 1986); mixed deciduous forest was 253 (Sahunalu *et al.*, 1979), teak forest was 262 to 395 (Bunyavejchewin, 1983; Dhanmanonda and Sahunalu, 1992) and of tropical rain forest was 818 to 1540 (Kiratiprayoon, 1986).

Tree density in the Vindhyan region ranges between 294 to 627 stems ha⁻¹ for several dry tropical forest communities (Singh and Singh, 1991; Jha and Singh, 1990). Kanade *et al.*, 2008 reported the tree density and basal area from 333-657 individuals ha⁻¹ and 10.2-50.9 m² ha⁻¹, respectively for species rich (25-57 tree species) forest in Chandoli National Park, of Northern Western Ghat of India. Singh *et al.* (2006) have reported a total tree density of 1203 stems ha⁻¹ and basal cover of 36.33 m² ha⁻¹ having 45 species for moist deciduous forest of Achanakmar- Amarkantak Biosphere Reserve.

Density and basal cover values in the present study area are compared with the forest of Vindhyan hills and other tropical forests studied elsewhere. In general the above values are comparable to the several tropical forests. However, Rodgers (1990) reported a very high value of basal cover ($131 \text{ m}^2 \text{ ha}^{-1}$) for the forests of Sariska Tiger Reserve. Comparison of vegetational properties of certain tropical forests is given in table 4.7.

4.1 Diversity pattern of open verses closed canopy forest

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 diversity (H') at different sites of same locality are not a good sign for better growth of forest of any area. Species diversity parameters are summarized in the table 4.8.

4.2.1 Shannon index (H')

Shannon index was found to be variable from site to site in the study area of Barnawapara wildlife sanctuary. The Shannon index values recorded for tree layer of open canopy forest site-1 (0.63) and site-2 (1.68) and for closed canopy forest (2.20). These values for sampling layer were 2.075 (site-1) and 2.63 (site-2) for open canopy forest sites and 2.38 for closed canopy forest site. Seedling layer showed the value for Shannon index as 1.128 (site-1) and 1.35 (site-2) for open canopy forest and 1.46 for closed canopy forest.

Table 4.7: Certain vegetational properties of tropical forest

Forest Ecosystems	Density (stems ha ⁻¹)	Basal cover (m ² ha ⁻¹)	Number of species per ha.	Source
Mixed deciduous forest	394-539	6.6-23.2	-	Jha and Singh (1990)
<i>Boswellia-Acacia</i> forest	342-627	3.8-10.4	-	Singh (1991), Singh and Singh (1991).
Mixed Sal forest	558-1744	15.0-31.5	-	Sharma <i>et al.</i> (1990)
Pure Sal forest	386-785	12.7-33.2	-	Sharma <i>et al.</i> (1990)
Sariska Tiger Reserve	1352	131.9	-	Rodgers (1990)
Sal dominated closed forest	1220-1290	25.4-44.65	15-22*	Singh <i>et al.</i> (2003)
Sal dominated open forest	390-930	20.05-45.89	11-16*	Singh <i>et al.</i> (2003)
Dry Dipterocarp forest	554-789	-	35-37	Visaratana <i>et al.</i> (1986)
Mixed deciduous forest	253	-	14	Sahunalu <i>et al.</i> (1979), Kiratiprayoon <i>et al.</i> (1995)
Teak forest	262-395	-	21	Bunyavejchewin (1983), Dhanmanonda and Sahunalu (1992)
Tropical rain forest	818-1540	-	61-109	Kiratiprayoon (1986)
Tropical moist deciduous	448-1217	21.43-34.05	31-59	Bhat <i>et al.</i> (2000)
Tropical evergreen	197-1556	6.38-37.43	30-61	Bhat <i>et al.</i> (2000)
Tropical Dry Deciduous Forest	390-2640	10.61-50.90	10-25	Present study

*Represents the number of species in 0.1 ha.

4.2.2 Simpson's index

The Simpson's index values for tree layer in open canopy forest sites were 0.08 (site-1) and 0.05 (site-2) and 0.16 in closed canopy forest. The Simpson index values for sapling layer in open canopy forest sites were 0.29 (site-1) and 0.19 (site-2) and 0.28 in closed canopy forest. The Simpson index values for seedling layer in open canopy forest sites were 0.28 (site-1) and 0.45 (site-2) and 0.57 in closed canopy forest.

4.2.3 Equitability (e)

Equitability (e) values for tree layer were 0.27 (site-1) to 0.60 (site-1) in open canopy forest and 0.76 for closed canopy forest. For sampling layer the equitability values ranged from 0.99 (site-1) to 1.99 (site-2) for open canopy forest and 0.90 for closed canopy forest sites. Seedling layer showed the values of equitability as 0.58 (site-1) to 0.75 (site-2) for open canopy forest sites and 0.66 for closed canopy forest.

4.2.4 Species richness (d)

In the tree layer the species richness was highest in closed canopy forest (4.34) followed by open canopy forest (3.89 for site-2 and 2.23 for site-1). In sapling layer these values showed the similar trend (14.46 for closed canopy forest and 8.08-17.53 for open canopy forest sites). Seedling layer showed the different trend (Table 4.8) from that of tree and sapling layer where closed forest site showed the minimum value (1.71) than that of open canopy forest sites (1.38-2.56).

4.2.5 Beta diversity

Beta diversity was highest in tree layer of open canopy forest site-1 (8.15) and site-2 (4.89) followed by closed canopy forest (2.86). For sampling layer the open forest sites showed the value of 6.1 (site-1) and 5.52 (site-2) followed by closed canopy forest (4.10). Whereas the beta diversity values (8.67) for seedlings were more in closed canopy forest area and less for open canopy forest sites (7.65 for site -1 and 8.12 for site-2)

The diversity parameters of these forests can be compared with the diversity indices reported in different tropical forests (Singh and Singh, 1991). Diversity parameters in the tropical dry forest communities of the Vindhyan region (Jha, 1991) had ranges of 0.68 to 2.08 (Shannon-Wiener index), 0.75-1.75 (equitability), 1.62 to 7.77 (Simpson's index) and 0.13 to 4.33 (Beta diversity). Diversity in the dry tropical forest of the Vindhyan hill as reported by Singh and Singh (1991) had ranged between 1.93 to 2.82 (Shannon-Wiener index), 0.83 to 1.04 (equitability), 0.18-0.39 (Simpson's index) and 0.88 to 1.4 (Species richness). Prasad and Pandey (1992); Ravan (1994); Verghese and Menon (1998); Singh and

Table 4.9: Diversity indices in various forests

<i>Community</i>	Shannon-Weiner index (SW)	Simpson's index (S)	Reference(s)
Satpuda, Bandhavgarh, Indravati and Madhav National park	2.505-2.511	-	Kushwah & Kumar, 2000
<i>Terminalia/Shorea/Diospyros</i>	3.90	0.89	Goparaju <i>et al.</i> 2005.
<i>Acacia catechu</i>	4.28	0.86	-do-
<i>Lagerstroemia-Tectona</i>	4.04	0.80	-do-
<i>Lagerstroemia-Tectona</i>	4.30	0.69	-do-
<i>Butea- Diospyros</i>	5.47	0.93	-do-
<i>Boswellia serrata</i>	3.47	0.50	-do-
<i>Acacia catechu</i>	4.39	0.59	-do-
<i>Shorea/Boswellia</i>	5.41	0.87	-do-
<i>Acacia catechu</i>	2.46	0.20	-do-
<i>Shorea mixed</i>	4.22	0.83	-do-
<i>Terminalia/Shorea/Acacia</i>	5.13	0.91	-do-
<i>Acacia-Soymida</i>	5.58	0.84	-do-
<i>Acacia catechu</i>	5.22	0.76	-do-
<i>Lagerstroemia-Butea-Boswellia</i>	4.30	0.86	-do-
<i>Acacia-Lagerstroemia</i>	4.76	0.87	-do-
<i>Lagerstroemia parviflora</i>	3.46	0.48	-do-
<i>Lagerstroemia/ Diospyros</i>	3.67	0.36	-do-
<i>Lagerstroemia/Anogeissus</i>	2.34	0.43	-do-
<i>Lagerstroemia/ Diospyros</i>	2.62	0.75	-do-
<i>Lagerstroemia/ Diospyros</i>	2.62	0.64	-do-
<i>Lagerstroemia/ Acacia</i>	1.84	0.40	-do-

