

**EFFECT OF FOREST FRAGMENTS ON SPECIES
COMPOSITION, SPECIES DIVERSITY AND BIOMASS IN
DRY DECIDUOUS FOREST**

M. Sc. (Forestry) THESIS

By

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DRY DECIDUOUS FOREST**

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CERTIFICATE – I

This is certify that the thesis entitled **“EFFECT OF FOREST FRAGMENTS ON SPECIES COMPOSITION, SPECIES DIVERSITY AND BIOMASS IN DRY DECIDUOUS FOREST”**, submitted in partial fulfillment of the requirement for the degree of **“MASTER OF SCIENCE IN FORESTRY”** of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **Mr. DHIRAJ KUMAR YADAV** under my guidance and supervision. The subject of the thesis has been approved by the 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 have been duly acknowledged by him.

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THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE

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This is to certify that the thesis entitled **“EFFECT OF FOREST FRAGMENTS ON SPECIES COMPOSITION, SPECIES DIVERSITY AND BIOMASS IN DRY DECIDUOUS FOREST”**

submitted by **Shri DHIRAJ KUMAR YADAV** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirement for the degree of M.Sc. in the Department of Forestry has been approved by the external examiner and Student's Advisory Committee after oral examination.

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LIST OF ABBREVIATIONS

Abbreviations	Description
%	Per cent
&	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
DBH	Diameter at breast height
EPCO	Environmental Planning and Coordination Organization
<i>et al.</i>	And others/co-workers
FAO	Food and Agricultural Organization
Fig.	Figure
FSI	Forest Survey of India
GBH	Girth at Breast Height
GIS	Geographical Information System
GPS	Global Positioning System
ha	hectare
ha ⁻¹	per hectare
ht.	Height
i.e.	That is
IVI	Importance Value Index
kg ha ⁻¹	kilogram per hectare
m	meter
MAB	Man And Biosphere

Abbreviations	Description
Mg	Magnesium
Mg	mega gram = 10^6 gram
MoEF	Ministry of Environments and Forest
N	Nitrogen
Na	Sodium
P	Phosphorus
R.B.A.	Relative Basal Area
R.D.	Relative Density
R.F.	Relative Frequency
t ha ⁻¹	ton per hectare
UNEP	United Nation Environment Programme
viz.	For example

CHAPTER-I

INTRODUCTION

Biodiversity is important for human survival and economic well-being and for the functioning and stability of ecosystem (Singh, 2002). Biodiversity of the natural ecosystems of the world is under threat due to forest fragmentation. The process of forest fragmentation is a detrimental one and has been increasing alarmingly throughout the world, especially in tropical forests that have the bulk of biodiversity. 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 and an increasing fragmentation of the remnant patches. Increasing fragmentation will result in the loss of a valuable portion of the forest ecosystem: the rare and shade tolerant species. Rapid fragmentation of formerly vast and uninterrupted forests has resulted in the present day species composition, which is not in full equilibrium. Tree species with small populations, will be the first to be lost in the process of forest fragmentation.

Forest fragmentation is the breaking up of a large portion of a forested land into several smaller portions. The forest fragmentation can be explained in two phases. The first phase results in the reduction of total amount of forest areas whereas the second phase leads to isolation of smaller patches. Fragmentation stems from the concept of "Island biogeography". It refers to forest habitats becoming isolated islands across the landscapes (MacArthur and Wilson, 1967). This may result either from natural disturbances or human interaction. Whether

forest fragmentation is caused by natural blow downs or clear cutting by timber companies, it has a dramatic effect on the inhabitants of its ecosystem.

Natural landscapes in particular forests, have been under severe pressure as a result of human population increase and associated economic development. Human impacts on the biotic richness and ecological roles of forest have included- clearing, burning, logging and thus resulting fragmentation. 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.

However, fragmentation is hard to quantify since anything from a bisecting road to suburban sprawl can be contributing factor (Tyrrell, 2001). Remote sensing and GIS have been successfully employed to monitor the fragmented ecosystems and thus can prove to be important tools to address the impacts due to forest fragmentation. Various satellite sensors with different spatial resolution have been utilized in the study of forest fragmentation. Remote sensing is perhaps the only feasible way to map tropical forest fragmentation at regional and global scales.

The process of forest fragmentation, a common phenomena occurring in tropical forests, not only results into continuously forest getting fragmented but also brings about several physical and biological changes in the environments of forests. Various changes takes place in the environment of forest landscapes as a result of increasing fragmentation. There are many physical and biological changes associated with forest fragmentation, such as habitat loss and

insularization. Apart from these, populations of forest species, both plants and animals are also affected. Some of the important consequences are reduction in the number of species, interference in dispersal and migration processes, altered ecosystem inputs and outputs and exposure of isolated core habitats of the forest. All these mechanisms are responsible for the progressive erosion of biodiversity. The environment of the fragments becomes conducive for weedy/exotic species. In some cases, the weedy species are incorporated into the remaining plant community and are responsible for the elimination of the species confined to the forest interior.

Fragmentation has an impact on forest dynamics and ecological functions through: 1) increasing rates of tree mortality and damage in fragmented forests, 2) decline in biomass near forest edges and emission of CO₂ and other green house gases and 3) changes in diversity of fauna and flora near forest edges. Fundamental changes in forest dynamics as a result of fragmentation can also have a number of implications for forest ecology. As a result of edge effect, vegetation structure changes and forest plots start losing biomass. In the first few years after fragmentation, there is a striking loss of biomass and an upsurge in tree mortality.

Subsequently, the secondary vegetation recovers and a new equilibrium is reached between mortality and rejuvenation albeit within a scrubber forest that harbours less biomass. Simulations attempting to estimate the importance of this collapse in biomass suggest that Amazonian forest fragmentation is producing 3 to 15 million tons of carbon per year. Fragmentation of tropical forests on a

global scale is modeled to produce between 20 to 150 million tons of carbon annually. When placed within the context of global warming, forest fragmentation impacts are not trivial.

This decrease in biomass also leads to dramatic changes in overall forest composition. Dense tangled vine (liana) become more common near forest edges, where the vines compete with trees for nutrients, water and light. Moreover, by growing up tree trunks, liana plays dynamic physical stress on trees. While the increased growth of liana may compensate somewhat for the loss of biomass, it does not offset the impact of fragmentation. In fact, the compensation effect accounts for only 12 % of the biomass lost as a result of tree mortality.

Biomass constitutes a primary data needed for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems (Chaturvedi and Singh, 1987; Tiwari, 1994). The different tree components (branches, roots, twigs and boles) are economically utilized for firewood, particleboard, composite boards, fodder, medicines and many commercial products. Therefore, quantification of total biomass is important as different components play a vital role in structural and functional process of ecosystems.

On the other hand, the estimation of woody biomass is also necessary for determining the status and flux of biological materials in an ecosystem (Anderson, 1970). The quantity of tree biomass per unit land area forms the primary data needed to understand the flow of materials and water through forest ecosystems (Swank and Schreuder, 1974).

The extent of forest area on the earth is about 37.2 per cent of the total geographical area. The area reported as forest in India is only about 75.1 million ha i.e. 22.3 per cent of the geographical area. The government owns about 95 per cent of the forests of the country. The remaining 4.0 per cent are owned by corporate bodies and 1.0 per cent by private individuals. Government forests are classified into reserved, protected and unclassed 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 17°C , 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 landmass is dominated by open or closed forest. Of this, 42% is dry forest, 33% is moist forest and only 25% are wet and rain forest (Sensu Holdridge).

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 chronic, especially in tropical regions, where the 14 hot spots (endangered zones) out of 25 in the world were identified by the biologists. During last few decades, the tropical ecosystems were severely affected by the anthropogenic disturbances like large-scale deforestation and denudation, resulting in fragmentation of habitats and loss of rich diversity (Stoms and Estos, 1993). 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.

Tropical forest deforestation has become a global concern in recent years. The 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% of the Tropical forest area, 54% is dry deciduous (Kaul and Sharma, 1971), which is largely threatened by lopping, burning, overgrazing and clearing for 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, dry savanna and dry grasslands, which are progressively species poor (Champion and Seth, 1968).

In India, habitat destruction, overexploitation, pollution and species introduction are identified as major causes of diversity loss (UNEP, 2001). The disturbance created by these factors determines forest dynamics and tree 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).

Prior to forest management operations, biodiversity inventories are used to determine the nature and distribution of diversity resource of the region being managed. Such diversity inventories are best integrated with the timber resources inventories in order that forest management operations can be planned (Rennolls and Laumonier, 2000). In these inventories, quantification on 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 to count (Condit *et al.*, 1996) and are also relatively better known, taxonomically (Gentry, 1992).

India's low per capita forest area of 695 sq. m. results in a large gap between supply and demand for forest products. India has 2.5 per cent of the world's land area and 1.8 per cent of the global forest area, but supports 15.6 per cent of the world's human population and 14 per cent of the livestock population. It has a large rural population of 700 million with a high population density of 2.57 persons/ha and 4.26 livestock/ha of forestland. This large population depends on forest for meeting diverse biomass needs and thus secondary forests are very important for the supply of fuelwood, raw materials for rural handicrafts and industries, among other products. They are potentially very important also for their environmental functions including soil and water conservation, flood control and carbon storage.

In recent years, a complex array of social, economic and political changes have altered human demands on forests. These changing demands have had devastating impact on forest status and integrity. The destruction of the world's tropical forests, which are disappearing at an alarming rate, is one of today's most urgent global environmental issues. Various changes take place in the environment of forest landscapes as a result of increasing fragmentation, therefore, understanding the ecological, biological and management issues of forest fragmentation is one of the main challenges of conservation biology.

There is a growing concern among the scientific community, planners, policy makers and administrators all over the world for the sustainable development of natural resources. Recently, concluded Earth summit at Johannesburg, South Africa also urged the world community to improve the global habitability and alleviate poverty through sustainable management of natural resources. Indiscriminate, unscientific and continuous exploitation of these resources over the decades are causing severe environmental degradation and affecting the functioning of different ecosystem.

As a result of fragmentation, large contiguous forests now exist as remnants of various sizes of plant communities. These forest remnants in the form of patches provide the last ray of hope in conserving the remaining biodiversity and the best possible way to do so is by protecting these fragmented habitats. More emphasis on the effects of habitat heterogeneity and quality in fragmented landscapes is needed to elucidate the ecological effects of fragmentation and assist in the development and implementation of methods, models and metrics related to habitat quality.

Presently there is a dearth of information on quantitative and qualitative pattern of forest communities as well as impact of fragmentation on vegetation status and biomass of tropical dry deciduous forest in Chhattisgarh.

No reports are available on structure, composition, diversity and biomass and no attempt was initiated to understand the variation on vegetation in tropical dry deciduous forests due to fragmentation. In view of this the present study entitled "Effect of Forest Fragments on Species Composition, Species Diversity

and Biomass in Dry Deciduous Forest” was undertaken. The study was carried out with the following objectives-

1. To quantify the structure and diversity in different forest fragments of dry deciduous forest.
2. To quantify the biomass in different forest fragments of dry deciduous forest.

CHAPTER – II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work done on effect of forest fragments on species composition, species diversity and biomass in dry deciduous forest. However, due to paucity of literature on few aspects, the similar types of studies carried in other forest ecosystems are also cited. The literature is broadly reviewed under the following major aspects.

- 2.1 Quantification of species composition and species diversity in different forest fragments.
- 2.2 Quantification of biomass in different forest fragments.
- 2.3 Variation in species composition, diversity and biomass due to forest fragmentation.

2.1 Quantification of species composition and species diversity in different forest fragments.

The structural and functional processes have to be quantified for thoroughly understanding the vegetation dynamics. The structural analysis of vegetation entails the floristic composition, stand density, basal area, vertical stratification and community types. While, the diversity provides information on species richness, distribution 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).

Tree species diversity is an important aspect of forest ecosystem diversity (Rennolls and Laumonier, 2000). Tree 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). 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 permanently 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).

Plant diversity inventories in tropical forests have mostly been concentrated on tree species than the other life forms, because tree species diversity is an important aspect of forest ecosystem diversity and also fundamental to total tropical forest biodiversity. They provide resources and habitat structure for almost all other species. Studies on tropical tree diversity

have accumulated over the past decades and there is a great deal of interest to decipher the pattern and process relating to tropical forest diversity.

India is recognized as one of the world's top 12 mega diversity nation (Myers, 1988). Their richness in biodiversity is due to immense variety of climatic 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 species, 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 centres. Among the Monocotyledons, out of 588 genera occurring in the country, 22 are strictly endemic.

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) 5B/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 since 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). In Chhattisgarh, so far only four species are endemic e.g. *Staurogyne perpusilla* (Henry and Balakr), *Maytenus bailadillana* (Narayan and Mooney) Raju and Babu, *Eriocaulon rajendrababui* Ansari & Balakr and *E. raipurensis* K.K. Khanna, V.Mudgal and Anand Kumar. An analysis has pointed out that about 480 taxa are rare in 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 /quadrant methods (Mishra, 1968, Whittaker, 1978). The conventional techniques of phytosociological analysis help in better understanding of community composition only at stand level. Several studies used correlation and regression relationship between species composition and structural factors, 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).

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 shrubs 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 ranges 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.

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 forests 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 hot spot exists in 10.7 per cent of closed forests. The four hot spots with the most elevated risk as assessed by human

population pressure were in the Western Ghats, Sri Lanka, Polynesia and Micronesia, Phillipines and Caribbean hot spots.

Longhi *et al.* (1999) studied floristic composition, tree community structure and dendromertic characteristics of a fragment of the deciduous seasonal forest in Rio Grande do sul, Brazil and located eighteen 200 m² sample plots and analysed it. They found that there were 56 plant species belonging to 46 genera and 28 families with CBH (circumference at breast height) $< \text{or} = > 15$ cm. The tree heights varied from 3.5 m in the understorey 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.

Sagar and Singh (2003) studied the forest inventory data collected during the year 1998 to 2000 from fifteen 1 ha permanent plots along a disturbance gradient in a dry tropical forest region of India. The study indicated 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.

Gillespie *et al.* (2000) encountered a total of 204 species and 1484 individuals $< \text{or} = > 2.5$ cm by establishing plots of 1000 m² in 7 tropical dry

forests in Costa Rica and Nicaragua in order to compare levels of species richness to those in other Neotropical dry forest sites and to identify environmental variables associated with species richness and abundance. They found that Santa Rosa National park was the richest site with the highest family (33), genera (69) and species (75) diversity of all sites. They also found that species richness and forest structure were significantly different between various sites. Fabaceae was the dominant tree and shrub family at most of the sites. There was a significant correlation between anthropogenic disturbances and total species richness, tree and shrub species richness and liana abundance.

Tabarelli *et al.* (1999) studied the species composition and guild structure of woody plants within 5 montane Atlantic forest fragments of the Tiet River basin, Sao Paulo, Brazil, ranging from 7 to 7900 ha and observed a negative relationship between fragment size and the relative importance of tree and shrub species. They observed that as fragment size decreased there was a significant rise in the relative importance of ruderal species, primarily in the Compositae, Euphorbiaceae, Solanaceae and Leguminosae. There was also a 9 % average decline in smaller fragments in relative importance of Myrtaceae, Lauraceae, Sapotaceae and Rubiaceae. They suggested that predictable shifts in plant guild structure may occur as tropical forest fragments are reduced in size and that small fragments may become dominated by edges and the surrounding habitat matrix and concluded that small forest fragments will be unlikely to preserve intact plant and animal assemblages.

Jha and Singh (1990) analysed the dry tropical forests of India and recognized five predominant plant communities forming a mosaic distributed in non-contiguous patches. The environmental relationships of these community types were analysed by detrended correspondence analysis (DCA) and discriminant analysis. The study showed the importance of soil texture in determining the distribution of these communities.

Hack *et al.* (2005) studied the diversity and important species of a deciduous seasonal forest fragment in Sao Roque locality, Jaguari country, Rio Grande do Sul, Brazil. A total of 54 species belonging to 28 families were identified. The Shannon diversity index was 3.63, which indicates a high diversity. Sapindaceae, Myrtaceae and Meliaceae were the most dominant families. The species with high importance values were *Cupanica vernalis*, *Patagonula Americana* and *Cabralea canjerana*. In the canopy forest, the dominant species were *P. Americana*, *C. canjerana* and *Luehea divarica*.

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 32.9 plant 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 sp of shrubs, 79 sp of herbs and 16 sp of lianas and climbers. 54 species are listed rare, endemic and threatened.

Singh and Singh (1981) reported the diversity of trees and shrubs in the fenced as 1173 and 132 tree ha⁻¹ and unfenced as 936 and 554 tree ha⁻¹ area of the

tropical dry deciduous forests. Tree density and total basal area in an equatorial forest ecosystem in Kongolo Islands Zaire ranged from 440 to 553 tree ha⁻¹ and 10,000 to 45,000 cm² ha⁻¹ respectively. Mosang, (1991) and Pande (2005) reported density and dominance (cm² ha⁻¹) as 690-1630 and 95643-155480 for closed canopy tropical dry deciduous teak forests of Satpura plateau.

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.

Shannon-Wiener diversity indices are generally higher for tropical forest, which ranges between 0.81-4.1 for the Indian sub continent (Singh *et al.*, 1984, Parthasarathy *et al.*, 1992, Visalakshi, 1995, Pande, 1999). Vishalakshi (1995) reported Shannon–Wiener diversity ranged between 0.83 and 2.43 for Marakkanam reserve forest in south India. The value reported by Parthasarathy *et al.*, (1992) for tropical evergreen forests were significantly higher than those of the Satpura Plateau between 1.19-1.98 for tree and between 1.19-1.89 for shrubs.

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 lie within the range of 0.21 to 0.92 (Bisht, 1989, Parthasarathy *et al.*, 1992; Visalkashi, 1995).

In several temperate forests the value 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, Ralthan *et al.*, 1982, Singh *et al.*, 1997). 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 forest between 1.16-3.4.

Kadavul (1999) studied the species richness, density and population structure of all trees inventoried 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 increasing tree girth.

Pande *et al.* (2002) studied the vegetation composition, species diversity, distribution pattern and other parameters of vegetation analysis along population structure and regeneration of some tree species in a Western Himalayan forest of Chakrate forest division (Uttaranchal). The density of the forest for tree species (plant 100 m⁻²) was 4.51-6.64, 23.56-41.62 for shrubs and 7280-11920 for herbaceous species, while the range for total basal cover (m² 100 m⁻²) was in between 0.332-0.938 for trees; 9.50-18.81 cm² 100 m⁻² for shrubs and 235-323

cm² 100 m⁻² for herbaceous species. The maximum diversity of trees was 12 (species richness) and minimum up to 1 for trees, 9-14 for shrubs, 20-23 for herbs. Concentration of dominance (cd) shows reverse trend to diversity that was 0.1201 for trees, 0.13-0.15 for shrubs and 0.1 to 0.13 for herbs. Diversity index varies from 0 to 2.25 for trees, 1.53 to 2.31 for shrubs and 2.41 to 2.69 for herbs. Beta diversity between 2 sites of forests shows 4 and 11 for trees, 1.25 and 3.67 for shrubs and 3.8 and 1.2 for herbs.

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 ha⁻¹ in RF and basal area 11.0 m² ha⁻¹. 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 services 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 enhances the productive capacity of many forest ecosystems and their ability to adapt to changing conditions.

2.2 Quantification of biomass in different forest fragments.

The biomass estimations in forests are conventionally made by the use of species specific allometric equations and component wise viz., stem, branch,

foliage and root biomass are estimated in both tree and shrub layer (Mishra, 1968; Odum, 1983; Rai, 1984). In this approach, the availability of species-specific local regression equations is essential for precisely estimating the forest biomass.

Singh and Singh (1991) studied the species composition, plant biomass and diversity, index in mixed dry deciduous forests of Vindhyan region. They found that the standing biomass of vegetation averaged 66.98 t ha⁻¹ with 46.70 t ha⁻¹ in tree layer, 13.97 t ha⁻¹ in the shrub layer, 0.35 t ha⁻¹ in the herb, 2.83 t ha⁻¹ in the litter layer and 3.13 t ha⁻¹ in the fine roots. A total of 83 per cent vegetation carbon was stored in above ground plant parts, while the above ground NPP was responsible for 72 per cent of the total carbon input into the system.

Ram Prasad and Mishra (1984) studied the standing biomass of various plant parts in selected tree species of dry deciduous teak forests of Gourjhamer, Sagar Forest Division, M.P. and correlate their biomass productivity with various plant parameters and age, utilizing wind fallen teak trees and felled trees of other species (*T. tomentosa*, *Diospyros melanoxylon* and *Anogeissus latifolia*). The crown, stem and root biomass of these species were tabulated against girth and (for teak) age. The culmination points in girth and age of different kinds of biomass productivity were established.

Mishra *et al.* (1998) studied the biomass status of mixed dry deciduous forest of Shiwalik hills in Haryana and studied the biomass structure of two sites - a biotically disturbed site (BD) and an undisturbed site (UD). The total basal area was 7.9 m² ha⁻¹ in BD and 9.7 m² ha⁻¹ in UD. Three important tree species

Anogeissus latifolia, *Acacia catechu*, and *T. tomentosa* accounted for 88% of total tree density in BD and 66% in UD. Total above ground tree biomass was 22.05 t ha⁻¹ in BD and 31.19 t ha⁻¹ in UD, indicating a significant difference.

Pande *et al.* (1986) studied the biomass production and distribution of nutrients in moist deciduous forests in Goa and found that the dominant species were *Terminalia tomentosa* in the upper storey and *Careya arborea* and *Lannea grandis* in the under storey and reported that as much as 92% of the total biomass was contributed by *T. tomentosa* with only 8% by the other two species.

Murali *et al.* (2005) studied biomass estimation equations for tropical deciduous and evergreen forests and developed linear and non-linear regression equations to estimate biomass of tropical forests along with estimates of goodness of fit and percentage of errors. Basal area and height of trees were found to give high goodness of fit and low percentage of errors for deciduous forests. They found that generally the coefficient of determination (r^2) was low for evergreen forests. The coefficient of determination was high and estimate of error was low for deciduous forest. They concluded that the biomass estimate equations for deciduous forests were precise and therefore useful for field applications.

Nascimento and Laurance (2002) studied total above biomass in Central Amazonian rain forests and quantified total above ground dry biomass (TAGB) within 20 1-ha plots in undisturbed site. TAGB values were very high averaging 397.7 + or - 30.0 t ha⁻¹. The most important component of above ground biomass were large trees (< or = > 10 cm dbh) which comprised 81.9% of TAGB followed by downed wood debris (7.0%), small trees, saplings, and seedlings (< 10 cm

dbh; 5.3%), lianas (2.1%), litter (1.9%), snags (1.5%), and stemless palms (0.3%). among large trees above ground biomass was greatest in intermediate sized (20-50 cm DBH) stems (46.7% of TAGB), with very large (\leq or \geq 60 cm DBH) trees also containing substantial biomass (13.4% of TAGB). They also found that there were no significant correlations between large tree biomass and that of any other live or dead biomass component.

Hall and Uhling (1991) estimated the biomass density of forest in south and south east Asia using the volume estimates and biomass comparison factors derived from Brown et al (1989). Their biomass estimates for India ranged from 116 Mg ha⁻¹ for undisturbed forest for 60-80 years and 35, 66 and 84 Mg ha⁻¹ for logged, unproductive and managed forests respectively. However, these estimates were only made from 9 per cent of the forest area and no information is given in relation to forest types and species composition.

Haripriya (2000) estimated the above ground biomass density and carbon storage in biomass of major forest strata (21) of India from data collected from 1,70,000 sampling units distributed all over the country in 1993. Biomass densities ranged from 14 to 210 Mg ha⁻¹ with a mean of 67.4 Mg ha⁻¹, which equals around 34 Mg C ha⁻¹.

Castellanos *et al.* (1991) studied the root biomass of dry deciduous tropical forest in Mexico and found that the above and belowground biomass of trees, shrubs and lianas was 73.6 t ha⁻¹ and 31 t ha⁻¹ respectively. A root: shoot biomass ratio of 0.42 was calculated.

2.3 Variation in species composition, diversity and biomass due to forest fragmentation.

There is an alarming threat to life support system on planet earth due to rapid declining of diversity and complexity of living organism. The problem is chronic, especially in tropical regions where the 14 hot spots (endangered zones) out of 25 in the world were identified by the biologist. Primary forests of Asia, particularly those of the Western and Eastern Ghats of peninsular India are disappearing at an alarming rate, due to anthropogenic pressure and they are either being replaced by forests containing inferior species or the land use pattern is changed (Parthasarathy, 1999).

During last few decades, the tropical ecosystems were severely affected by the anthropogenic disturbances like large-scale deforestation and denudation, resulting in fragmentation of habitats and loss of rich species diversity (Stoms and Estes, 1993). Forests are the most species rich terrestrial habitats. Deforestation affects biodiversity through destruction of habitat, isolated fragments of formerly contiguous habitat, edge effects within a boundary zone between forest and deforested areas (Ravan, 1994).

In India, habitat destruction, over exploitation, environmental pollution and species introduction are identified as major causes of diversity loss (UNEP, 2001). The disturbance created by these factors determines forest dynamics and tree diversity at the local and regional scales (Burslem and Whitmore, 1999; Hubbell *et al.*, 1999). India has the largest livestock population in the world, estimated as 445

million in 1990. It is estimated that in 2010 it would exceed 5 million, of these 270 million cattle grazed on forestland, leading to its degradation.

Habitat fragmentation affects the ecology of tropical forests in many ways, such as altering the diversity and composition of fragment biotas and changing ecological processes like seed germination and predation intensity (Lovejoy *et al.* 1986, Bierregaard *et al.* 1992, Laurance *et al.* 2002). Recent studies reveal that fragmentation also alters forest dynamics, causing sharply elevated rates of tree mortality and canopy-gap formation, apparently as a result of microclimatic changes and increased wind turbulence near forest edges (Laurance *et al.* 1998b). Large (60 cm diameter at breast height, dbh) trees are particularly vulnerable, dying nearly three times faster within 300 m of forest edges than in forest interiors (Laurance *et al.* 2000).

Singh *et al.* (2005) have compared the diversity and dominance of pure Sal and degraded moist deciduous forest of Achanakmar wild life sanctuary. The pure Sal forest was characterized by high trees (1233 stems ha⁻¹) and understorey vegetation densities (1575 stems ha⁻¹) as well as basal cover (tree, 36.36 m² ha⁻¹, understorey vegetation 1.85 m² ha⁻¹). The degraded moist deciduous forest sites represent the degraded stage with low density of tree and basal cover (633 stems ha⁻¹ basal cover 32.82 m² ha⁻¹) and under storey plants (density 918 stems ha⁻¹, basal cover 0.37 m²ha⁻¹). The total numbers of species was high (30 species) in pure Sal forest as compared to degraded moist deciduous forest (19 species). The diversity of plants in pure Sal forest was 2.82 (Shannon index), 4.76 (richness index) and 0.99 (equitability index). The diversity of plants was low in degraded

forest, the values being 1.99 (Shannon index), 3.48 (riches index) and 0.78 (equitability).

Jha *et al.* (2004) studied the impact of forest fragmentation on species diversity in tropical dry deciduous forests of Vindhyan highlands, India using satellite remote sensing and GIS techniques. A considerable change in the vegetation cover occurred due to industrialization and urbanization, which led to forest fragmentation. The remote sensing data has been analyzed to describe the changes brought about in vegetated areas over a period of 10 years as a result of fragmentation and its impact on biodiversity was assessed. It was observed that the rate of decreasing number of species is faster in case of negative change areas as compared to positive change areas of the region. The diversity of the vegetation was decreased due to fragmentation.

Pimm (1998) and Laurance (1999) reported that tropical forests are undergoing fragmentation, leading to loss of habitat and subsequently erosion of biodiversity. Several researches in recent years have focused towards erosion of tropical biodiversity at regional and local scales.

Devi and Behera (2003) have made a comparison between a relatively undisturbed dry deciduous forest and two degraded forests in the Badrama Reserve Forest of Bamra Division in Orissa, India and found that the dominant tree species association in the undisturbed natural forest was *Shorea-Terminalia-Pterocarpus* which changed to *Shorea-Cleistanthus-Terminalia* and *Soymida-Semecarpus-Buchanania* in the disturbed forests. Diversity indices of tree, shrub and liana were maximum in the undisturbed natural forest and disturbance led to the decline in the

diversity of these life forms. Disturbance in the natural forest led to the development of savannah with shrubby bushes and perennial grass species.

Rao *et al.* (2001) studied the size class distribution of sandal population in B.R.T. wildlife sanctuary along different protected sites, where high density of individuals were decreased from the core zone (37.5) to buffer zone (32.5) to the periphery zone (29.5). Highest girth was found in core zone where as highest regeneration was found in periphery zone.