<i>Community</i>	Shannon-Weiner index (SW)	Simpson's index (S)	Reference(s)
<i>Lagerstroemia/Anogeissus</i>	2.95	0.12	-do-
<i>Boswellia serrata</i>	3.83	0.80	-do-
<i>Acacia/Anogeissus</i>	4.60	0.89	-do-
<i>Boswellia / Acacia</i>	5.37	0.82	-do-
<i>Acacia catechu</i>	3.19	0.19	-do-
<i>Acacia catechu</i>	3.48	0.65	-do-
Tropical Dry Deciduous Forest	2.39-3.62	0.12-1.0	-do-
Miscellaneous open canopy forest	2.995	0.068	Patra <i>et al.</i> 2005
Miscellaneous closed canopy forest	2.79	0.096	-do-
Sal open canopy forest	2.189	0.153	-do-
Sal closed canopy forest	2.048	0.216	-do-
Tropical semi-evergreen forest	0.109- 2.498	-	Devi & Yadava, 2006
Rajaji- Corbett National park (U.K.)	2.57	-	De, Aparajita, 2007
Chandoli National park	2.0	3.2	Kanade <i>et al.</i> 2008
Tropical evergreen forest	0.931-3.16	-	Khurana & Kalpana 2008

Singh (1998) reported the Shannon-wiener index values between 2.4 and 3.7, concentration of dominance from 0.18 to 0.75 and beta diversity was 3.1 for dry deciduous forests of Vindhyan region, India. Prasad and Pandey (1992) in sal and teak forests of Chattisgarh and Madhya Pradesh found species diversity varying from 0.32 to 3.76 and concentration of dominance from 0.07 to 0.63 at different distances from habitation in Bilaspur district of Chattisgarh and Mandla, Balaghat and Jabalpur districts of M.P., India. The forest within habitation having more open canopy recorded lower diversity and dominance compared to forests away from habitation. Sagar and Singh (2003) reported Shannon-wiener index between 1.398 to 2.629 for dry tropical forest located along the disturbance gradient.

The Shannon index values of dry tropical forests in different forests were comparatively lower than those reported by Singh *et al.* (1984) and Swamy (1998) for tropical forests of India. Singh *et al.* (1984) reported Shannon index value between 3.4 to 4.8 for tropical rain forests of Silent valley in Western Ghats, India. Similarly, Swamy (1998) reported 1.49 to 3.67 Shannon index values for tropical evergreen forests of Karnataka, India. It is also evident from the results that Shannon index values were higher than concentration of dominance in both the forest sites. These results are in agreement with earlier findings of Singh and Singh (1991), Swamy (1998), Patra *et al.*(2007), De (2001), Khande *et al.*(2008). The comparative account of diversity indices in various forest sites of Vindhyan region and other forest are presented in table 4.9.

4.3 Comparison of species composition and diversity pattern in open and closed canopy forest.

4.3.1 Comparison of species composition

4.3.1.1 Tree layer

The present study showed that higher number (18) of species of 14 families present in closed canopy forest as compared to open canopy forest sites (17) species of 13 families. Similarly the values for density and basal area (Table 4.10) were also higher ($1520 \text{ trees ha}^{-1}$), $50.35 \text{ m}^2 \text{ ha}^{-1}$, respectively) as compared to the open canopy forest sites ($700 \text{ trees ha}^{-1}$ and $47.78 \text{ m}^2 \text{ ha}^{-1}$, respectively).

Sapling layer

In the sapling layer closed canopy forest showed the 14 species of 13 families and in open forest sites there were 13 species grouped in 11 families. The density and basal area values were also higher ($590 \text{ saplings ha}^{-1}$, and $2.46 \text{ m}^2 \text{ ha}^{-1}$, respectively in closed canopy forest as compared to open canopy forest sites $490 \text{ sapling ha}^{-1}$ and $2.07 \text{ m}^2 \text{ ha}^{-1}$, respectively, Table 4.11).

4.3.1.3 Seedling layer

In contrast to tree and sapling layers higher number of seedling species (10) having higher density ($395 \text{ seedlings ha}^{-1}$) were presented in the open forest sites, where as the closed canopy forest comprise of only 9 species having $380 \text{ seedlings ha}^{-1}$. Similar pattern was also found for the basal area (Table 4.12).

4.3.1.4 Population Structure

Population structure shows the regeneration status of a forest ecosystem. Relative proportion of individual of tree species in different age classes has been depicted in figure 4.1. In both the open canopy forest sites the tree species exhibited lower proportion of seedling layer (22.9-26.9%). Sapling layer showed the greater proportion (30.4-31.4%) as compared to seedlings. The tree layer exhibited the highest proportion dominance (41.6-46.5%).

In the closed canopy forest site the trend was same as in open canopy forest sites but tree layer exhibited more than 60% proportion followed by saplings (about 24%) and seedlings (about 15%).

4.3.2 Comparison of diversity pattern

Result of different diversity parameters (Table 4.13) revealed that values for Shannon index, species richness and equitability in tree layer were higher for closed canopy forest as compared to open canopy forest sites and Simpson index and beta diversity showed the opposite trends. In sapling layer values for Shannon index, Simpson's index and species richness were higher in closed canopy forest as compared with the open canopy forest sites, but equitability and beta diversity values were higher in open canopy forest sites. The seedling layer showed the higher values of Shannon index, Simpson's index and beta diversity in closed canopy forest site where as species richness and equitability values were higher in open canopy forest ecosystems. In the open forest ecosystems the tree canopy was sparse and enough space was available and the

sun light easily penetrates the ground which favoured the higher number of seedling in these sites.

Patra *et al.*(2007) have compared the vegetational composition of open and closed canopy Sal and miscellaneous forests of Satpura Plateau where he has also reported the higher seedling diversity in open forest sites and stated that the openness of the forest stand invites the species for regeneration in an ecosystem. One of the measures of the well being and stability of any ecosystem is the estimation of its species diversity and richness. These values also indicate the nature of the forests of the region. Along with the composition of the forest, information on the diversity of the communities and of the landscape as a whole provides better insight into the state of the forests of an area.

It has also been observed that a change in the habitat variables such as nature of substrate can affect species diversity. Nature or anthropogenic disturbances can reduce low population densities of plant species even further and isolate populations of commonly found species by habitat destruction. Plant species diversity is also dependent on the regeneration potential of various species and the presence of competitors that may either inhibit or promote regeneration.

Rawat and Bhainsora (1999) have reported the Shannon and Wiener index for tree species was 1.84-2.46, 1.39 and 0.53 for Shewalik, Doon vally and outer Himalayas, respectively. De (2007) has reported the diversity values have reported the diversity values for Rajaji-Corbett National parks ranged from 0.87-3.89. The diversity values obtained in the present study were also comparable to the studies done in the Corbett National park by Singh *et.al.*,

(1995) where the values ranged from 1.79 to 3.64. The diversity values calculated from both the forest ecosystems (closed and open canopy forests) are comparable to those reported from studies done elsewhere.

The open forest sites are facing anthropogenic disturbances such as extraction of timber, fire wood and cattle grazing as compared to the closed forest site that's why the values of density, basal area and diversity patterns are different and in the lower range. In the open canopy forest sites the seedling populations are more as compared to the closed forest sites which need protection to become saplings and further in tree stage with the progress of time. Chronic disturbances do not provide time for ecosystem recovery and arrest the regeneration, therefore, these need to be minimized for the ecosystem health and maintaining the high biodiversity. The prevention of cattle grazing and restricted extraction of wood may help in the conservation and management of these forests not only for maintaining the biodiversity also to meet the basic needs of tribal population living around these forests. Thus management and conservation of overall biodiversity should be considered at ecosystem level.

CHAPTER-V

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

The “**Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests**” was carried out at Barnawapara wildlife Sanctuary (North Raipur Division) situated in North-Eastern corner of Raipur district which is located between 21⁰20’0” to 21⁰25’47” North latitudes and 82⁰21’17” to 82⁰26’27” East longitudes having an area of 244.66 km², during the year 2007-2008.

The species composition of open and closed canopy forest was conducted by randomly laying 10 quadrats of 10 x 10 m² in size. Randomly 10 sample plots were laid down in each forest site. In each quadrat, for tree species the individuals >31.5 cm G.B.H. were categorized as trees, <31.5 but >10 cm as saplings and <10 cm as seedlings. Within each quadrat sub-quadrats of 5×5 m and 2×2m were used to quantify the saplings and seedlings, respectively.

The structural analysis was done by determining primary variables (density, frequency and basal area). Subsequently secondary variables (relative frequency, relative density, relative basal area and IVI) were computed from primary data. The diversity parameters viz. Shannon index, Simpson’s index and beta diversity were also calculated for each forest site. The salient findings on Comparative study of species composition and diversity pattern in open and closed canopy Dry Deciduous Forests are summarized below:

- **Species composition**
- **Tree layers**

Open canopy forests

On average across the sites a total of 700 trees ha⁻¹ were encountered.