Gunasekara *et al.* (2001) enumerated the temporal vegetation changes in selectively logged and unlogged stands in Sinhareja forest reserve, Srilanka. The highest number (121-134) of species was recorded in unlogged and (116-114 sp) in logged area. After 20 years 13 and 4 additional species were recorded in unlogged and logged areas, respectively.

Forman (1995) and Lomolino (2001) have discussed that larger patches have more species than smaller patches and that area is more important than isolation, patch age and many other variables in predicting species number. Density of trees and their regeneration in the forest are largely dependent on the response of the seedling and sapling to the forest microenvironment and interactive influence of an array of biotic and abiotic factors (Umashankar. 2001, Mishra *et al.*, 2003).

Species area curves help in understanding the relationship between the number of species occurring and the patch size and at the same time the probable decrease / loss in species can be assessed in the forest areas with patch sizes.

Methods using a species area curves lead to the thumb rule calculation that a loss of 90% habitat leads to 50% loss of species (Heywood and Stuart, 1992).

Ramirez-Marcial *et al.* (2001) studied the influence of anthropogenic disturbance on forest structure and composition in the highly populated montane rainforests of northern Chiapsa, Mexico. Here, the number, absolute density and basal area of canopy and understorey tree species were found to be decreased with disturbance intensity.

Ayyappan and Parthasarathy (1999) have conducted a biodiversity inventory in the large scale permanent plots in the tropical evergreen forests of the Western Ghats in India and suggested that monitoring of permanent plots would provide additional information about diversity and density of tree species.

Pande (1999) compared the vegetation of Sal forest of Doonvalley and relate the magnitude of disturbance with quantification of vegetation, their resource apportionment and the regeneration of Sal. The whole area was divided into five sites as per their disturbance magnitude. Total basal area (cm^2 100 m^{-2}) ranged between 2324-3775 for trees, 74-354 for shrubs and 1.28-30 for herbs. The distribution patterns for most of the species at different sites were random, where as some species of younger stand showed contagious/clumped pattern of distribution. The range of diversity index (Shannon-wiener index) was 0.89-2.31 for trees, 0.87-1.99 for shrubs, and 0.64-2.34 for herbs. Diversity index was invariably higher for herbs followed by shrubs and trees. The tree diversity was higher for least disturbed sites (2.31), where as shrubs and herb density followed reverse trend. Maximum turn over of species was recorded between site I and III

(5) and lowest at site II and V (0.25). The range for turnover of shrub layer was 0.60 (Site II and IV)-3.33 (Site I and III) while herbs were ranged between 1.8 (I-V) to 6.5 (Site IV and V). He noticed that not only disturbance and stand age affect the Sal regeneration due to invasion of new competitors at seedling and sapling stage but the compactness of stand due to old and big trees also reduce it by increasing moisture status of soil at the moist areas.

Shrestha *et al.* (2000) analyze the vegetation of natural and degraded forests in Chir pine in Siwalik region of Central Nepal. Where the total number of species vary from 39, 10 and 15 for natural forest, degraded forest and regenerating mixed forest, respectively and he found that the density of natural forest was high (264 ha^{-1}) compared to the degraded forest (23 ha^{-1}). Basal area of natural forest was also high ($59.6 \text{ m}^2 \text{ ha}^{-1}$) compared to degraded forest ($11.4 \text{ m}^2 \text{ ha}^{-1}$). Seedling density was also high in natural forest (8649 ha^{-1}) compared to degraded forest (1830 ha^{-1}).

Honnay *et al.* (1999) studied the distribution of 203 forest plant species over 234 isolated patches in western Belgium and France and concluded that even small forest fragments can be very important for maintaining plant species diversity, especially if they are of high habitat quality and if the forest management is appropriate and suggested that the extinction of forest plants occurred and still occurs in a deterministic way.

Ramanujam and Kadamban (2001) studied the natural vegetation of southeastern coast of Peninsular India and found that it has now been reduced to patches, some of which are preserved as sacred groves. The plant biodiversity and

population structure of woody plants >20 cm GBH (girth at breast height) in two such groves, Oorani and Olagapuram, occurring on the northwest of Pondicherry have been analyzed. The vegetation structure indicates that the Oorani grove is a relic of tropical dry evergreen forest, whereas Olagapuram is reduced to thorny woodland.

Kumar *et al.* (2000) studied the impact of disturbance along the gradients, in vegetation of Central Himalaya. They found that species diversity and species richness decreased from highly to least disturbed site. Variations in density, basal cover and crown cover also reported along the disturbance gradient.

Arvind *et al.* (2001) analyzed the impact of anthropogenic pressure on vegetation structure of different vegetation types of B.R.T wildlife sanctuary of Western Ghats, along the disturbance gradient. Study revealed that there was a decrease in both density and diversity of trees with disturbance.

Parthasarathy (1999, 2001) studied the tree diversity and distribution in tropical evergreen forests of the Western Ghats in India and identified disturbance and predation as the underlying causes of maintaining species diversity against strong competitive interaction.

Pascal *et al.* (1988) analyzed the Kan forest of Karnataka plateau for floristic composition and noticed the structural change due to exploitation. The basal area of the forest for the tree species was 40.6-70 m² ha⁻¹. The number of species varied from 480-960 ha⁻¹. Simpson's index varied from 0.86-0.92. Shannon-Wieners index of diversity values varied from 3.5-3.82.

Oliveria *et al.* (2003) tested the hypothesis that there are significant impacts in above ground alive standing biomass among areas under fragmentation and evaluated the standards of biomass distribution among four areas around the highways BR364 and BR 364 (Acre, Brazil) through allometric equations and found that the dynamics of biomass in primary forests are related to the process of forest fragmentation. They found the smallest values for the variable basal area ($20.3 \text{ m}^2 \text{ ha}^{-1}$) and biomass (384 tons ha^{-1}) in the smallest forest fragments. The effect of selective logging was evident and showed a drastic reduction in biomass for the logged species.

Studies relating to the tropics have documented the relationship between patch area and species diversity (Pimm and Raven, 2000, Hill and Curran, 2001, Wagner and Edwards, 2001) other studies have addressed the issue of patch area in relation to the community structure (Lovejoy *et al.*, 1983, 1986, Bunge and Fitzpatrick, 1993, Colwell and Coddington, 1994, Turner and Corlett, 1996, Kemper *et al.*, 1999) emphasizing the overall concern about forest fragmentation and its effect on plant diversity.

Cadotte *et al.* (2002) worked on the tree and shrub diversity and abundance in fragmented littoral forest of south eastern Madagascar and studied the DBH (diameter at breast height) of trees $>10 \text{ cm}$ in $20, 50 \times 50 \text{ m}$ plots in each of four forest fragments and understorey woody vegetation (DBH $< 10 \text{ cm}$, $>$ or $=1 \text{ m}$ tall) in $60, 10 \times 10 \text{ m}$ plots in three of the fragments. One forest fragment was located in the highly degraded Lokaro region, and three in the near by Sainte-Luce forest. A total of 3476 trees, representing 169 species in 55 families, were recorded in the 50

× 50 m plots, and 10282 understorey stems, representing 195 species in 54 families, were found in the 10 × 10 m plots. However, the fragments differed significantly both in tree and understorey stem densities, species richness and diversity values, and family richness values, with the Lokaro fragment having the lowest values for all measures. Furthermore, floristic patterns, family importance values and community similarity measures revealed that the species composition at the Lokaro fragment was very different from the Sainte-Luce fragments. Anthropogenic disturbance appears most pronounced in the isolated Lokaro forest, where biotic resources are limited.

Prasad and Pandey (1992) reported species diversity ranging from 0.32 to 3.76 and concentration of dominance from 0.07 to 0.63 at varying distances from habitation in Sal and teak forests in four districts of M.P., India. The forest within 0.5 km radius of habitation recorded lower diversity and dominance compared to forest within 5 km radius of habitation leading to conclusion that there is a decline in biodiversity due to anthropogenic disturbances.

Bhygan (2001) investigated four stands of tropical wet evergreen forest in Arunachal Pradesh. The four stands were selected based on the disturbance index. In these stands species richness varied along the disturbance gradient in different stands. The mildly disturbed stand showed the highest species richness 54 of 51 genera. It was lowest (16 of 15 genera) in highly disturbed stand. In undisturbed stand, 47 species of 42 genera were recorded while in moderately disturbed stand 42 species of 36 genera were found. Tree species diversity ranged from 0.7 to 2.02. In all the stands *Shorea assamica*, *Dipterocarpus macrocarpus*, *Messua ferrea*,

Castanopsis indica, *Terminalia chebula*, *Vatica lanceifolia* were dominant except in the highly disturbed stand. In undisturbed stand only 8 species of 26 were found to be regenerating. In mildly disturbed stand 37 out of 54 species were regenerating. The moderately disturbed stand shows 22 species out of 42, where as no regeneration was recorded in the highly disturbed stand.

Laurance *et al.* (1997) studied the biomass collapse in the Amazonian forest fragments and indicated that rain forest fragments in Central Amazonian experience a marked loss of above ground tree biomass. These losses were largest within 100 m of fragment edges where tree mortality is sharply increased by microclimatic changes and elevated with turbulence. Permanent study plots within 100 m of edges lost up to 36% of their biomass in the first 10 to 17 years after fragmentation. Lianas increased near the edges but usually compensated for only a small fraction of their biomass lost as a result of increased tree mortality.

Recently, Wilsey and Potvin (2000) reported that total and belowground biomass increased with increasing levels of species evenness. Recent studies on biodiversity in relation to ecosystem functioning have revealed that species diversity enhances the productivity and stability of ecosystems (Naeem *et al.*, 1994; Tilman *et al.*, 1996).

Recently, Gerwing (2002) tried to understand the implications of forest degradation by comparing the impacts of varying intensities of logging on forest structure and composition in the eastern Brazilian Amazon Forests and found 20 to 40 per cent reduction in the above ground live biomass was due to logging.

The disappearance of tropical forests comes at a time when our knowledge of their structure and dynamics is still inadequate (Hubbell and Foster, 1992). Human impacts on forests date back to antiquity and even to pre-history. However, documenting such impacts on the genetic diversity of forest trees is difficult and few quantitative data exist (Ledig, 1992). An understanding of forest processes is fundamental to the management of natural and disturbed vegetation. Such an understanding is necessary for assessment of potential impacts, the amelioration of effects of disturbance, optimization of productivity and rehabilitation of degraded ecosystems (Congdon and Herbohn, 1993).

CHAPTER - III

MATERIALS AND METHODS

The study on “**EFFECT OF FOREST FRAGMENTS ON SPECIES COMPOSITION, SPECIES DIVERSITY AND BIOMASS IN DRY DECIDUOUS FOREST**” was carried out at Barnawapara wildlife sanctuary of North Raipur Forest Division in Raipur district (Chhattisgarh) and Achanakmar-Amkantak Biosphere Reserve (Achanakmar, Bilaspur Forest Division) during the year 2005–2006. 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 Lavan, Ravan and Bar ranges of Barnawapara wildlife Sanctuary (North Raipur Division) situated in North-Eastern corner of Raipur district and Game Range (Paschim Chaparawa) and Shiv Tari range of Achanakmar-Amkantak Biosphere Reserve (Achanakmar, Bilaspur Forest Division). The geographical location and physiographic features of study area are given below.

3.1.1 Barnawapara Wildlife Sanctuary

3.1.1.1 Geographical location and physiography

The study area is located between $21^{\circ}20'0''$ to $21^{\circ}25'47''$ North latitudes and $82^{\circ}21'17''$ to $82^{\circ}26'27''$ East longitudes. It is situated about 17 km away from Patewa on Raipur-Sambalpur NH No. 6 just on the border of Chhattisgarh. 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.

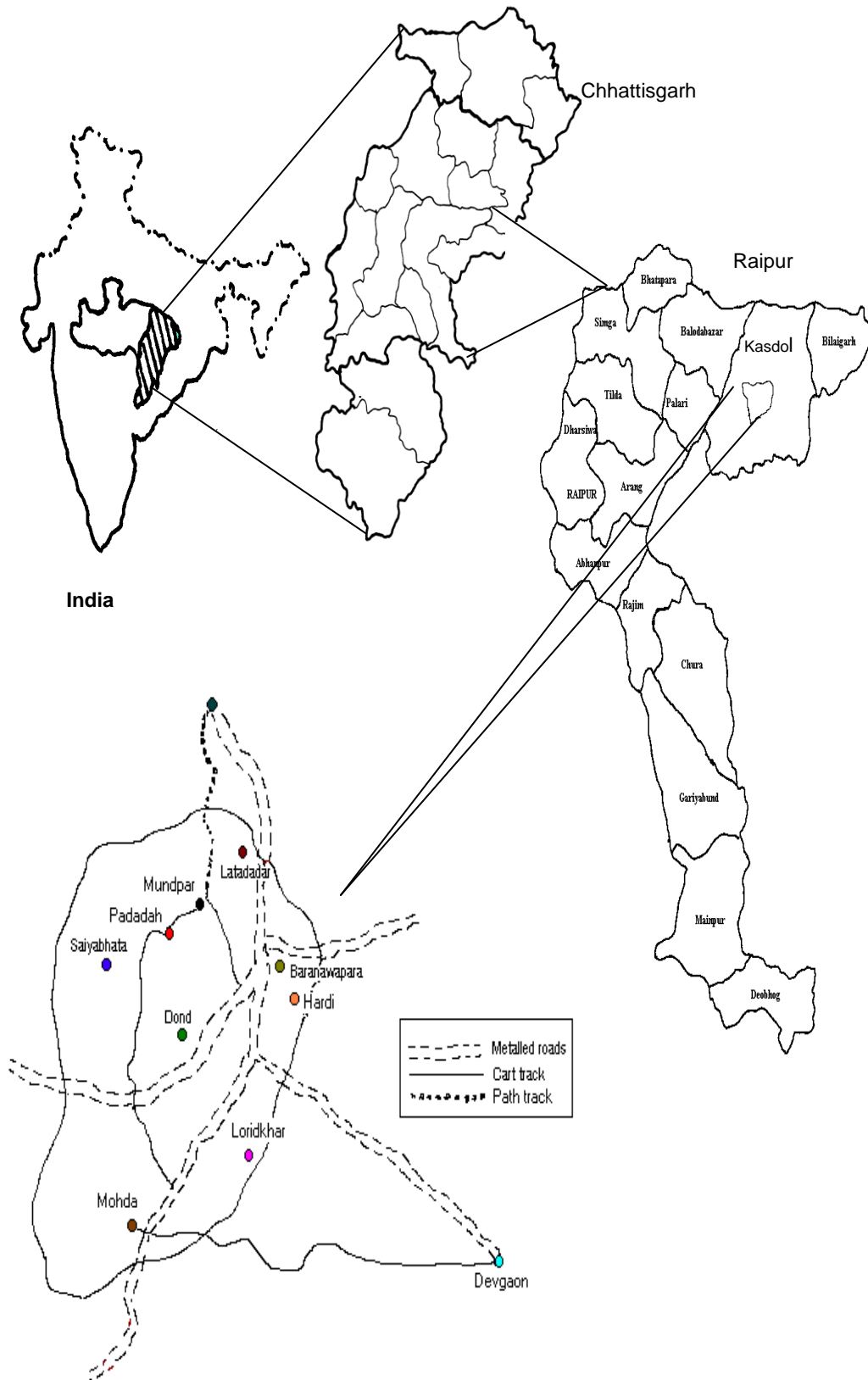
3.1.1.2 Climate

The climate of study area is dry humid tropical consists of three seasons viz. rainy, winter and summer. The rainy season commences from about the middle of June. 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.