Site-1

- In site-1 *Terminalia alata* was the most dominant tree species followed by *Bridelia retusa* and *Lagerstroemia parviflora*.
- Highest density was recorded in *Terminalia alata* (370 stems ha⁻¹) followed by, *Lagerstroemia parviflora* (80 stems ha⁻¹) and *Buchanania lanzan* (60 stems ha⁻¹).
- Highest basal area was observed in *Terminalia alata* (44m² ha⁻¹) followed by, *Bridelia retusa* (1.605 m² ha⁻¹), *Lagerstroemia parviflora* (1.128 m² ha⁻¹) and *Buchanania lanzan* (0.72 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.013 m² ha⁻¹ to 44.03 m² ha⁻¹ and 10 to 370 stems ha⁻¹, respectively.
- *Terminalia alata* showed highest value of IVI (185.14) followed by *Bridelia retusa* (25.83) and *Lagerstroemia parviflora* (25.75).
- The total basal area and density of site-1 was recorded 650 stems ha⁻¹ 48.28 m² ha⁻¹.

Site-2

- *Terminalia alata* was the most dominant tree species followed by *Cleistanthus collinus* and *Butea monosprema*.

- Highest density was recorded in *Terminalia alata* (200 stems ha⁻¹) followed by *Cleistanthus collinus* (150 stems ha⁻¹) and *Butea monosprema* (70 stems ha⁻¹).
- Highest value for basal area was observed in *Terminalia alata* (32.62 m² ha⁻¹) followed by *Cleistanthus collinus* (5.805 m² ha⁻¹) and *Butea monosprema* (2.793 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.021 m² ha⁻¹ to 32.62 m² ha⁻¹ and 10 to 200 stems ha⁻¹, respectively.
- *Terminalia alata* showed highest value of IVI (98.45) followed by *Cleistanthus collinus* (43.39), and *Butea monosprema* (29.13).
- The total density and basal area of site-2 recorded 750 stems ha⁻¹ and 47.269 m² ha⁻¹, respectively.
- Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and only few species showed regular distribution.

Closed canopy forest

- *Bridelia retusa* was the most dominant tree layer followed by *Diospyros melanoxylon*, *Shorea robusta* and *Lagerstroemia parviflora*.
- Highest density was represented by *Bridelia retusa* (270 stems ha⁻¹) followed by *Cassia fistula* (240 stems ha⁻¹), *Diospyros melanoxylon* (200 stems ha⁻¹) and *Lagerstroemia parviflora* (150 stems ha⁻¹).
- Highest value for basal area was observed in *Diospyros melanoxylon* (11.28 m² ha⁻¹) followed by *Bridelia retusa* (11.043 m² ha⁻¹) and *Shorea robusta* (10.064 m² ha⁻¹).

- Basal area and density of individual tree species varied from 0.005 m² ha⁻¹ to 11.28 m² ha⁻¹ and 20 to 270 stems ha⁻¹, respectively.
- *Bridelia retusa* showed highest value of IVI (51.38) followed by *Diospyros melanoxylon* (45.95), and *Shorea robusta* (34.98)).
- The total density and basal area of this site was recorded 1520 stems ha⁻¹ and 50.351 m² ha⁻¹.
- Abundance to frequency ratio indicated that most of the species were distributed randomly followed by contagious distribution pattern.

Sapling layer

Open canopy forests

On average across the two sites a total of 450 saplings were recorded.

Site-1

- *Terminalia alata* was the most dominant tree species followed by *Cleistanthus collinus* and *Lagerstroemia parviflora* and *Diospyros melanoxylon*.
- Highest density was recorded in *Terminalia alata* (140 stems ha⁻¹) followed by *Cleistanthus collinus* (110 stems ha⁻¹) and *Lagerstroemia parviflora* (90 stems ha⁻¹)
- Highest basal area was observed in *Terminalia alata* (1.0178351 m² ha⁻¹) followed by *Cleistanthus collinus* (0.5874351 m² ha⁻¹), *Lagerstroemia parviflora* (0.4176351 m² ha⁻¹) and *Diospyros melanoxylon* (0.2520351 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.0058 m² ha⁻¹ to 1.017 m² ha⁻¹ and 10 to 140 stems ha⁻¹, respectively.

- *Terminalia alata* (90.60) showed highest value of IVI followed by *Cleistanthus collinus* (62.54), and *Lagerstroemia parviflora* (55.16).
- The total density and basal area of site-1 was recorded 490 stems ha⁻¹ and 2.3779 m² ha⁻¹.
- Abundance to frequency ratio indicated that most of the species showed random and few species showed the contagious distribution and none of the species were regularly distributed.

Site -2

- *Cleistanthus collinus* was the most dominant sapling layer followed by *Bridelia retusa* and *Lagerstroemia parviflora* and *Grewia tiliaefolia*.
- Highest density was recorded for *Cleistanthus collinus* (100 stems ha⁻¹) followed by *Bridelia retusa* (80 stems ha⁻¹), *Lagerstroemia parviflora* (70 stems ha⁻¹)
- Highest value for basal area was observed in *Cleistanthus collinus* (0.532 m² ha⁻¹) followed by *Bridelia retusa* (0.352 m² ha⁻¹) and *Grewia tiliaefolia* (0.274 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.0062 m² ha⁻¹ to 0.532 m² ha⁻¹ and 10 to 100 stems ha⁻¹, respectively.
- *Cleistanthus collinus* showed highest value of IVI (67.72) followed by *Bridelia retusa* (53.46) and *Lagerstroemia parviflora* (43.75).
- The total density and basal area of open forest was recorded 490 stems ha⁻¹ and 1.769 m² ha⁻¹.

- Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and only few species showed regular distribution.

Closed canopy forest

- *Cleistanthus collinus* was the most dominant sapling layer followed by *Lagerstroemia parviflora* and *Terminalia alata*.
- Highest density was recorded in *Cleistanthus collinus* (140 stems ha⁻¹) followed by *Lagerstroemia parviflora* (90 stems ha⁻¹) and *Terminalia alata*. (40 stems ha⁻¹)
- Highest value for basal area was observed in *Cleistanthus collinus* (1.1438 m² ha⁻¹) followed by *Lagerstroemia parviflora* (0.4104 m² ha⁻¹) and *Terminalia alata* (0.364 m² ha⁻¹).
- Basal area and density of individual sapling varied from 0.0045 m² ha⁻¹ to 1.1434 m² ha⁻¹ and 10 to 140 stems ha⁻¹, respectively.
- *Cleistanthus collinus* showed highest value of IVI (88.22) followed by *Lagerstroemia parviflora* (42.21) and *Terminalia alata* (41.19).
- The total density and basal area of closed forest site was recorded 590 stems ha⁻¹ and 2.4576 m² ha⁻¹.
- Abundance to frequency ratio indicated that most of the species showed contagious and random distribution and few species showed the regular distribution at this site.

Seedling layer

Open canopy forest

On average across the sites about 395 seedlings were encountered in open forest sites.

Site -1

- *Lagerstroemia parviflora* was the most dominant seedling layer followed by *Diospyros melanoxylon* and *Terminalia alata*.
- Highest density was recorded in *Terminalia alata* (140 seedlings ha⁻¹) followed by *Diospyros melanoxylon* (100 seedlings ha⁻¹) and *Lagerstroemia parviflora* (60 seedlings ha⁻¹).
- Highest basal area was observed in *Lagerstroemia parviflora* (0.06155), *Diospyros melanoxylon* (0.032) and *Terminalia alata* (0.00136).
- Basal area and density of individual seedlings species varied from 0.000202 m² ha⁻¹ to 0.0000057 m² ha⁻¹ and 10 to 140 seedling ha⁻¹, respectively.
- *Lagerstroemia parviflora* showed highest value of IVI (94.85) followed by *Diospyros melanoxylon* (84.81) and *Terminalia alata* (68.08).
- The total density and basal area of seedlings was recorded 420 seedling ha⁻¹ and 0.09632 m² ha⁻¹ respectively.
- Abundance to frequency ratio indicated that most of the species showed random and contagious distribution and regular distribution was not shown by any species in this forest site.

Site -2

- *Diospyros melanoxylon* was the most dominant seedling layer followed by *Holarrhena pubescens* and *Emblica officinalis*.
- Highest density was recorded in *Diospyros melanoxylon* (210 seedling ha⁻¹) followed by *Holarrhena pubescens* (60 seedling ha⁻¹).
- Highest basal area was observed in *Holarrhena pubescens* (0.0129 m² ha⁻¹) followed by *Diospyros melanoxylon* (0.0124 m² ha⁻¹).
- Basal area and density of individual seedling species varied from 0.0024 m² ha⁻¹ to 0.0129 m² ha⁻¹ and 10 to 210 seedling ha⁻¹, respectively.
- *Diospyros melanoxylon* showed highest value of IVI (153.27) *Holarrhena pubescens* (83.06), *Emblica officinalis* (21.53).
- The density and basal area of this site was recorded 370 seedlings ha⁻¹ and 0.0268 m² ha⁻¹.
- Abundance to frequency ratio indicated that most of the species showed contagious distribution and few species showed random distribution pattern.