3.1.1.3 Rainfall

The average annual rainfall in the study area ranges from 1200-1350 mm. It gradually decreases from south east direction to North West direction. 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.



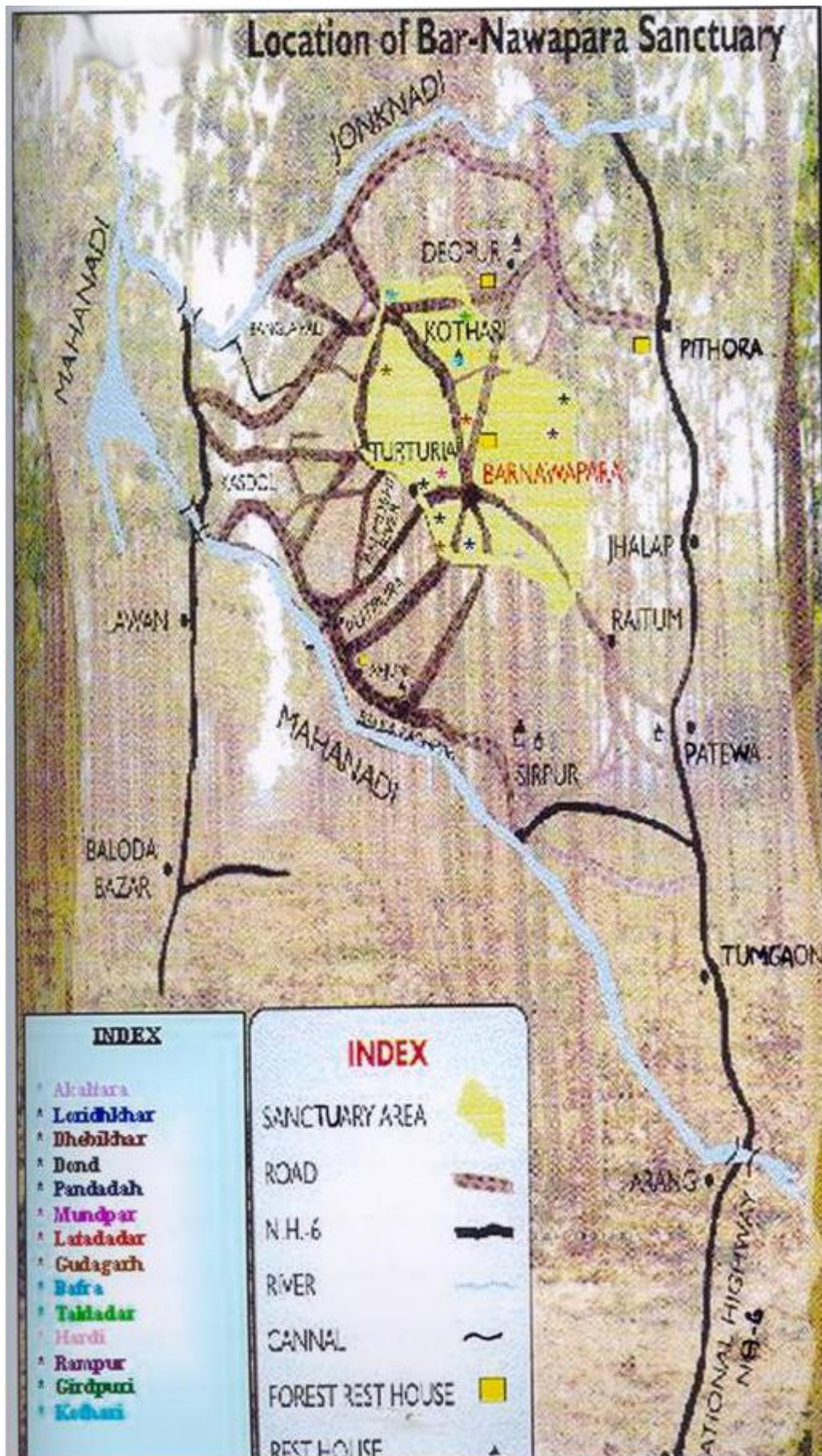


Fig.3.2: Area and Linkages of Barnawapara Wildlife Sanctuary

3.1.1.4 Temperature

The mean monthly maximum temperature ranges from 27.3⁰C in January to 41.8⁰C in May and mean monthly maximum temperature ranges from 12.7⁰C in Dec. to 27.3⁰C in May. The mean annual maximum and minimum temperature of study area are 33.1⁰C and 20.5⁰C, respectively.

3.1.1.5 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.

3.1.1.6 Geology

The area has 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.

3.1.1.7 Soils

Soils of study area are grouped into three classes viz., *Inceptisols*, *Alfisols* and *Vertisols*. The *Inceptisols* are immature soils mostly sandy loams having light texture and shallow to moderate depth. They are low in organic matter and available nutrients, which support mainly grasslands and degraded forests. These soils are commonly found in the Eastern and Southern aspects. *Alfisols* occur in

mid land situation which are moderately deep and hence have good water holding capacity and bear luxuriant vegetation, on the other hand *Vertisols* are deep clayey soils having good water holding capacity and are supporting rich vegetation. Some of these lands are utilized for cultivation of agricultural crops. The Physico-chemical properties of different soils are given in Table below.

Important physical and chemical properties of soils (0-20cm depth)

Properties	Soil types		
	<i>Inceptisols</i>	<i>Alfisol</i>	<i>Vertisols</i>
A. Physical properties			
Mechanical composition (%)			
Coarse sand	5.50 %	2.9 %	7.8%
Fine sand	28.12%	22.7%	11.0%
Silt	35.80%	29.8%	22.8%
Clay	28.50%	41.4%	50.6%
Ca CO ₃	0.39%	0.5%	Nil
B. Chemical properties			
pH	6.1	7.6	7.3
E.C. inch. Mhos/cm. At 25 °C	0.20	0.65	0.20
Average nutrient kg/ha			
P ₂ O ₅	33.6	10.0	26.4
K ₂ O	82.40	220	280
N total	132.44	182.62	211.22
Water holding capacity (%)	40.06	50.5	61.01

Source: working plan of Raipur forest division, period 1986-1996.

3.1.1.8 Forest types and flora

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), (4) Dry Bamboo Brakes (5/E₉).

3.1.2 Achanakmar-Amarkantak Biosphere Reserve

3.1.2.1 Locations and extent

The Achanakmar-Amarkantak Biosphere Reserve lies between 22⁰ 15' to 22⁰ 58' North latitude and 81⁰ 25' to 82⁰ 5' East longitude, having an area of 3835.51 sq. km, partly falling in Madhya Pradesh and partly falling in Chhattisgarh State. The state-wise distribution of the area shows that 1224.98 sq. km area comes under Madhya Pradesh and remaining 2610.53 sq. km. area in Chhattisgarh. It comprises parts of Bilaspur district of Chhattisgarh and Dindori and Anuppur districts of Madhya Pradesh falling in agro-climatic zone 'The Central Plateau and Hill Region'. Out of the total area, 68.1 % lies in Bilaspur district followed by Anuppur (16.2%) and Dindori (15.7%). It includes one Protected Area (PA) viz, Achanakmar Sanctuary lying in Bilaspur district with a total geographical area of 551.15. sq. km. The general location and Area & Linkages of the area has been given in Figs. 3.3 and 3.4, respectively.

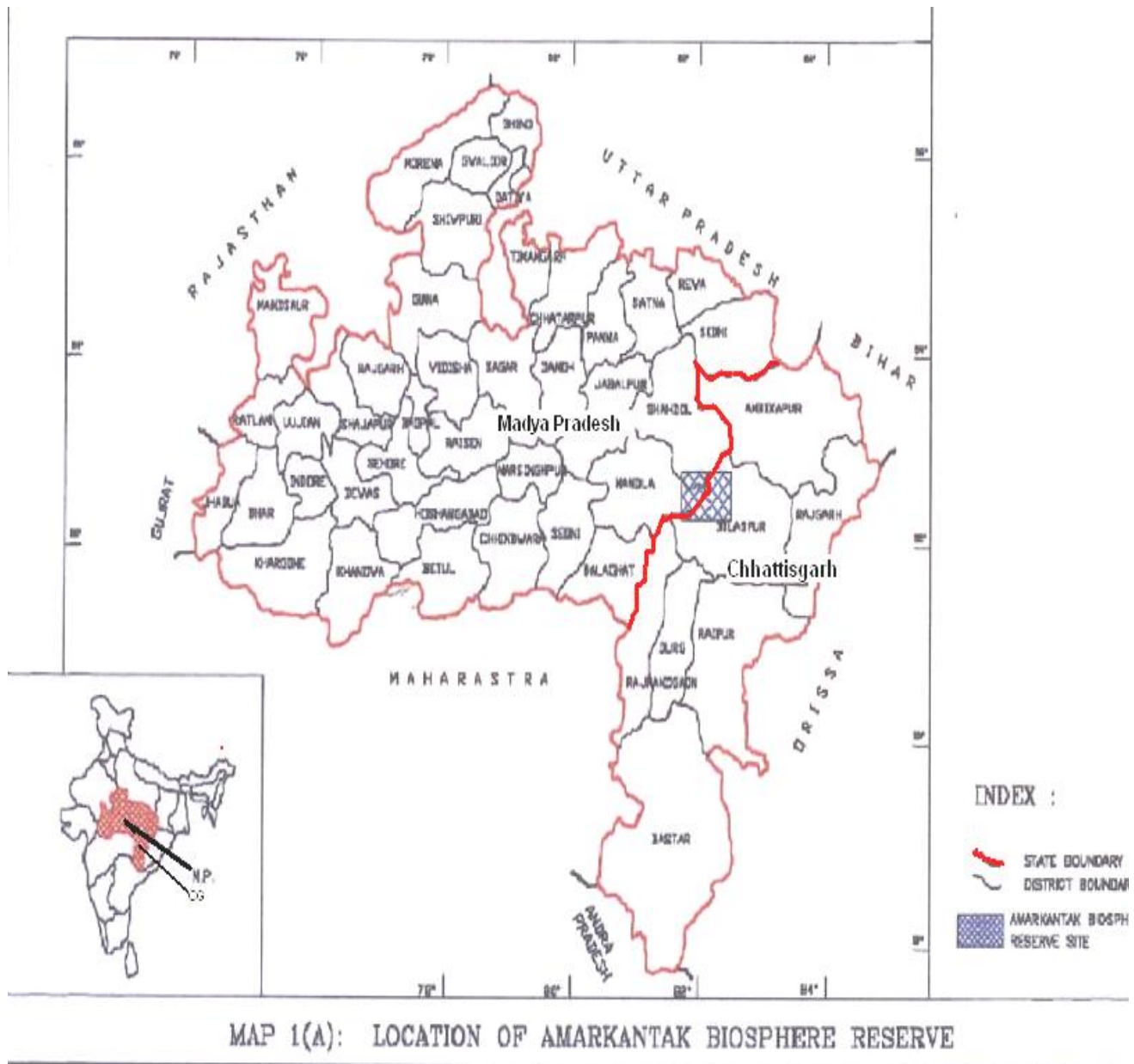


Fig.3.3: Location of Achanakmar-Amarkantak Biosphere Reserve

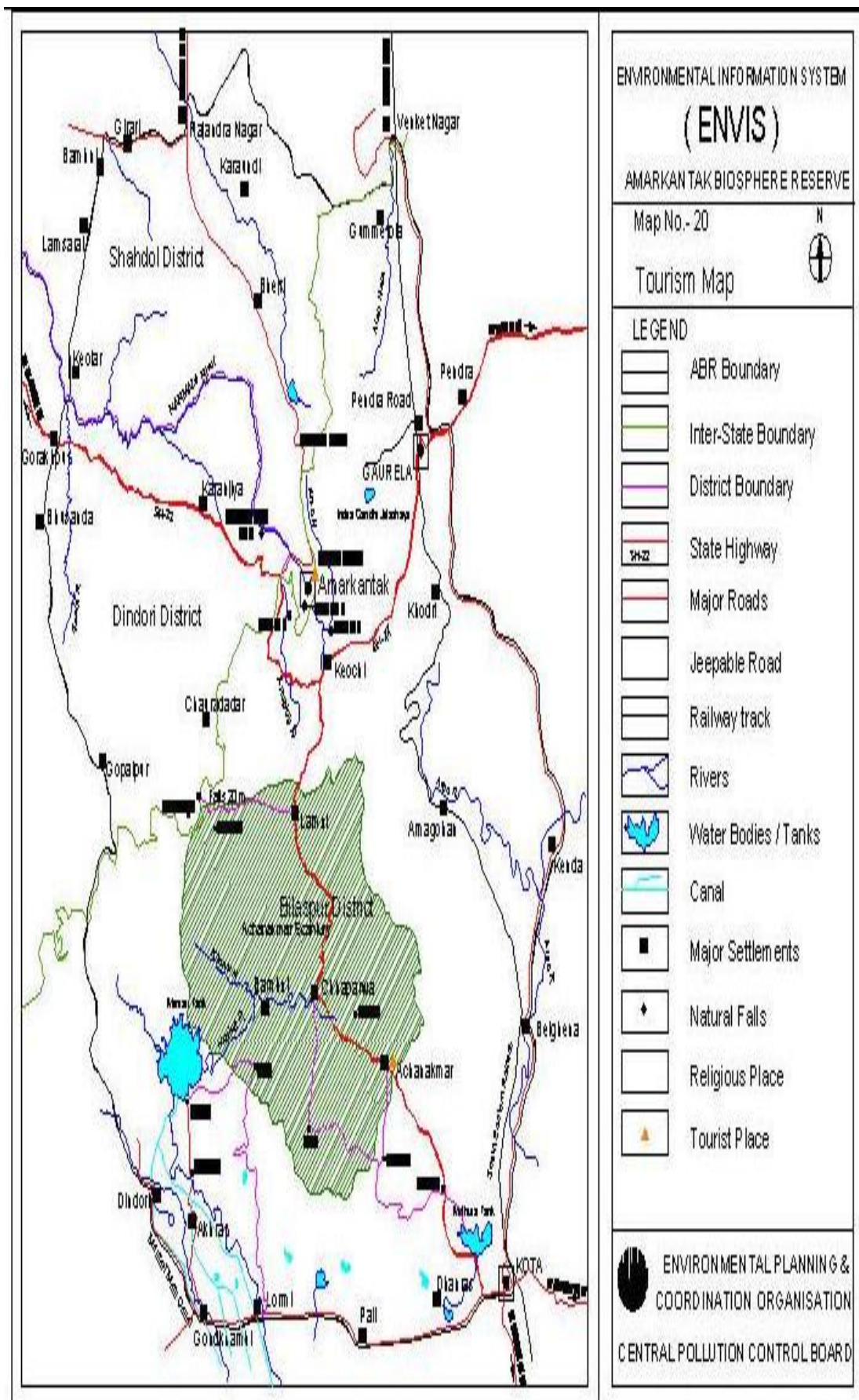


Fig.3.4: Area and Linkages of Achanakmar-Amarkantak Biosphere Reserve

3.1.2.2 Zonation

Presently the Achanakmar-Amarkantak Biosphere Reserve has been divided into core and buffer zone area only. However, the buffer zone area has to be further divided into buffer and restoration zone with consent of both states Governments.