Closed canopy forest

- *Shorea robusta* was the most dominant tree species followed by *Diospyros melanoxylon* and *Cassia fistula*.
- Highest density was recorded in *Diospyros melanoxylon* (110 seedlings ha⁻¹) followed by *Bridelia retusa* (40 seedlings ha⁻¹) and *Schleichera oleosa* (40 seedlings ha⁻¹).
- Highest basal area was observed in *Shorea robusta* (0.00679 m² ha⁻¹) followed by *Bridelia retusa* (0.000792 m² ha⁻¹).

- Basal area and density of individual tree species varied from $0.0000314\text{m}^2\text{ha}^{-1}$ to $0.00697\text{ m}^2\text{ ha}^{-1}$ and 20 to 110 seedling ha^{-1} , respectively.
- *Shorea robusta* showed highest value of IVI (91.90) followed by *Diospyros melanoxylon* (58.59), and *Cassia fistula* (29.29).
- The total density and basal area of closed forest site was recorded 380 seedlings ha^{-1} and $0.00915\text{ m}^2\text{ ha}^{-1}$.
- Abundance to frequency ratio indicated that most of the species showed contagious distribution and only few species were randomly distributed.

Diversity pattern of open verses closed canopy forest

Shannon index (H')

- The Shannon index values for tree layer of open canopy forest sites were 0.63 (site-1) and 1.68 (site-2) and 2.20 for closed canopy forest (2.20).
- These values for sapling layer were 2.075 (site-1) and 2.63 (site-2) for open canopy forest sites and 2.38 for closed canopy forest site.
- Seedling layer showed the value for Shannon index as 1.128 (site-1) and 1.35 (site-2) for open canopy forests and 1.46 for closed canopy forest.

Simpson's index

- The Simpson's index values for tree layer in open canopy forest sites were 0.08 (site-1) and 0.05 (site-2) and 0.16 in closed canopy forest.
- The Simpson's index values for sapling layer in open canopy forest sites were 0.29 (site-1) and 0.19 (site-2) and 0.28 in closed canopy forest.

- The Simpson index values for seeding layer in open canopy forest sites were 0.28 (site-1) and 0.45 (site-2) and 0.57 in closed canopy forest.

Equitability (e)

- Equitability (e) values for tree layer were 0.27 (site-1) to 0.60 (site-1) in open canopy forest and 0.76 for closed canopy forest.
- For sapling layer the equitability values ranged from 0.99 (site-1) to 1.99 (site-2) for open canopy forest and 0.90 for closed canopy forest sites.
- Seedling layer showed the values of equitability as 0.58 (site-1) to 0.75 (site-2) for open canopy forest sites and 0.66 for closed canopy forest.

Species richness (d)

- In the tree layer the species richness was highest in closed canopy forest (4.34) followed by open canopy forest (3.89 for site-2 and 2.23 for site-1).
- In sapling layer these values showed the similar trend (14.46 for closed canopy forest and 8.08-17.53 for open canopy forest sites).
- Seedling layer showed the different trend (Table 4.8) from that of tree and sapling layer where closed forest site showed the minimum value (1.71) than that of open canopy forest sites (1.38-2.56).

Beta diversity

- Beta diversity was highest in tree layer of open canopy forest site-1 (8.15) and site-2 (4.89) followed by closed canopy forest (2.86).
- For sapling layer the open forest sites showed the value of 6.1 (site-1) and 5.52 (site-2) followed by closed canopy forest (4.10).

- Whereas the beta diversity values (8.67) for seedlings were more in closed canopy forest site and less for open canopy forest sites (7.65 for site -1 and 8.12 for site-2).

Comparison of species composition and diversity pattern in open and closed canopy forest.

Comparison of species composition

Tree layer

- The present study showed that higher number (18) of species of 14 families were present in closed canopy forest as compared to open canopy forest sites (17) species of 13 families.
- Similarly the values for density and basal area were also higher (1520 trees ha⁻¹), 50.35m²ha⁻¹, respectively) as compared to the open canopy forest sites (700 trees ha⁻¹ and 47.78 m²ha⁻¹, respectively).

Sapling layer

- In the sapling layer closed canopy forest showed the 14 species of 13 families and in open forest sites there were 13 species grouped in 11 families.
- The density and basal area values were also higher (590 sapling ha⁻¹, and 2.46 m²ha⁻¹, respectively in closed canopy forest as compared to open canopy forest sites 490 sapling ha⁻¹ and 2.07 m² ha⁻¹, respectively).

Seedling layer

- In contrast to tree and sapling layers higher number of seedling species (10) having higher density (395 seedling ha⁻¹) were presented in the open forest sites, where as the closed canopy forest comprise of only 9 species having 380 seedlings ha⁻¹

Population Structure

- In both the open canopy forest sites the tree species exhibited lower proportion of seedling layer (22.9-26.9%). Sapling layer showed the greater proportion (30.4-31.4%) as compared to seedlings. The tree layer exhibited the highest proportion dominance (41.6-46.5%). In the closed forest sites the trend was same but tree layer exhibited greater proportion (60%) followed by saplings (24%) and seedling (about 15%).

Comparison of diversity pattern

- Shannon index, species richness and equitability in tree layer were higher for closed canopy forest as compared to open canopy forest sites and Simpson's index and beta diversity showed the opposite trends.
- . In sapling layer values for Shannon index, Simpson's index and species richness were higher in closed canopy forest as compared to open canopy forest sites, but equitability and beta diversity values were higher in open canopy forest sites.
- The seedling layer showed the higher values of Shannon index, Simpson's index and beta diversity in closed canopy forest site where as species richness and equitability values were higher in open canopy forest ecosystems.

CONCLUSION

- The present study showed that higher number (18) of species of 14 families was present in closed canopy forest as compared to open canopy forest sites (17) species of 13 families.
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The open forest sites are facing anthropogenic disturbances such as extraction of timber, fire wood and cattle grazing as compared to the closed forest site that's why the values of densities, basal area and diversity patterns are different and in the lower range. In the open canopy forest sites the seedling populations are more as compared to the closed forest sites which need protection to become saplings and further in tree stage with the progress of time. Chronic disturbances do not provide time for ecosystem recovery and arrest the regeneration, therefore, these need to be minimized for the ecosystem health and maintaining the high biodiversity. The prevention of cattle grazing and restricted extraction of wood may help in the conservation and management of these forests not only for maintaining the biodiversity also to meet the basic needs of tribal population living around these forests. Thus management and conservation of overall biodiversity should be considered at ecosystem level.

SUGGESTIONS FOR FUTURE WORK

In the present study the conversion rate of seedlings into sapling and trees is less in open canopy forest sites as compared to closed canopy forest. It shows that these sites are facing some stress. In Indian conditions where the forest cover is below 21% and much of it is under the anthropogenic pressure/ stress. In such conditions, a strategy is required to conserve what ever remains and restore areas where it is possible, rather than spending time and resources on selecting new biodiversity rich areas. A detailed study on biodiversity of shrub and herb layer as well as anthropogenic pressure/ stress on these forest areas are also needed at ecosystem level.

**“COMPARATIVE STUDY OF TREE SPECIES COMPOSITION
AND DIVERSITY PATTERN IN OPEN AND CLOSED
CANOPY DRY DECIDUOUS FORESTS”**

by

VED PRAKASH PANDEY

ABSTRACT

In the present study an attempt was made to investigate the “Comparative study of tree species composition and diversity pattern in open and closed canopy Dry Deciduous Forests” during the year 2007–2008. The study sites were located in Barnawapara wildlife sanctuary (North Raipur Forest Division). The study was conducted in two sites of open canopy forest and one site in closed canopy forest of dry deciduous forest. The variation in composition, structure and diversity in open and closed canopy forest were quantified.

The present study in tree layers showed that higher number (18) of species of 14 families were present in closed canopy forest as compared to open canopy forest sites (17 species of 13 families). Similarly the values for density and basal area were also higher (1520 trees ha⁻¹, 50.35 m²ha⁻¹, respectively) as compared to the open canopy forest sites (700 trees ha⁻¹ and 47.78 m²ha⁻¹, respectively). In the sapling layer closed canopy forest showed the 14 species of 13 families and in open forest sites there were 13 species grouped in 11 families. The density and basal area values were also higher (590 sapling ha⁻¹, and 2.46 m²ha⁻¹, respectively) in closed canopy forest as compared to open canopy forest sites (490 sapling ha⁻¹ and 2.07 m² ha⁻¹, respectively). In contrast to tree and sapling layers higher number of seedling species (10) having higher density (395 seedling ha⁻¹) were present in the open forest sites, where as the closed canopy forest comprised of only 9 species having 380 seedlings ha⁻¹. In both the open canopy forest sites the tree species exhibited lower proportion of seedling layer (22.9-26.9%). Sapling layer showed the greater proportion (30.4-31.4%) as compared to seedlings. The tree layer exhibited the highest proportion (41.6-46.5%). In the closed forest sites the trend was same but tree

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The open forest sites are facing anthropogenic disturbances such as extraction of timber, fire wood and cattle grazing as compared to the closed forest site that's why the values of densities, basal area and diversity patterns are different and in the lower range. In the open canopy forest sites the seedling populations are more as compared to the closed forest sites which need protection to become saplings and further in tree stage with the progress of time. Chronic disturbances do not provide time for ecosystem recovery and arrest the regeneration, therefore, these need to be minimized for the ecosystem health and maintaining the high biodiversity. The prevention of cattle grazing and restricted extraction of wood may help in the conservation and management of these forests not only for maintaining the biodiversity also to meet the basic needs of tribal population living around these forests. Thus management and conservation of overall biodiversity should be considered at ecosystem level.

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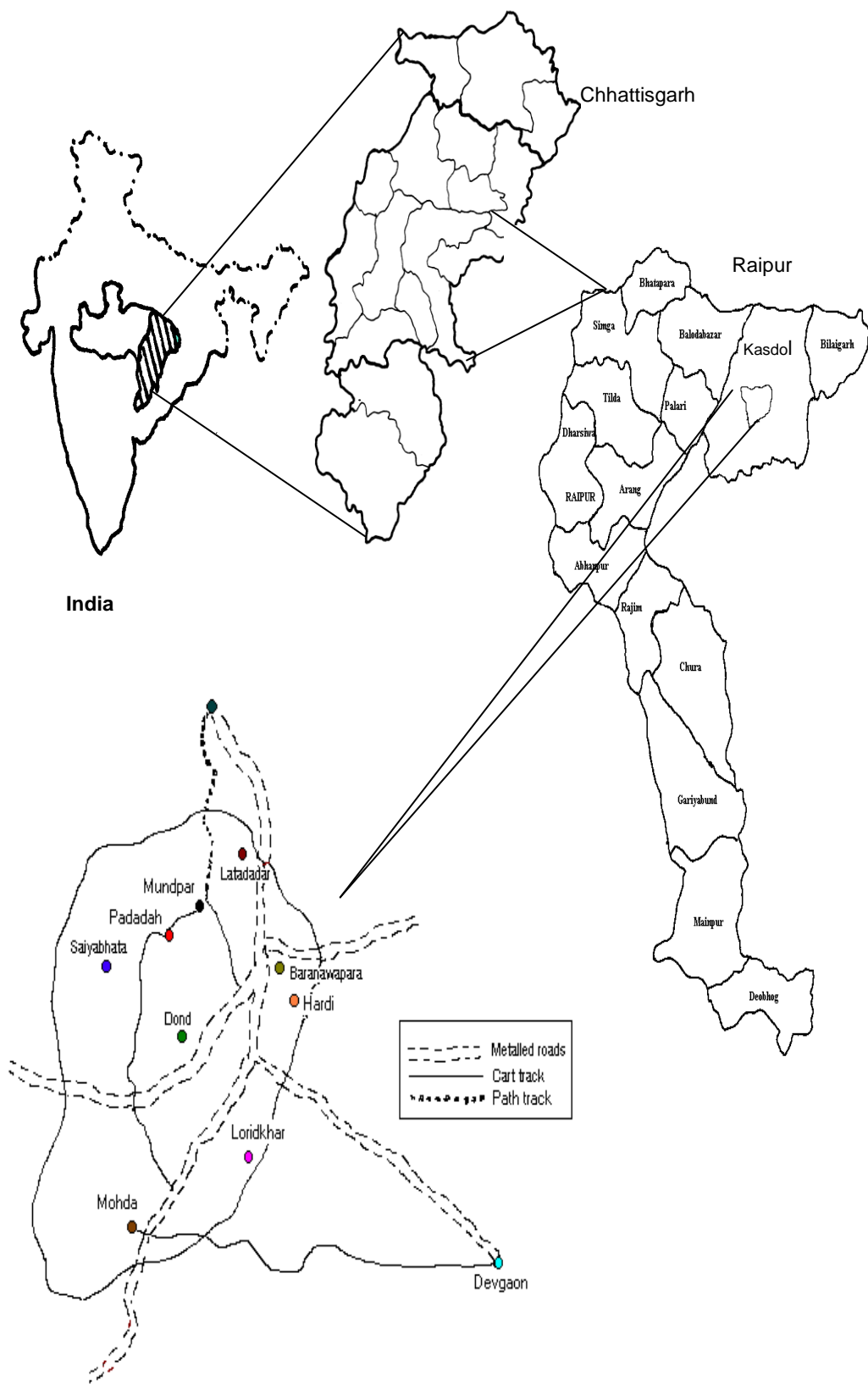