Core zone

The Achanakmar-Amarkantak Biosphere Reserve has a core zone of 551.15 sq. km constituted by Achanakmar sanctuary. The entire core zone area falls in Chhattisgarh State.

Buffer Zone

Of the total area an area of 3283.96 sq. km serves as buffer zone of the Biosphere Reserve. Out of this an area of 1224.98 sq. km falls in Madhya Pradesh and the rest of the area of 2058.98 sq. km. falls in Chhattisgarh.

3.1.2.3 Topography and geology

The topography is very varied from the rice fields below in Bilaspur and Anuppur and Wheat fields in Dindori to the hills of Maikal range of Satpuras, culminating in the Amarkantak plateau of bauxite rocks. Steep escarpments are seen surrounding the Plateau. Numerous streams and Nallas, many of which are perennial, cut up the whole area. Thus variety of landforms is one of the major attributes of Achanakmar- Amarkantak Biosphere Reserve. The biosphere reserve area is one of major watershed of Peninsular India separating rivers draining into Arabian Sea and Bay of Bengal. Its uniqueness lies in the fact that it is the source of **three major river systems** namely Narmada, Johilla and Sone (Ganga basin) and Ama Nallah stream that join Arpa river (Mahanadi basin).

The biosphere reserve area includes **Maikal hill ranges**, the junction of Vindhyan and Satpura hill ranges forming a triangular shape. The geology of the area is varied. Archaeans, Gondwanas Lametas, Deccan trap and Laterite are the major formations, the rock types being Schists and gneisses with granite intrusion, sandstones, shales, limestone, basaltic lava and Laterite with bauxite, in the same order. These rocks have weathered to give a wide variety of soils, which together with topography determine the vegetation and land-use. Thus the area is also unique and important from geological point of view.

3.1.2.4 Climate

The biosphere area has a typical monsoon climate, with three distinct seasons-summer from March - June, rainy from July - October and winter from November-February. Generally, May and June are the hottest months whereas December and January are the coolest months of the year. Clouds prevail during the southwestern monsoon season i.e. from June-September to the degree of about 6 Oktas as recorded by the IMD Station at Pendra. The sky is generally overcast during July-August. During the summer and post-monsoon months it is moderately cloudy and in the November- March the sky is mostly clear. The relative humidity of the region is fairly high due to thick vegetation of Sal forest at higher elevations and frequent showers of rain throughout the year. The humidity remains very high during July-September.

3.1.2.5 Rainfall

The average annual rainfall of the area is about 1624.3 mm distributed over an average annual rainy days of 92 (range 71-118 days). The average monthly rainfall indicates that a few showers of rain occur throughout the year in

this area but 85.42% of average annual rainfall is received during the monsoon months extending from June to September. The rainfall during the period January to April fluctuates up and down and from May the rainfall increases and reaches maximum of 460.58 mm in the month of August, after which it decreases to the lowest is 12.98 mm in the month of December.

3.1.2.6 Soils

The soils of the area are generally lateritic, alluvial and black cotton type, derived from granite, gneisses and basalts. Black cotton soil is occurring in Dindori-Pendra Road and also along the Narmada river. In parts of Amarkantak, laterite occurs mainly as cappings above the Deccan trap. Red soil is also found on hilltops, which is murramy or loosely packed and gritty, generally shallow and incapable of supporting good forest growth. Alluvial soils are found along the nalas and rivers. Alluvial soils and black cotton soils are the most fertile for agriculture in the area. The soil cover on the plateau generally varies between 1 to 5 m thickness. A plastic olive green clay zone upto 5 m in thickness is also observed at some places. It is probably in such areas that marshy conditions develop due to poor seepage. At places where run-off has stripped away the soil mantle, fairly extensive pavements of laterite or bauxite are seen, particularly along the margins of this plateau.

3.1.2.7 Land use pattern

The land use and forest cover data revealed that out of the total geographical area of Biosphere Reserve area 61.1% lies in Bilaspur district followed by Anuppur (16.2%) and Dindori (15.7%). The land use analysis indicates that the forests constitute 66.31% of the area (2423.54 sq. km), while

agricultural lands constitute 34.03% (1305 sq. km) and wastelands are about 1.36% covering 52.22 sq. km only. The rest of the area is built up land (0.28%), water bodies (1.03 %) and other uses (0.11%), totaling 1.42% of the total area. Under the forest category, maximum area is covered by closed forest with 55.35 %, followed by open forest (4.53%), degraded forests (2.45%) and forest blank (0.85%) respectively. Thus, whole range of land use is available in the area except an industrial state and there is thus vast opportunity for introducing sustainable, environment friendly technologies to various land uses under Biosphere Reserve programme.

3.1.2.8 Vegetational spectrum

The forest area of the Achanakmar-Amarkantak biosphere reserve represents tropical deciduous vegetation and can be classified into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous forests (Champion and Seth, 1968). The former type predominates in the Biosphere Reserve area.

A. Northern Moist Deciduous Forests: It can be sub-classified into the following Sub types:

(i) Moist Peninsular High Level Sal occurring on the lateritic trap and Crystalline rocks of moist hilly parts covering the southern, central as well as southwestern parts in the Lamni and Achanakmar ranges of Wildlife Sanctuary in Bilaspur Forest Division, Karangi range of Dindori Forest Division and Pendra range of North Bilaspur Forest Division. The altitude Varies from 500-800 m.

(ii) Moist Peninsular Low Level Sal on the soils derived from crystalline rocks with yellow loam soils and is dominated by Sal of III quality. Part area of

the hilly tracts of Karngia, Kota, Khudia, Kenda and Rajendragaoon ranges of Dindori, Bilaspur and Anuppur Forest divisions are covered with this forest types.

(iii) Moist Peninsular Valley Sal occurring in part area of Karangia range of Dindori Division, Kota and Khudia ranges of Bilaspur Division, Kenda range of Marwahi Division and Rajendragram of South Shahdol division. They occupy the low-lying location in deep loam soil. The Sal is of quality II having excellent regeneration.

B. Southern Dry Mixed Deciduous Forests: It occupies a peripheral part of the Biosphere Reserve and serves to enrich the biodiversity of the area. This type differs from the dry teak forests mainly floristically. The thorny plants generally occur and tend to increase in proportion with heavy grazing etc. Bamboo is usually found in a few pockets.

3.1.2.9 Socio-economic profile

The area is largely of agricultural rural settings with preponderance of forests indicative of its inter land-situation covering a geographical area of 3835.51 sq. km under 7 developmental blocks of 3 civil districts. The total area of Achanakmar-Amarkantak Biosphere Reserve covers a total of 416 villages and 2 urban agglomerations. Out of the total villages 349 falls under revenue villages and remaining 67 falls under forest village category. In Madhya Pradesh there is no urban agglomeration as per 1991 census. Out of total villages of the Biosphere Reserve area 171(74 in Dindori and 97 in Anuppur) falls in MP and remaining 245 villages fall in Chhattisgarh. There are only 10 forest villages all located in Dindori district. Total population of the area is 3,38,738 (1991 Census), of which

54.11% and 6.90% are Schedule Tribes (ST) and Schedule Castes, respectively. Thus tribal population dominates the area. The common tribes are Gonds (Maria, Mudia, Gurva, Agariya and Rajgond sub tribes) and Baiga, Kaul, Kavar and Pradhans. The Population density in the Biosphere Reserve area is 177 / sq. km. Sex ratio in the Area is far above than the national average figure as 976/1000 male. The literacy rate is far below as 25.0 (Male-37 & Female-13).

The main occupation of majority of population is agriculture but it is still primitive. The cultivation is mainly rain-fed type in view of unavailability of irrigation facilities in the area. Flow irrigation is absolutely lacking in the region. The occupational pattern in the region clearly depicts that about 88% of population is directly and/or indirectly depend on Primary sector of agriculture, which further sub divided in to cultivars (69.25%) and agricultural labours (27.3%). The secondary and tertiary sectors support only 4.0% and 8.2 % of population requires immediate attention for its further development. Average size of land holding is between 1.4 and 2.7 ha. Paddy is the main crop. Cattle rearing are an auxiliary occupation and all cattle are forest fed or scrub fed. Forest produce collection also augments the earnings of the villagers seasonally. Clean and wholesome water supply is a far cry in the entire region.

3.2 Experimental details

3.2.1 Sampling/ Ground Inventory

The study on effect of forest fragments on species composition, species diversity and biomass in dry deciduous forest was conducted after repeated reconnaissance survey of Barnawapara wild life sanctuary and Achanakmar-Amarkantak Biosphere Reserve. Five sites were selected, out of which three sites

namely Lavan, Ravan and Bar were selected from Barnawapara wildlife Sanctuary and two sites namely Game range (Paschim Chaparawa) and Shiv Tarai were selected from Achanakmar-Amarkantak Biosphere Reserve.

3.2.2 Method

The stratified random sampling procedure was adopted for characterization of vegetation. The phyto-sociological analysis in each forest fragment was carried by randomly laying sample plots of 10 x 10 m² in size. Randomly 10 sample plots were laid down in each forest fragment. In each quadrat, GBH (Girth at Breast height) of each adult individual (≥ 9.6 cm GBH) was measured. Stem girth of each adult individual tree was measured at 1.37 m (gbh) from the ground level. Thus all individuals were enumerated by species and the girth of all the individuals was measured.

3.2.3 Phytosociological analysis

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

$$\text{Density (tree/ha)} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates studied}} \times 100$$

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

$$\text{Abundance (\%)} = \frac{\text{Total number of individual of the species in all sampling units}}{\text{Number of sampling units in which the species occurred}} \times 100$$

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 ith species.

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

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

Where,

Ni 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 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** was calculated as (Whittaker, 1972)

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

Where,

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

These indices were calculated following Sagar and Singh (1999). The data thus generated were synthesized and Potential diversity of each fragment was characterized. The diversity value of each stand was assessed on the extent of fragmentation. The diversity across the fragmented forest site was correlated with the structure parameters (IVI, Basal Area, Density etc.).

3.2.5 Biomass estimation

For the measurement of tree biomass, allometric equations relating tree circumference to biomass developed earlier by Singh and Mishra (1979) for the dry deciduous forest species were used. The tree individuals in each quadrat were categorized into different girth classes. The mean GBH (circumference at breast height) value for each species for a girth class was used in the regression equation to get an estimate of biomass (by component) for that girth class. Then this value was multiplied by the density of trees in that girth class. The girth class values were summed to obtain the biomass estimate for each of the 10 quadrats in each site.

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

$$\mathbf{Log\ y = a + b\ logx}$$

Where,

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

x = girth (cm) at 1.37 m height

a and b = allometric constants

3.2.6 Soil analysis

Soil samples were collected upto 0-10 cm depth from representative forest fragments and were analyzed by following methods.

Organic carbon– Organic carbon of soil was determined by the Walkley and Black method following Jackson, (1958).

Phosphorus– Available phosphorus was determined by ammonium molybdate stannous chloride method following Jackson, (1958).

Potassium– Available potassium was determined using flame photometer method following Jackson, (1958).

Nitrogen- Available nitrogen was determined by Micro-kjeldhal method.

All the results were expressed on oven dry weight basis.

% organic carbon in various forest fragments ranged from 0.72 to 1.78 %.

Available N in various forest fragments ranged from 281.01 to 140 kg ha⁻¹.

Available P in various forest fragments ranged from 5.13 to 14.8 kg ha⁻¹.

Available K in various forest fragments ranged from 120.0 to 370.11 kg ha⁻¹.

CHAPTER-IV

RESULTS AND DISCUSSION

The results on “Effect of forest fragments on species composition, species diversity and biomass in dry deciduous forest” are discussed in this chapter. The findings are presented in two separate parts to facilitate the interpretation of results in accordance with topics. First part deals with the results on quantification and variation of species composition and species diversity (Phytosociological analysis) of various forest fragments in dry deciduous forest and the second part deals with the results on quantification and variation of biomass due to fragmentation in various forest fragments of dry deciduous forest of Barnawapara wildlife Sanctuary and Achanakmar-Amarkantak Biosphere Reserve. Results on different aspects in each part are described below.

4.1 Quantification and variation of Species Composition and Species Diversity in various Forest Fragments:

4.1.1 Species composition

In the present study a total of 8120 trees ha⁻¹ in all the forest sites representing 50 species and 23 families were encountered. The most diverse families were Leguminosae (10), Anacardiaceae (7), Euphorbiaceae (4), Combretaceae (3), Myrtaceae (3), Rhamnaceae (3), Rubiaceae (2) and Rutaceae (2). The Euphorbiaceae family was represented by 184 individuals followed by Dipterocarpaceae (147), Combretaceae (97) and Lythraceae (92). Out of which 2130 trees ha⁻¹ were encountered in Bar Range, 1930 trees ha⁻¹ in Ravan Range, 1030 trees ha⁻¹ in Lavan Range, 2640 trees ha⁻¹ in Game Range and 390 ha⁻¹ trees

in Shiv Tarai Range was observed. Results on Phytosociological analysis in various forest fragments are given in the table 4.1 and 4.2.