Fig. 3.1: Location map of Barnawapara Wildlife Sanctuary

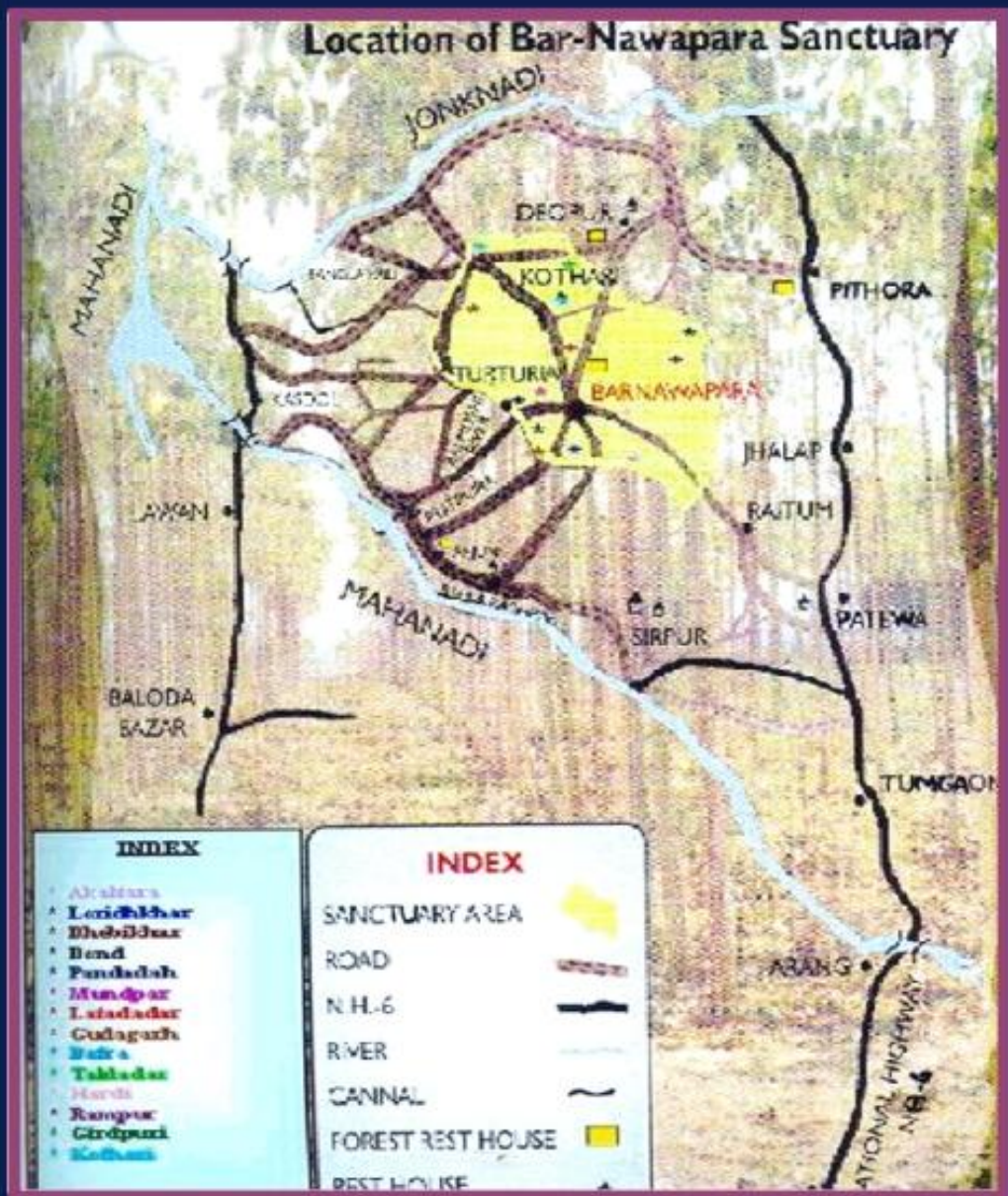


Fig. 3.2 : Area and Linkages of Barnawapara Wildlife Sanctuary

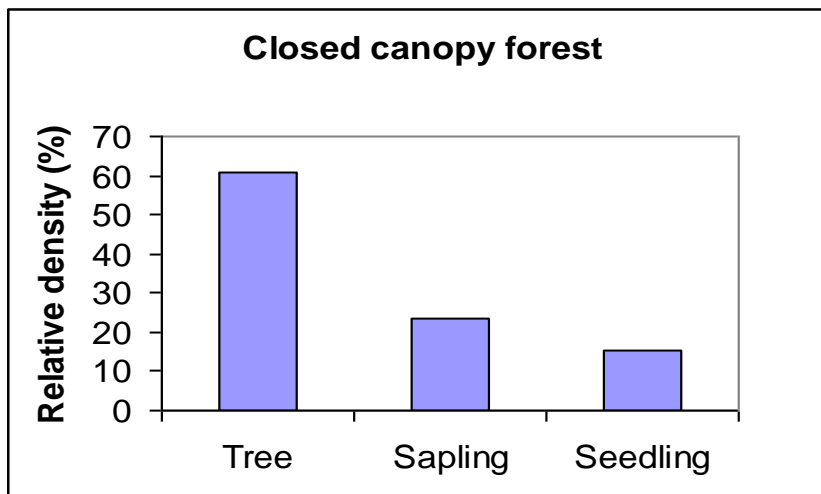
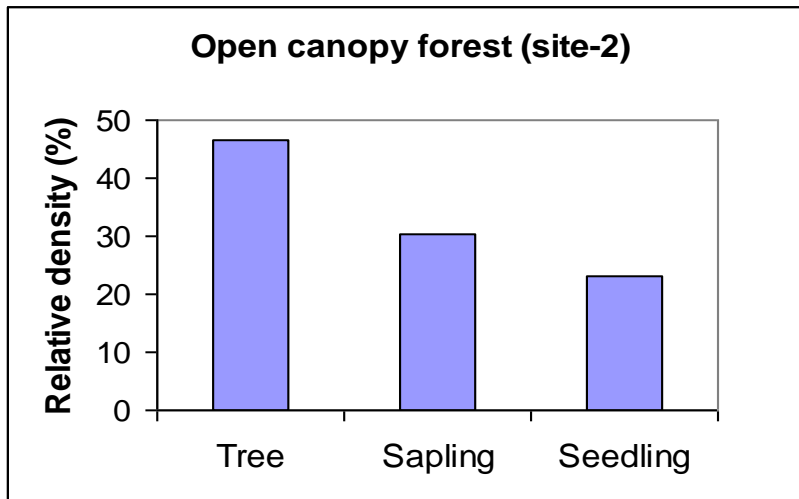
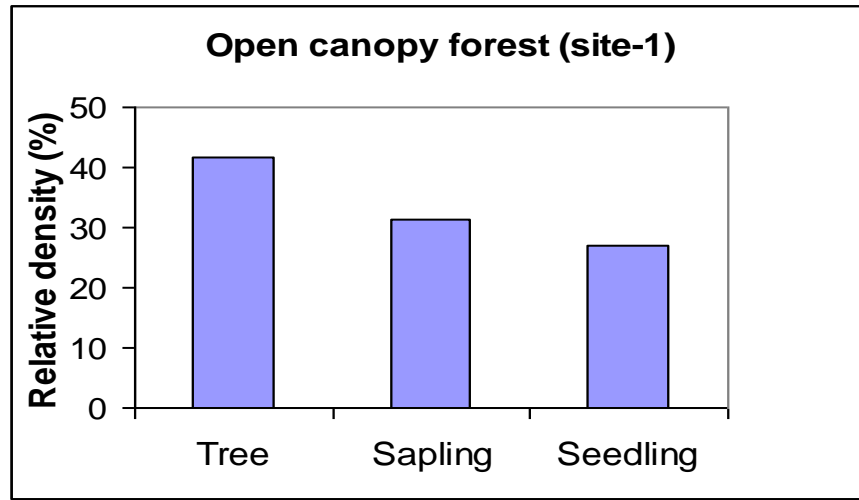


Figure 4.1 : Population structures of open canopy forests and closed canopy forest