4.1.1.1 Bar Range

In the Bar Range a total of 2130 trees ha⁻¹ representing 25 species and 14 families were encountered. The Euphorbiaceae family was represented by 65 individuals followed by Combretaceae (53), Anacardiaceae (23) and Lythraceae (20). It is evident from the data presented in the table 4.1 that *Terminalia tomentosa* was the most dominant tree layer followed by *Cleisthenus collinus* and *Lagerstroemia pariviflora*. Highest density was recorded in *Cleisthenus collinus* followed by *Terminalia tomentosa*, *Lagerstroemia pariviflora*, *Buchanania lanzan* and *Anogeissus latifolia*. Lowest density was recorded in case of *Ficus hispida*, *Holoptelea integrifolia*, *Shorea assamica* and *Delomix regia*. Highest basal area was observed in *Terminalia tomentosa* followed by *Cleisthenus collinus*, *Anogeissus latifolia*, *Emblica officinalis* and *Terminalia chebula*. Lowest basal area was observed in *Holoptelea integrifolia*. Basal area and density of individual tree species varied from 0.02 m² ha⁻¹ to 12.72 m² ha⁻¹ and 10 to 410 stems ha⁻¹, respectively. *Terminalia tomentosa* showed highest value of IVI (53.67) followed by *Cleisthenus collinus* (40.72) and *Lagerstroemia pariviflora* (23.29). The total density and basal area of Bar Range was recorded 2130 trees ha⁻¹ and 50.90 m² ha⁻¹, respectively.

Table 4.1: Species Structure of Tropical Dry Deciduous Forest at Barnawapara Wildlife Sanctuary

Species	Bar Range				Ravan Range				Lavan Range			
	F %	D St/ha	BA m ² /ha	IVI	F %	D St/ha	BA m ² /ha	IVI	F %	D St/ha	BA m ² /ha	IVI
<i>Terminalia tomentosa</i> Wt & Ang.	90	380	12.72	53.67	40	80	4.99	23.44	10	10	0.4	4.58
<i>Buchanania lanzan</i> _ spreng.	70	160	2.64	21.13	10	10	0.38	3.01	-	-	-	-
<i>Anogeissus latifolia</i> _ Wall. ex Bedd.	60	120	4.51	21.72	50	90	4.18	23.25	-	-	-	-
<i>Lagerstroemia parviflora</i> Roxb.	70	200	2.78	23.29	30	280	3.12	27.29	100	340	7.76	81.58
<i>Zizyphus xylopyra</i> Willd.	20	20	0.25	3.83	30	30	0.34	6.88	-	-	-	-
<i>Grewia tiliaefolia</i> Vahl.,	40	70	1.55	11.14	-	-	-	-	-	-	-	-
<i>Andidesma acidum</i>	50	80	0.63	11.03	10	10	0.09	2.22	-	-	-	-
<i>Ficus hispida</i>	10	10	0.41	2.49	-	-	-	-	-	-	-	-
<i>Aegle marmelos</i> Correa ex. Roxb.	10	20	0.12	2.38	-	-	-	-	-	-	-	-
<i>Holoptelea integrifolia</i> Planch.	10	10	0.02	1.72	-	-	-	-	-	-	-	-
<i>Garuga pinnata</i> Roxb.	50	100	2.63	15.89	-	-	-	-	-	-	-	-
<i>Madhuca indica</i> J.F. Gmel.	50	120	2.65	16.86	40	40	3.94	18.54	-	-	-	-
<i>Terminalia chebula</i> _ Retz.	30	30	3.13	11.17	-	-	-	-	-	-	-	-
<i>Tectona grandis</i> Linn.f.	10	70	0.32	5.13	20	40	0.44	6.18	-	-	-	-
<i>Bridelia squamosa</i> Gehrhm.	50	70	1.97	13.18	10	10	0.11	2.29	-	-	-	-
<i>Cassia fistula</i> Linn.	20	20	0.06	3.47	-	-	-	-	-	-	-	-
<i>Bauhinia variegata</i> Linn.	20	20	0.89	5.09	-	-	-	-	-	-	-	-
<i>Cleisthenus collinus</i> (Roxb) Benth & Hook.	60	410	7.25	40.72	100	850	8.54	81.69	70	200	3.68	47.58
<i>Zizyphus mauritiana</i> Lamk.	20	30	0.33	4.45	-	-	-	-	20	20	0.50	8.15
<i>Emblca officinalis</i> Gaerth.	40	90	4.33	17.55	10	10	0.48	3.29	-	-	-	-
<i>Butea monosperma</i> (Lamk) Taub.	10	20	0.22	2.58	-	-	-	-	-	-	-	-
<i>Diospyros melanoxylon</i> Roxb.	10	30	0.33	3.25	80	160	4.91	33.24	90	200	6.99	63.15
<i>Careya arborea</i> Roxb.	10	30	0.98	4.53	-	-	-	-	-	-	-	-
<i>Shorea assamica</i> Dyer.	10	10	0.03	1.73	-	-	-	-	-	-	-	-
<i>Delomix regia</i> (Boj) Rafin.	10	10	0.16	2	-	-	-	-	10	20	1.05	7.69
<i>Mangifera indica</i> Linn.	-	-	-	-	10	40	0.64	5.27	-	-	-	-
<i>Syzygium cumini</i> (Linn.) Skeels.	-	-	-	-	10	10	0.02	2.03	-	-	-	-
<i>Lansea coromendellica</i> (Houtt.) Merr.	-	-	-	-	50	60	1.65	14.89	20	20	0.31	7.54
<i>Gmelina arborea</i> Linn.	-	-	-	-	40	40	0.32	8.8	-	-	-	-
<i>Chloroxylon swietenia</i> D.C.	-	-	-	-	60	80	1.52	17.04	-	-	-	-
<i>Semicarpus anacardium</i> Linn.f.	-	-	-	-	20	20	0.09	4.22	-	-	-	-
<i>Sterculia urens</i> Roxb.	-	-	-	-	20	30	0.22	5.08	-	-	-	-
<i>Pterocarpus marsupium</i> Roxb.	-	-	-	-	10	10	0.51	3.36	-	-	-	-
<i>Cordia dichotoma</i> , Frost, F.	-	-	-	-	20	20	0.06	4.14	-	-	-	-
<i>Dalbergia paniculata</i> Roxb.	-	-	-	-	10	10	0.66	3.76	-	-	-	-
<i>Ixora arborea</i> Roxb. Ex J.E.sm	-	-	-	-	-	-	-	-	30	40	0.39	12.0
<i>Ougeinia oojeinensis</i> (Roxb.) Hochr.	-	-	-	-	-	-	-	-	80	170	8.76	63.87
<i>Limonia acidissima</i>	-	-	-	-	-	-	-	-	10	10	0.17	3.82
Total	830	2130	50.90	300	680	1930	37.21	300	440	1030	30.02	300

Table 4.2: Species Structure of Tropical Dry Deciduous Forest at Achanakmar-Amarkantak Biosphere Reserve

Species	Game Range				Shiv Tarai Range			
	F %	D St/ha	BA m ² /ha	IVI	F %	D St/ha	BA m ² /ha	IVI
Miliusa tomentosa (Roxb.) J.Sinclair	50	80	1.53	13.4	-	-	-	-
<i>Shorea robusta</i> Gaertn F.	100	1460	22.77	128.23	-	-	-	-
<i>Diospyros melanoxylon</i>	40	150	0.99	13.33	40	100	3.43	73.93
<i>Lannea grandis</i> Engl.	60	60	1.18	13.02	-	-	-	-
<i>Schleichera oleosa</i> (Lour) Oken.	10	20	0.39	3.08	-	-	-	-
<i>Caesalpinia sepiaria</i>	60	110	0.21	12.32	-	-	-	-
<i>Ventilago clayculata</i>	10	10	0.03	1.76	-	-	-	-
<i>Anogeissus latifolia</i>	60	70	0.68	12.04	10	10	0.22	8.67
<i>Emblica officinalis</i>	60	100	0.65	13.11	10	10	0.23	8.75
<i>Casearia graveolena</i>	40	60	0.17	7.75	-	-	-	-
<i>Mitragyna parviflora</i> (Roxb.) Korth,	20	40	0.36	4.96	-	-	-	-
<i>Ougeinia oojeinensis</i>	20	20	0.88	5.59	-	-	-	-
<i>Woodfordia fruticosa</i> Kurz.	10	40	0.03	2.88	-	-	-	-
<i>Semicarpus anacardium</i>	10	10	0.01	1.705	10	10	1.30	18.85
<i>Terminalia tomentosa</i>	50	110	4.21	21.63	50	70	1.47	51.75
<i>Butea monosperma</i>	20	20	0.55	4.71	10	10	0.46	10.89
<i>Zizyphus xylopyra</i>	10	10	0.01	1.7	-	-	-	-
<i>Buchanania lanzan</i>	30	40	0.81	7.45	50	80	1.19	24.37
<i>Garuga pinnata</i>	10	10	0.54	3.1	-	-	-	-
<i>Syzygium cumini</i>	20	50	0.13	4.75	-	-	-	-
<i>Lagerstroemia parviflora</i>	30	100	0.79	9.7	-	-	-	-
<i>Cassia fistula</i>	10	10	0.01	1.71	-	-	-	-
<i>Bauhinia racemosa</i> Lam.	10	10	0.18	2.16	-	-	-	-
<i>Eugenia heyneana</i> _ Druce,	30	30	0.07	5.12	-	-	-	-
<i>Madhuca indica</i>	20	20	0.56	4.73	20	50	1.0	30.25
<i>Pterocarpus marsupium</i>	-	-	-	-	20	20	0.57	18.52
<i>Tectona grandis</i>	-	-	-	-	10	10	0.01	6.67
<i>Bombax malabaricum</i> Linn.	-	-	-	-	20	20	0.72	47.25
TOTAL	790	2640	37.75	300	250	390	10.61	300

4.1.1.2 Ravan Range

In the Ravan Range a total of 1930 trees ha⁻¹ representing 22 species and 13 families were encountered. The Euphorbiaceae family was represented by 88 individuals followed by Lythraceae (28), Combretaceae (17) and Ebenaceae (16). It is evident from the data presented in the table 4.1 that *Cleistenthus collinus* was the most dominant tree layer followed by *Diospyros melanoxylon* and *Lagerstroemia pariviflora*. Highest density was recorded in *Cleistenthus collinus* followed by *Lagerstroemia pariviflora* and *Diospyros melanoxylon*. Lowest density was recorded in case of *Syzygium cumini*, *Bridelia retusa*, *Pterocarpus marsupium*, *Emblica officinalis*, *Dalbergia paniculata*, *Buchanania lanzan* and *Andidesma acidum*. Highest basal area was observed in *Cleistenthus collinus* followed by *Terminalia tomentosa* and *Diospyros melanoxylon*. Lowest basal area was recorded in *Syzygium cumini*. Basal area and density of individual tree species varied from 0.02 m² ha⁻¹ to 8.54 m² ha⁻¹ and 10 stems ha⁻¹ to 850 stems ha⁻¹. *Cleistenthus collinus* showed highest value of IVI (81.69) followed by *Diospyros melanoxylon* (33.24) and *Lagerstroemia pariviflora* (27.29). The total density and basal area of Ravan Range was recorded 1930 trees ha⁻¹ and 37.21 m² ha⁻¹, respectively.

4.1.1.3 Lavan Range

In the Lavan Range a total of 1030 trees ha⁻¹ representing 10 species and 9 families were encountered. The Lythraceae family was represented by 34 individuals followed by Euphorbiaceae (20) and Ebenaceae (20). Data presented in the table 4.1 revealed that *Lagerstroemia pariviflora* was the most dominant tree layer followed by *Ougeinia oojeinensis* and *Diospyros melanoxylon*. Highest

density was recorded for *Lagerstroemia pariviflora* followed by *Cleisthenus collinus* and *Diospyros melanoxylon* and *Ougeinia oojeinensis*. Lowest density was recorded for *Terminalia tomentosa* and *Limonia acidissima*. Highest basal area was observed in *Ougeinia oojeinensis* followed by *Lagerstroemia pariviflora* and *Diospyros melanoxylon*. Lowest basal area was observed in *Limonia acidissima*. Basal area and density of individual tree species varied from 0.17 m² ha⁻¹ to 8.76 m² ha⁻¹ and 10 stems ha⁻¹ to 340 stems ha⁻¹. *Lagerstroemia pariviflora* showed highest value of IVI (81.58) followed by *Ougeinia oojeinensis* (63.87) and *Diospyros melanoxylon* (63.15). The total density and basal area of Lavan Range was 1030 stems ha⁻¹ and 30.02 m² ha⁻¹, respectively.

4.1.1.4 Game Range

In the Game Range a total of 2640 trees ha⁻¹ representing 25 species and 15 families were encountered. The Dipterocarpaceae family was represented by 146 individuals followed by Combretaceae (18), Anacardiaceae (15) and Ebenaceae (15), Euphorbiaceae (10) and Lythraceae (10). Data presented in the table 4.2 revealed that *Shorea robusta* was the most dominant tree layer followed by *Terminalia tomentosa* and *Milium tomentosum*. Highest density was recorded in *Shorea robusta* followed by *Diospyros melanoxylon* and *Terminalia tomentosa* and *Caesalpinia sepiaria*. Lowest density was recorded in case of *Ventilago clayculata*, *Semicarpus anacardium*, *Zizyphus xylopyra*, *Garuga pinnata*, *Cassia fistula* and *Bauhinia racemosa*. Highest basal area was observed in *Shorea robusta* followed by *Terminalia tomentosa* and *Milium tomentosum*. Lowest basal area was recorded in *Semicarpus anacardium*, *Zizyphus xylopyra* and *Cassia fistula*. Basal area and density of individual tree species varied from 0.01 m² ha⁻¹

to 22.77 m² ha⁻¹ and 10 stems ha⁻¹ to 1460 stems ha⁻¹. *Shorea robusta* showed highest value of IVI (128.23) followed by *Terminalia tomentosa* (21.63) and *Miliusa tomentosa* (13.4). The total density and basal area of Game Range were 2640 stems ha⁻¹ and 37.75 m² ha⁻¹, respectively.