Table 4.1 Species composition of tree layer in open canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Open canopy forests									
	Site-1					Site-2				
	F %	D St/ha	BA m2 /ha	IVI	A/F	F %	D St/ha	BA m2/ha	IVI	A/F
<i>Lagerstroemia parviflora</i> Roxb.	30	80	1.128	25.27	0.09	40	60	1.02	21.27	0.03
<i>Terminalia alata</i> Roth.	100	370	44.03	185.14	0.04	10	200	32.62	98.45	0.02
<i>Buchanania lanzan</i> Spreng.	30	60	0.72	21.83	0.07	20	20	0.064	8.36	0.05
<i>Bridelia retusa</i> (L) Spreng.	40	50	1.605	25.83	0.03	50	60	1.86	25.82	0.02
<i>Butea monosprema</i> Lam.	20	20	0.208	10.92	0.05	50	70	2.793	29.13	0.028
<i>Mitragyna parviflora</i> Roxb.	10	10	0.056	5.36	0.10	10	10	0.073	4.27	0.100
<i>Diospyros melanoxylon</i> Roxb.	10	20	0.424	7.66	0.20	10	10	0.024	4.16	0.100
<i>Emblica officinalis</i> Gaertn.	10	20	0.086	6.96	0.20	10	10	0.021	4.16	0.100
<i>Cassia fistula</i> L.	10	10	0.013	5.27	0.10					
<i>Grewia tiliaefolia</i> Vahl.	10	10	0.017	5.28	0.10	20	30	0.216	10.01	0.075
<i>Antidesma bunius</i>						20	20	0.106	8.45	0.05
<i>Tectona grandis</i> L.F.						10	20	0.062	5.58	0.200
<i>Madhuca indica</i> J.Gmel.						30	50	1.74	18.68	0.055
<i>Cleistanthus collinus</i> (Roxb)						40	150	5.805	43.39	0.092
<i>Anogeissus latifolia</i> (DC)Wall.Ex Bedd.						10	10	0.061	4.24	0.100
<i>Schleichera oleosa</i> (Lour)						10	10	0.04	4.20	0.100
<i>Ougeinia oojeinensis</i> (Roxb.)Hochreat.						20	20	0.764	9.89	0.050
Total	270	650	48.287	299.52		360	750	47.269	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.2 Species composition of trees layer in closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Closed canopy forest				
	F %	D St/ha	BA m ² /ha	IVI	A/F
<i>Lagerstroemia parviflora</i>	60	150	5.805	29.19	0.04
<i>Terminalia alata</i>	30	80	1.129	11.40	0.08
<i>Buchanania lanzan</i>	50	70	0.544	12.18	0.028
<i>Bridelia retusa</i>	90	270	11.043	51.38	0.03
<i>Butea monosprema</i>	40	50	0.007	8.50	0.03
<i>Mitragyna parviflora</i>	10	20	0.018	2.00	0.200
<i>Diospyros melanoxylon</i>	80	200	11.28	45.95	0.03
<i>Emblica officinalis</i>	10	30	0.005	3.28	0.3
<i>Cassia fistula</i>	30	240	0.06	6.65	0.04
<i>Antidesma bunius</i>	50	90	1.053	14.51	0.036
<i>Madhuca indica</i>	50	90	4.011	20.38	0.036
<i>Cleistanthus Collinus</i>	50	70	2.794	16.65	0.028
<i>Schleichera Oleosa</i>	30	30	0.168	6.20	0.03
<i>Bauhinia variegata</i> L.	10	20	0.066	2.75	0.2
<i>Shorea robusta</i> Gaertn F.	60	110	10.064	34.98	0.03
<i>Semecarpus anacardium</i> L.F.	50	80	0.688	13.12	0.03
<i>Holarrhena pubescence</i> Buch	40	80	0.57	11.59	0.05
<i>Chloroxylon swietenia</i> D.C.	30	40	1.064	8.64	0.04
Total	770	1520	50.351	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.3 Species composition of sapling layer in open canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Open canopy forests									
	Site-1					Site-2				
	F %	D St/ha	BA m2 /ha	IVI	A/F	F %	D St/ha	BA m2/ha	IVI	A/F
<i>Terminalia alata</i>	50	140	1.0178	90.60	0.05	10	20	0.0256	28.75	0.20
<i>Cleistanthus collinus</i>	40	110	0.5874	62.54	0.06	50	100	0.532	67.72	0.04
<i>Antidesma bunius</i>						20	30	0.0558	16.17	0.07
<i>Lagerstroemia parviflora</i>	50	90	0.4176	55.16	0.03	40	70	0.2772	43.75	0.04
<i>Holarrhena pubescence</i>						30	60	0.195	33.61	0.06
<i>Diospyros melanoxylon</i>	40	70	0.2520	40.27	0.04					
<i>Mitragyna parviflora</i>						10	20	0.024	8.89	0.20
<i>Buchanania lanzan</i>	10	10	0.0058	6.13	0.10	10	10	0.0062	5.84	0.10
<i>Schleichera oleosa</i>						10	10	0.0066	5.86	0.10
<i>Cassia fistula</i>	20	20	0.0206	12.64	0.05					
<i>Butea monosprema</i>	20	20	0.0248	12.82	0.05	20	20	0.0204	12.13	0.05
<i>Grewia tiliaefolia</i>	30	30	0.0519	19.84	0.03	40	70	0.2744	43.59	0.04
<i>Bridelia retusa</i>						50	80	0.352	53.46	0.03
Total	260	490	2.3779	300		290	490	1.7692	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.4 Species composition of sapling layer in closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Closed canopy forest				
	F	D	BA	IVI	A/F
	%	St/ha	m ² /ha		
<i>Terminalia alata</i>	50	80	0.364	41.19	0.032
<i>Cleistanthus collinus</i>	70	140	1.1438	88.22	0.029
<i>Antidesma bunius</i>	10	20	0.0248	6.96	0.200
<i>Lagerstroemia parviflora</i>	40	90	0.4104	42.21	0.056
<i>Madhuca indica</i>	30	50	0.113	20.76	0.056
<i>Holarrhena pubescence</i>	10	10	0.0058	4.50	0.100
<i>Diospyros melanoxylon</i>	50	60	0.1806	30.34	0.024
<i>Mitragyna parviflora</i>	10	10	0.0045	4.44	0.100
<i>Buchanania lanzan</i>	10	10	0.0066	4.53	0.100
<i>Schleichera oleosa</i>	30	30	0.0468	14.68	0.033
<i>Shorea robusta</i>	40	50	0.124	23.78	0.031
<i>Chloroxylon swietenia</i> D.C.	20	20	0.023	9.45	0.050
<i>Cassia fistula</i>	10	10	0.0045	4.44	0.100
<i>Grewia tiliaefolia</i>	10	10	0.0058	4.50	0.100
Total	390	590	2.4576	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.5 Species composition of seedling layer in open canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Open canopy forests									
	Site-1					Site-2				
	F %	D St/ha	BA M2 /ha	IVI	A/F	F %	D St/ha	BA m2/ha	IVI	A/F
<i>Diospyros melanoxylon</i>	50	100	0.032	84.81	0.04	80	210	0.012474	153.27	.0.033
<i>Lagerstroemia parviflora</i>	30	60	0.06155	94.85	0.06					
<i>Terminalia alata</i> Roth.	60	140	0.00136	68.08	0.03					
<i>Chloroxylon swietenia</i>	10	30	0.0002019	12.91	0.30					
<i>Bridelia retusa</i>	10	60	0.0000492	19.89	0.60					
<i>Butea monosprema</i>	10	10	0.0000057	7.94	0.10	10	30	0.000564	16.46	0.300
<i>Emblica officinalis</i>	10	20	0.001158	11.52	0.20	20	30	0.000246	21.53	0.075
<i>Holarrhena pubescence</i>						30	60	0.0129	83.06	0.067
<i>Schleichera oleosa</i>						10	30	0.000393	15.82	0.300
<i>Cassia fistula</i>						10	10	0.00024	9.85	0.100
Total	170	420	0.09632	300		160	370	0.026817	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.6 Species composition of seedling layer in closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Closed canopy forest				
	F	D	BA	IVI	A/F
	%	St/ha	m ² /ha		
<i>Diospyros melanoxylon</i>	40	110	0.000278	58.59	0.069
<i>Lagerstroemia parviflora</i>	20	30	0.000129	22.61	0.075
<i>Terminalia alata</i>	10	30	0.000266	17.41	0.300
<i>Bridelia retusa</i>	10	40	0.000792	25.68	0.400
<i>Emblica officinalis</i>	20	30	0.000462	21.72	0.075
<i>Schleichera oleosa</i>	10	40	0.0003161	20.58	0.400
<i>Cassia fistula</i>	20	40	0.0005062	29.29	0.100
<i>Madhuca indica</i>	10	20	0.0000314	12.27	0.200
<i>Shorea robusta</i>	10	40	0.00679	91.90	0.400
Total	150	380	0.00915	300	

*F = Frequency, D = Density, BA = Basal area, IVI = Importance value index, A/F=Abundance/Frequency

Table 4.8 Diversity patterns of trees, sampling and seedling layers of open and closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Site	Different layers	Shannon Index(H')	Simpson's Index(CD)	Species richness(d)	Equitability(e)	Beta Diversity (bd)
Open canopy	1	2	3	4	5	6
Site -1	Tree Layer	0.63	0.83	2.32	0.27	8.15
	Sapling layer	2.075	0.29	8.08	0.99	6.1
	Seeding layer	1.128	0.28	2.56	0.58	7.65
Site-2	Tree Layer	1.68	0.5	3.89	0.60	4.89
	Sapling layer	2.63	0.19	17.53	1.09	5.52
	Seeding layer	1.35	0.45	1.38	0.75	8.12
Closed canopy						
Site-3	Tree Layer	2.20	0.16	4.34	0.76	2.86
	Sapling layer	2.38	0.28	14.46	0.9	4.1
	Seeding layer	1.46	0.57	1.71	0.66	8.67

Table 4.10 Species composition of trees layer open and closed canopy Dry Deciduous Forests at Barnawapara Wildlife Sanctuary

Species	Open canopy forests								Closed canopy forest			
	Site-1				Site-2							
	F	D	BA	IVI	F	D	BA	IVI	F	D	BA	IVI
%	St/ha	m2 /ha		%	St/ha	m2/ha		%	St/ha	m2/ha		
<i>Lagerstroemia parviflora</i>	30	80	1.128	25.27	40	60	1.02	21.27	60	150	5.805	29.19
<i>Terminalia alata</i>	100	370	44.03	185.14	10	200	32.62	98.45	30	80	1.129	11.40
<i>Buchanania lanzan</i>	30	60	0.72	21.83	20	20	0.064	8.36	50	70	0.544	12.18
<i>Bridelia retusa</i>	40	50	1.605	25.83	50	60	1.86	25.82	90	270	11.043	51.38
<i>Butea monosprema</i>	20	20	0.208	10.92	50	70	2.793	29.13	40	50	0.007	8.50
<i>Mitragyna parviflora</i>	10	10	0.056	5.36	10	10	0.073	4.27	10	20	0.018	2.00
<i>Diospyros melanoxylon</i>	10	20	0.424	7.66	10	10	0.024	4.16	80	200	11.28	45.95
<i>Emblica officinalis</i>	10	20	0.086	6.96	10	10	0.021	4.16	10	30	0.005	3.28
<i>Cassia fistula</i>	10	10	0.013	5.27					30	240	0.06	6.65
<i>Grewia tiliaefolia</i>	10	10	0.017	5.28	20	30	0.216	10.01				
<i>Antidesma bunius</i>					20	20	0.106	8.45	50	90	1.053	14.51
<i>Tectona grandis</i>					10	20	0.062	5.58				
<i>Madhuca indica</i>					30	50	1.74	18.68	50	90	4.011	20.38
<i>Cleistanthus collinus</i>					40	150	5.805	43.39	50	70	2.794	16.65
<i>Anogeissus latifolia</i>					10	10	0.061	4.24				
<i>Schleichera oleosa</i>					10	10	0.04	4.20	30	30	0.168	6.20
<i>Ougeinia oojeinensis</i>					20	20	0.764	9.89				
<i>Bauhinia variegata</i>									10	20	0.066	2.75
<i>Shorea robusta</i>									60	110	10.064	34.98
<i>Semecarpus anacardium</i>									50	80	0.688	13.12
<i>Holarrhena pubescence</i>									40	80	0.57	11.59
<i>Chloroxylon swietenia</i>									30	40	1.064	8.64
Total	270	650	48.287	299.52	360	750	47.269	300	770	1520	50.351	300

*F = Frequency, D = Density, BA= Basal area, IVI = Importance value index

Table4.11 Species composition of sapling layer open and closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Open canopy forests								Closed canopy forest			
	Site-1				Site-2							
	F	D	BA	IVI	F	D	BA	IVI	F	D	BA	IVI
	%	St/ha	m2 /ha		%	St/ha	M2/ha		%	St/ha	m2/ha	
<i>Terminalia alata</i>	50	140	1.0178	90.60	10	20	0.0256	28.75	50	80	0.364	41.19
<i>Cleistanthus collinus</i>	40	110	0.5874	62.54	50	100	0.532	67.72	70	140	1.1438	88.22
<i>Antidesma bunius</i>					20	30	0.0558	16.17	10	20	0.0248	6.96
<i>Lagerstroemia parviflora</i>	50	90	0.4176	55.16	40	70	0.2772	43.75	40	90	0.4104	42.21
<i>Madhuca indica</i>									30	50	0.113	20.76
<i>Holarrhena pubescence</i>					30	60	0.195	33.61	10	10	0.0058	4.50
<i>Diospyros melanoxylon</i>	40	70	0.2520	40.27					50	60	0.1806	30.34
<i>Mitragyna parviflora</i>					10	20	0.024	8.89	10	10	0.0045	4.44
<i>Buchanania lanzan</i>	10	10	0.0058	6.13	10	10	0.0062	5.84	10	10	0.0066	4.53
<i>Schleichera oleosa</i>					10	10	0.0066	5.86	30	30	0.0468	14.68
<i>Shorea robusta</i>									40	50	0.124	23.78
<i>Chloroxylon swietenia</i>									20	20	0.023	9.45
<i>Cassia fistula</i>	20	20	0.0206	12.64					10	10	0.0045	4.44
<i>Butea monosprema</i>	20	20	0.0248	12.82	20	20	0.0204	12.13				
<i>Grewia tiliaefolia</i>	30	30	0.0519	19.84	40	70	0.2744	43.59	10	10	0.0058	4.50
<i>Bridelia retusa</i>					50	80	0.352	53.46				
Total	260	490	2.3779	300	290	490	1.7692	300	390	590	2.4576	300

*F = Frequency, D = Density, BA= Basal area, IVI = Importance value index

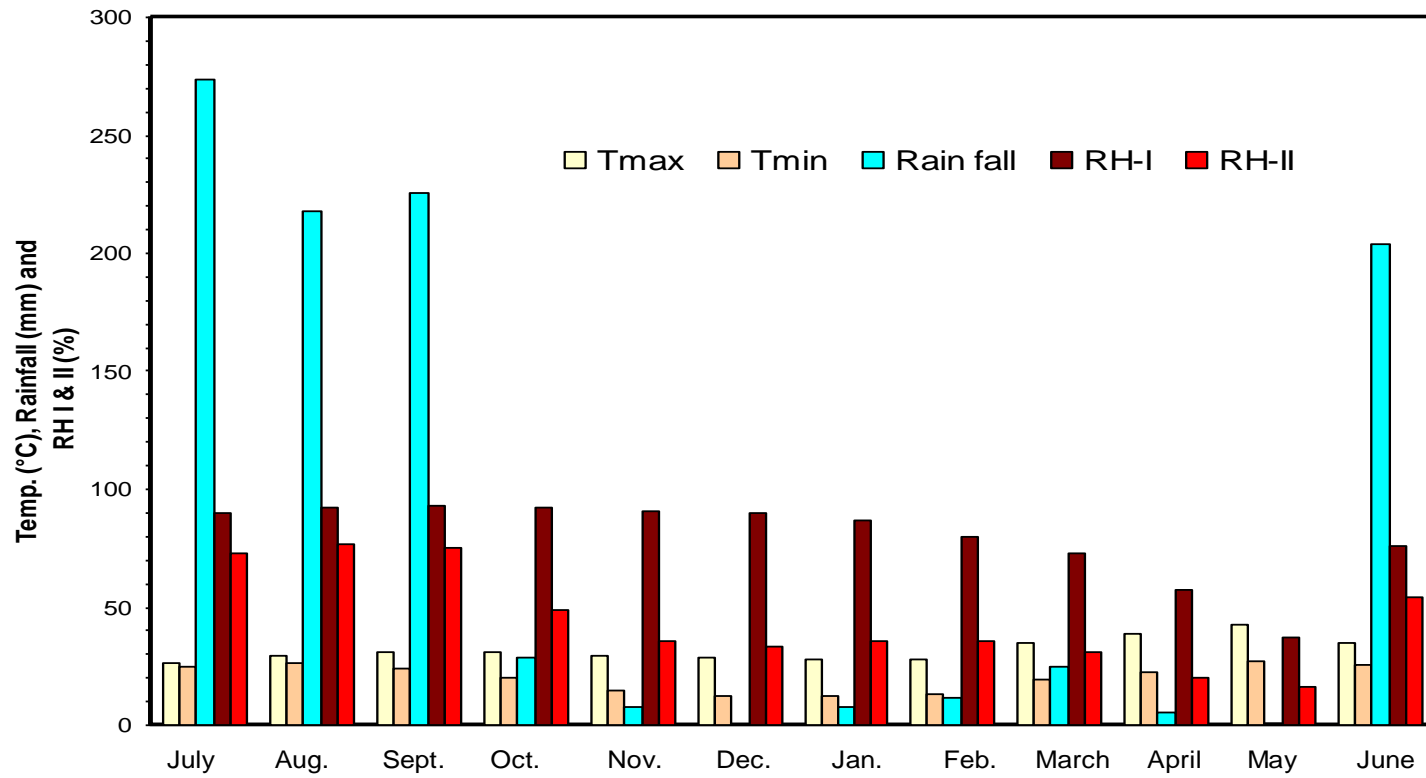
Table 4.12 Species composition of seedling layer open and closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Open canopy forests								Closed canopy forest			
	Site-1				Site-2							
	F	D	BA	IVI	F	D	BA	IVI	F	D	BA	IVI
	%	St/ha	m2 /ha		%	St/ha	m2/ha		%	St/ha	m2/ha	
<i>Diospyros melanoxylon</i>	50	100	0.032	84.81	80	210	0.012474	153.27	40	110	0.000278	58.59
<i>Lagerstroemia parviflora</i>	30	60	0.06155	94.85					20	30	0.000129	22.61
<i>Terminalia alata</i>	60	140	0.00136	68.08					10	30	0.000266	17.41
<i>Chloroxylon swietenia</i>	10	30	0.0002019	12.91								
<i>Bridelia retusa</i>	10	60	0.0000492	19.89					10	40	0.000792	25.68
<i>Butea monosprema</i>	10	10	0.0000057	7.94	10	30	0.000564	16.46				
<i>Emblica officinalis</i>	10	20	0.001158	11.52	20	30	0.000246	21.53	20	30	0.000462	21.72
<i>Cleistanthus Collinus</i>												
<i>Holarrhena pubescence</i>					30	60	0.0129	83.06				
<i>Schleichera oleosa</i>					10	30	0.000393	15.82	10	40	0.0003161	20.58
<i>Cassia fistula</i>					10	10	0.00024	9.85	20	40	0.0005062	29.29
<i>Madhuca indica</i>									10	20	0.0000314	12.27
<i>Shorea robusta</i>									10	40	0.00679	91.90
Total	170	420	0.09632	300	160	370	0.026817	300	150	380	0.00915	300

*F = Frequency, D = Density, BA= Basal area, IVI = Importance value index

Table 4.13 Diversity pattern of tree, sapling and seedling layers in open and closed canopy Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Diversity index	Tree layer				Sapling layer				Seedling layer			
	Open forests			Closed forest site	Open forests			Closed forest site	Open forests			Closed forest site
	Site-1	Site-2	Average		Site-1	Site-2	Average		Site-1	Site-2	Average	
Shannon Index(H)	0.63	1.68	1.16	2.20	2.075	2.63	2.35	2.38	1.128	1.35	1.24	1.46
Simpson's Index(CD)	0.83	0.5	0.67	0.16	0.29	0.19	0.24	0.28	0.28	0.45	0.37	0.57
Species richness(d)	2.32	3.89	3.11	4.34	8.08	17.53	12.81	14.46	2.56	1.38	1.97	1.71
Equitability(e)	0.27	0.6	0.44	0.76	0.99	1.09	1.04	0.9	0.58	0.75	0.67	0.66
Beta Diversity (bd)	8.15	4.89	6.52	2.86	6.1	5.52	5.81	4.1	7.65	8.12	7.89	8.67



**Figure 3.3 : Monthly meteorological data during the study period.
(from July 2007 to June 2008)**