4.1.1.5 Shiv Tarai Range

In the Shiv Tarai Range a total of 390 trees ha⁻¹ representing 11 species and 8 families were encountered. The Ebenaceae family was represented by 10 individuals followed by Anacardiaceae (9) and Combretaceae (8). Data given in the table 4.2 revealed that *Diospyros melanoxylon* was the most dominant tree layer followed by *Terminalia tomentosa* and *Buchanania lanzan*. Highest density was recorded for *Diospyros melanoxylon* followed by *Buchanania lanzan* and *Terminalia tomentosa*. Lowest density was recorded for *Anogeissus latifolia*, *Butea monosperma*, *Tectona grandis*, *Embllica officinalis* and *Semicarpus anacardium*. Highest basal area was observed in *Diospyros melanoxylon* followed by *Terminalia tomentosa* and *Semicarpus anacardium*. Lowest basal area was recorded in *Tectona grandis*. Basal area and density of individual tree species varied from 0.01 m² ha⁻¹ to 3.43 m² ha⁻¹ and 10 stems ha⁻¹ to 100 stems ha⁻¹. *Diospyros melanoxylon* showed highest value of IVI (73.93) followed by *Terminalia tomentosa* (51.75) and *Buchanania lanzan* (47.25). The total density and basal area of Shiv Tarai Range was 390 stems ha⁻¹ and 10.61 m² ha⁻¹, respectively.

Tree basal cover in the present study varied from 10.61 to 50.90 m² ha⁻¹ for various forest fragments. These basal cover values were higher than the values reported for several dry tropical forest communities in Vindhyan region

by Jha and Singh (1990) between 6.58 and 23.21 m² ha⁻¹ and from 3.84 to 10.36 m² ha⁻¹ by Singh and Singh (1991). The total tree basal cover in the present study, ranged between 10.61 to 50.90 m² ha⁻¹. These values compare with 17 to 40 m² ha⁻¹ for dry tropical forest and 20 to 75 m² ha⁻¹ for wet forest (Murphy and Lugo, 1986a). Basal cover in a Puerto Rican sub-tropical dry forest was 19.8 m² ha⁻¹ (Murphy and Lugo, 1986b). In the present study, tree density ranged between 390 to 2640 for various forest fragments in dry deciduous forest. Compared to the present study the density of forest in Thailand, of dry *Dipterocarp* forest, was 554 to 789 (Visaratana *et al.*, 1986); of mixed deciduous forest was 253 (Sahunalu *et al.*, 1979), of 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 and 627 stems ha⁻¹ for several dry tropical forest communities (Singh and Singh, 1991; Jha and Singh, 1990). The forest canopy was three storied in the present forest. The dry tropical forest usually has 1-3 and the wet tropical forest three or more canopy strata (Murphy and Lugo, 1986a).

Density and basal cover values in the forests of the 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 m² ha⁻¹) for the forests of Sariska Tiger Reserve.

Inverse relationship between density and GBH showed small structure of the forests where only 28.57 % individuals were in the class exceeding 50 cm

GBH. This may be related to faster turnover, biotic removal or low capacity of biomass accumulation. Relating tree density with GBH, in Puerto Rican tropical dry forest, Murphy and Lugo (1986b) have found that only 2.3 % individuals exceeds 10 cm DBH. Singh and Singh (1991) reported that only 3 to 5 % individuals were in the classes exceeding 50 cm GBH.

The relationship between density and GBH distribution was inverse. The relationship between girth class (cm) and number of trees for the different forest fragments are illustrated in figures 4.1a to 4.1e. The relationship followed an exponential model $[y = \exp (a-bx)]$ in Bar, Ravan and Shiv Tarai Range, Logarithmic model in Game Range ($\ln y = a-b \ln x$) and followed by the Linear model ($y = a+bx$) in Lavan Range. The relationship for Bar Range was $y = \exp (80.69 - 6.028 x)$, for Ravan Range $y = \exp (51.03-0.026 x)$ and for Shiv Tarai $y = \exp (6.47 - 0.01 x)$, respectively. The relationship for Game Range was logarithmic, ($\ln y = 98.28-20.37 \ln x$) and in case of Lavan Range the relationship was linear, $y = (17.15 - 0.12 x)$.

In all the forest sites studied most of the trees i.e. 71-90 % species comes under middle girth class. This indicates that the forest of this study area is under middle aged. Hence, they should be managed on sustainable basis for the future use.

Bar Range

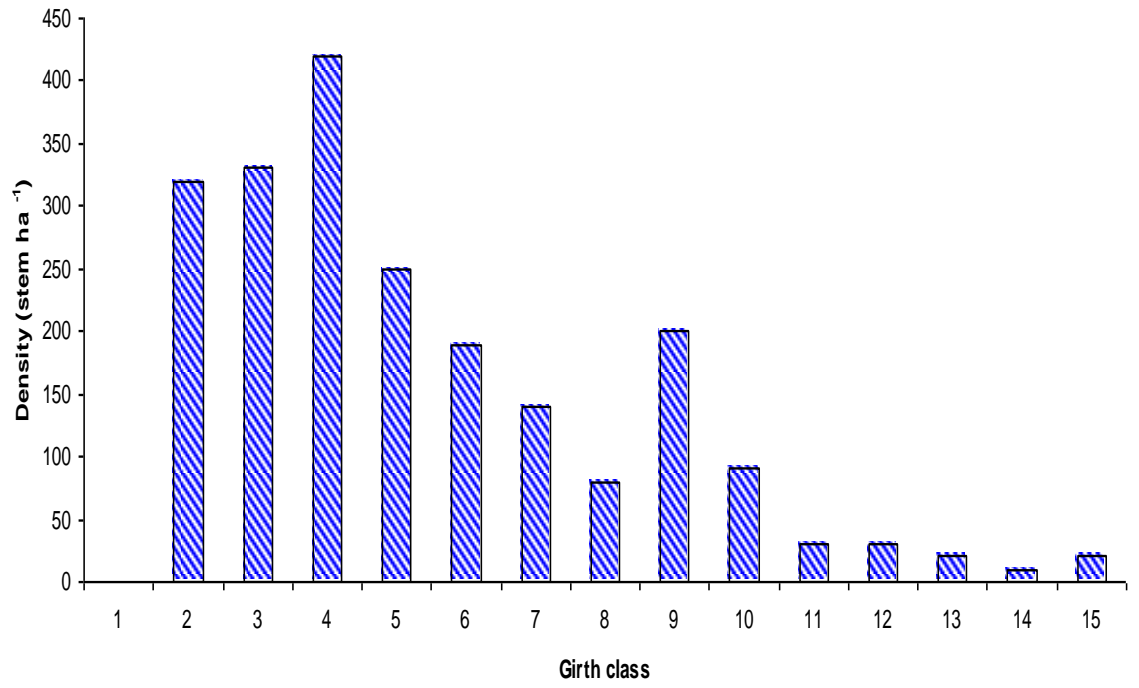


Fig. 4.1 (a)

Game Range

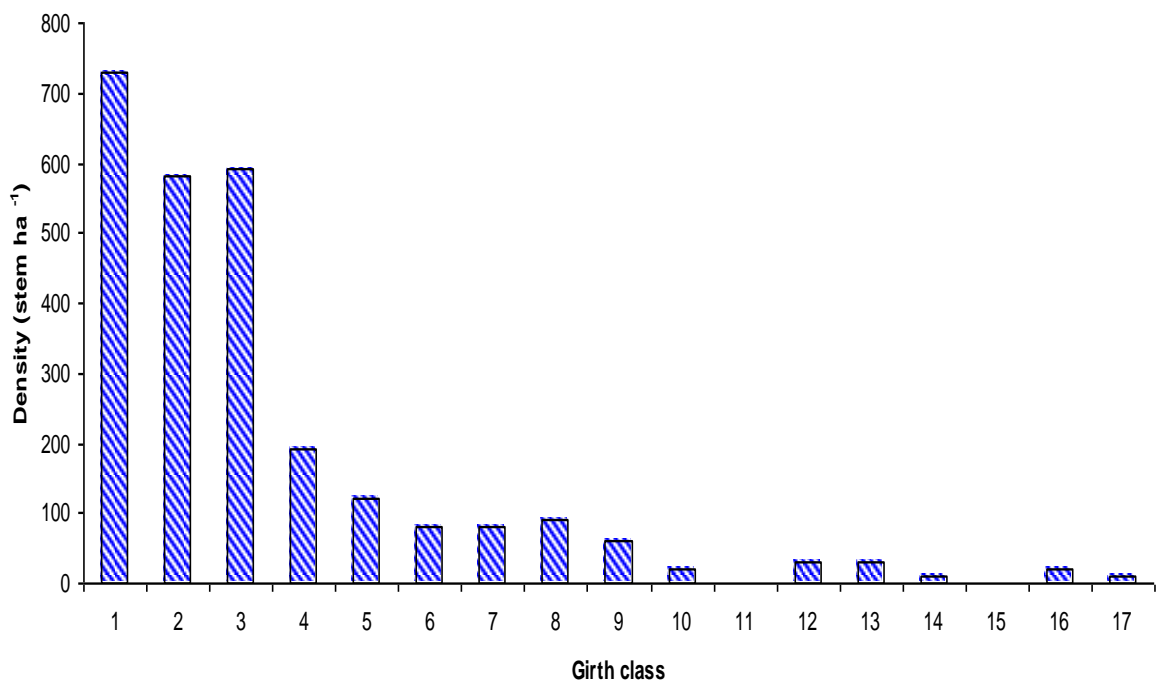


Fig. 4.1 (b)

Ravan Range

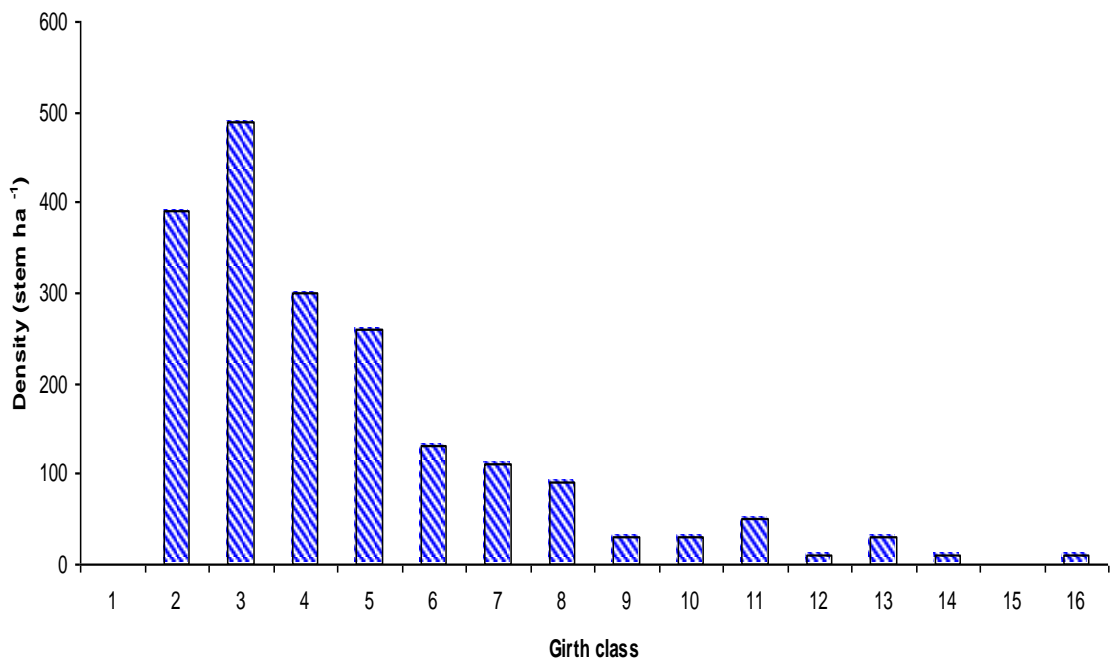


Fig. 4.1 (c)

Lavan Range

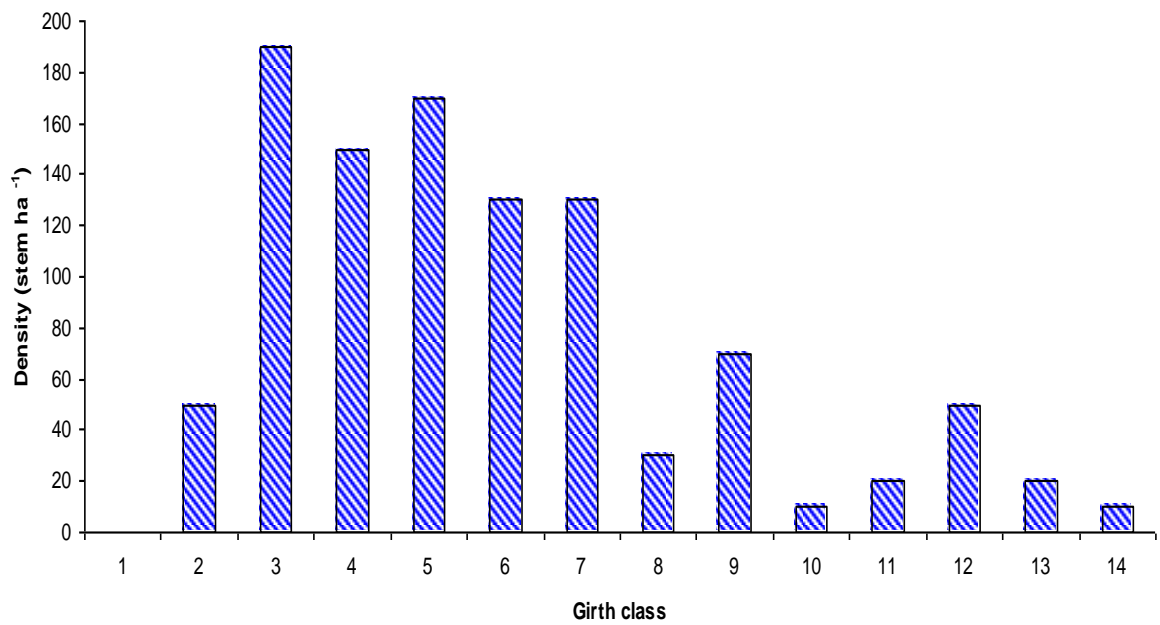


Fig. 4.1 (d)

Shiv Tarai Range

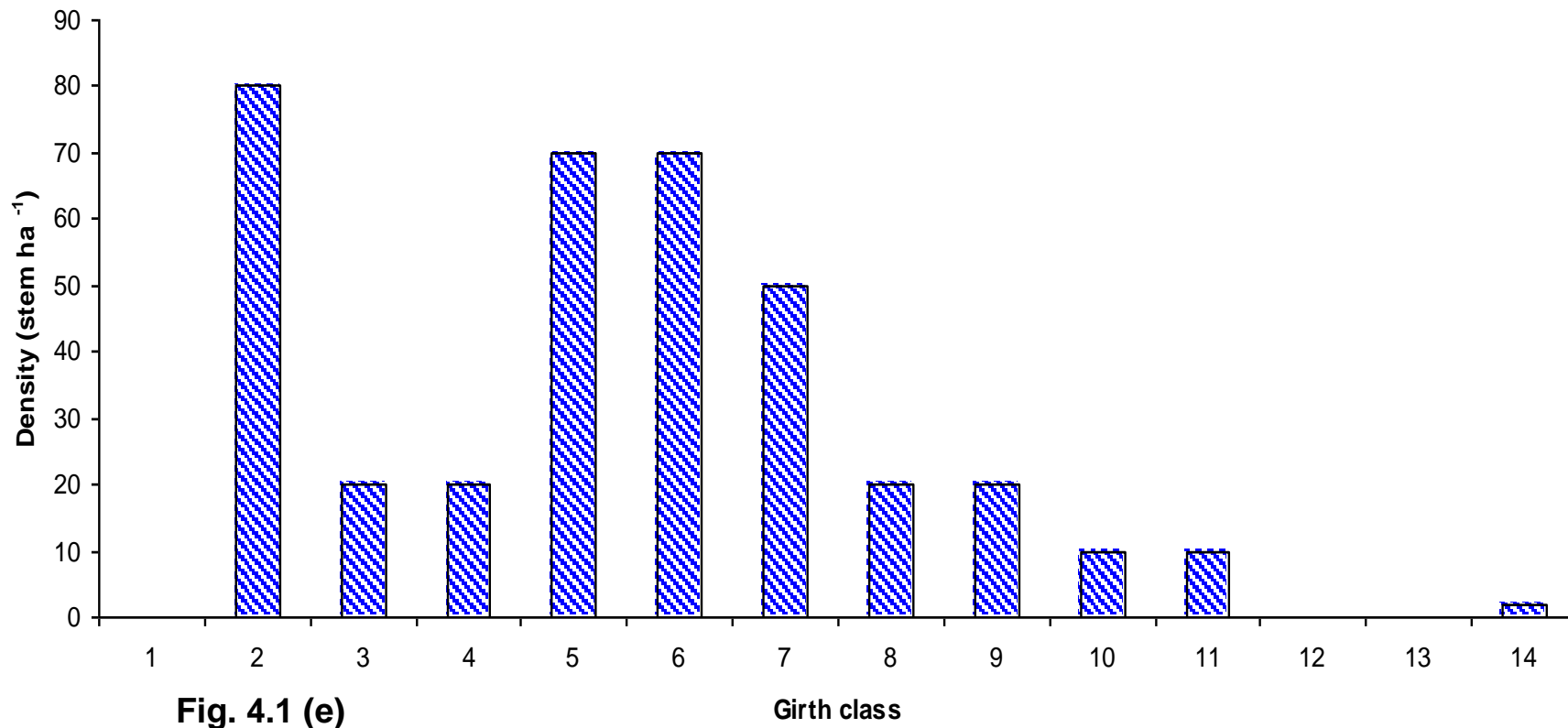


Fig. 4.1 (a) to (e) : Relationship between density of woody species and mean girth
Girth classes (cm): 1 (\hat{A} 10), 2(>10 ; \hat{A} 20), 3(>20 ; \hat{A} 30), 4(>30 ; \hat{A} 40)..... and so on.

Small fragments of forests have very different ecosystem characteristics than the large forest fragments, supporting more light loving species, more trees with wind or water dispersed seeds and relatively few under storey species (Laurance, 1999). Conservation strategies need to ensure the preservation and restoration of large unfragmented forest habitats in each region (Aksins, 1995).

It is argued that if environmental changes produced by disturbance is large; it may become lethal to greater numbers of established species than are, or can be immediately replaced by immigrants. Disturbance such as logging, usually cause an immediate decline in biodiversity followed by a recovery, although not necessarily of the same species (Noble and Dirzo, 1997). Species richness of the site experiencing disturbances, therefore, will be cumulative outcome of differential responses of species to disturbance. Some species may tolerate the disturbance and the other may disappear.

The presence of maximum number of species with only one or 1 to 10 individuals of all the forest sites may indicate the mixed nature of the forest (Richards, 2002) and a marked diversity. In the present study the species represented by a single individual varied from 1 to 28 %. Black *et al* (1950) in the Amazonian rain forests found that among trees of at least 10 cm dbh, over one third of the species were represented by single individuals. Soil N is supposed to be the most limiting nutrient in a majority of terrestrial ecosystems (Fenn *et al.*, 1998).

Many studies suggested that the heterogeneity of the environment as well as disturbance is the prime cause for patch formation in the forests (Jha and Singh, 1990). A small number of unique species on the more disturbed sites and

a decrease in the total number of species along the disturbance gradient may reflect high utilization pressure (Bhat *et al.*, 2000). The recurrent human intervention for collection of fuel wood and minor forest products and the practice of grazing and trampling may change the habitat fitness for many species.

The clumped distribution is common in nature while random distribution is found to be only in very uniform environments. The clumped distribution of individuals of a species may be due to insufficient mode of seed dispersal (Richards, 1996), or when death of trees creates a large gap encouraging recruitment and growth of numerous saplings (Armesto *et al.*, 1986, Richards, 1996). Vegetative reproduction by sucker and coppice also encourages clumpiness (Lieberman, 1979). *Anogeisus latifolia*, *Diospyros melanoxylon*, *Lagerstromia parviflora*, and *Shorea robusta* are the species, which form coppice and as a result of stem poaching, they either recover or increase in number through coppice when the disturbance is moderate. Of this coppice forming species, only *Anogeisus latifolia* and *Shorea robusta* are able to tolerate high degree of disturbance.

Connell (1971) suggested that the uniform dispersion pattern of species in tropical forest largely enables the maintenance of high levels of diversity. The changes in the dispersion pattern may reflect the reactions of species to disturbance as well as to changes in the habitat conditions. For example, the stem density of species changing from clumped to uniform dispersion was lower and that of species changing from uniform to clumped dispersion was on the more disturbed sites. Uniform dispersion of species is possible in case of edible fruits

by birds and animals e.g. *Zizyphus xylocarpa*, *Diospyros melanoxylon*, *B. lanzan*,
Grewia tilifolia, *T. chebula* etc.

Table 4.3: 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), Kiratipayoon <i>et al.</i> (1995)
Teak forest	262-395	-	21	Bunyavejchewin (1983), Dhanmanonda and Sahunalu (1992)
Tropical rain forest	818-1540	-	61-109	Kiratipayoon (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.

The study of Ramirez-Marcial *et al.*, (2001) showed decreasing density and basal area with disturbance intensity. Smiet (1992) correlated the basal area with disturbance. Current study also indicated that the stem density declined with disturbance. The decline in stem density along the disturbance gradient may be due to gradual increase in the extraction of firewood, small timbers, insect attack and rotting of boles.

Changes in density and basal area of trees in different forest fragments shows that prevailing biotic factors such as exploitation of forests to meet daily requirements of fuel wood, wood for agricultural implements and house hold construction, for preparation of boundaries along the houses and farm land, unregulated grazing by domestic cattle are the key determinants of structure and function of the forest. These factors in the absence of any viable alternatives defy all regulatory measures. As a result the forest goes on degrading year after year without any hope of rejuvenation without exclusion of these pressures. Variation in vegetation attributes such as IVI, tree density, basal area and distribution of tree species at different sites in the forest indicate the complex plant succession resulting from varying degree of pressures at different sites. The comparative account of certain vegetational properties of tropical forests is presented in table 4.3.

4.1.2 Species diversity

Species diversity, the number of species in a community is ecologically important. Since, it seems to increase as more stable community. The valuations of species 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 4.4.

4.1.2.1 Shannon index (H')

Shannon index was found to be variable from site to site in the study area of Barnawapara wildlife sanctuary and Achanakmar-Amarkantak Biosphere Reserve. The Shannon index values recorded for various forest fragments were 3.62 for Bar Range, 3.42 for Ravan Range, 2.39 for Lavan, 2.42 for Game Range and 2.99 for Shiv Tarai Range.

4.1.2.2 Equitability (e)

Equitability (e) values were 1.04 for Lavan Range, 1.11 for Ravan Range, 1.12 for Bar Range, 0.75 for Game Range and 1.25 for Shiv Tarai Range.

4.1.2.3 Species richness (d)

Species richness was highest in Game Range (6.61) followed by Bar Range (6.12), Ravan Range (5.80) and Shiv Tarai (4.24). However, the lowest value was recorded in Lavan Range (2.65).

4.1.2.4 Beta diversity

Beta diversity was highest in Shiv Tarai Range (20.0) followed by Lavan Range (11.36), Ravan Range (7.35) and Game Range (6.33) and the lowest value was recorded in Bar Range (6.02).

Table 4.4: Diversity parameters of various forest fragments

Parameters	Bar range	Ravan range	Lavan range	Game range	Shiv Tarai range
Species richness (d)	6.12	5.80	2.65	6.61	4.24
Shannon index (H')	3.62	3.42	2.39	2.42	2.99
Concentration of dominance (Cd)	1.0	0.12	0.22	1.00	0.17
Equitability (e)	1.12	1.11	1.04	0.75	1.25
Beta diversity (Bd)	6.02	7.35	11.36	6.33	20.0

4.1.2.5 Concentration of dominance (Cd)

The values recorded for Concentration of dominance in different forest fragments were 1.0 for Bar Range, 0.12 for Ravan Range, 0.22 for Lavan Range, 1.0 for Game Range and 0.17 for Shiv Tarai Range.

Results of diversity parameters revealed that Shannon index values in different forest fragments ranged from 2.39 to 3.62, equitability (e) from 0.75 to 1.25, species richness from 2.65 to 6.61, concentration of dominance from 0.12 to 1.0 and beta diversity from 6.02 to 20, respectively. The diversity parameters of these forests can be compared with the diversity indices reported in different tropical forests (Singh and Singh, 1991).

The Shannon index in the present study was low 2.39 to 3.62 in various forest fragments compared to Dry *Dipterocarp* Forest and Mixed Deciduous Forest of Thailand (3.75 to 4.49; Kiratiprayoon *et al.*, 1995), tropical rain forest of silent valley, India (3.8 to 4.8; Singh *et al.*, 1984) and of Barro Colorado Island (4.8; Knight, 1975). In other studies, the Shannon–Wiener index of diversity in forests of Thailand was 1.9 to 4.0 for dry *Dipterocarp* forest (Sahunalu *et al.*, 1979; Nilroung, 1986), 3.5 to 3.9 for mixed deciduous forest (Sahunalu *et al.*, 1976); 2.9 for teak forest (Dhanmanonda and Sahunalu, 1992) and 5.0 to 6.2 for tropical rain forest (Kiratiprayoon, 1986).

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 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

Table 4.5: Diversity indices in various forest fragments

Community	Shannon-Weiner index (SW)	Simpson index (S)
Terminalia/Shorea/ Diospyros	3.90	0.89
<i>Acacia catechu</i>	4.28	0.86
<i>Lagerstroemia-Tectona</i>	4.04	0.80
<i>Lagerstroemia-Tectona</i>	4.30	0.69
<i>Butea- Diospyros</i>	5.47	0.93
<i>Boswellia serrata</i>	3.47	0.50
<i>Acacia catechu</i>	4.39	0.59
<i>Shorea/Boswellia</i>	5.41	0.87
<i>Acacia catechu</i>	2.46	0.20
<i>Shorea mixed</i>	4.22	0.83
<i>Terminalai/Shorea/Acacia</i>	5.13	0.91
<i>Acacia-Soymida</i>	5.58	0.84
<i>Acacia catechu</i>	5.22	0.76
<i>Lagerstroemia-Butea-Boswellia</i>	4.30	0.86
<i>Acacia-Lagerstroemia</i>	4.76	0.87
<i>Lagerstroemia pariviflora</i>	3.46	0.48
<i>Lagerstroemia/ Diospyros</i>	3.67	0.36
<i>Lagerstroemia/Anogeissuss</i>	2.34	0.43
<i>Lagerstroemia/ Diospyros</i>	2.62	0.75
<i>Lagerstroemia/ Diospyros</i>	2.62	0.64
<i>Lagerstroemia/ Acacia</i>	1.84	0.40
<i>Lagerstroemia/Anogeissuss</i>	2.95	0.12

<i>Boswellia serrata</i>	3.83	0.80
<i>Acacia/Anogeissuss</i>	4.60	0.89
<i>Boswellia / Acacia</i>	5.37	0.82
<i>Acacia catechu</i>	3.19	0.19
<i>Acacia catechu</i>	3.48	0.65
Tropical Dry Deciduous Forest	2.39-3.62	0.12-1.0

* Source Goparaju *et al.* 2005.

Menon (1998); Singh and 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 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, Mandla, Balaghat and Jabalpur districts of M.P., India. The forest within habitation 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 forest fragments 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. The lower diversity of dry tropical ecosystem in this study is attributed to sharing of large

proportion of resources to only few species (< 27) while in tropical evergreen forests more number of species (> 75) efficiently shared the resources. Therefore, higher diversity was found in those forests. It is also evident from the results that Shannon index values were higher than concentration of dominance in different forest fragments. The inverse relationship was found between Shannon index and Simpson's index. These results are in agreement with earlier findings of Singh and Singh (1991) and Swamy (1998). The comparative account of diversity indices in various fragments of Vindhyan region is presented in table 4.5.

4.2 Quantification and variation of biomass in various forest fragments

The total biomass in various forest fragments is given in the table 4.6 to 4.10.

4.2.1 BAR RANGE

The total biomass recorded in Bar Range was 468.58 t ha^{-1} of which 406.38 t ha^{-1} was above ground biomass and 62.22 t ha^{-1} below ground. The distribution of biomass in the different components was as follows 155.44 t ha^{-1} in bole, 233.74 t ha^{-1} in branch, 17.20 t ha^{-1} in leaf and 62.22 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 33.17, 49.88, 3.67 and 13.28 %, respectively of the total biomass. Among the individual species *Terminalia tomentosa* constituted the highest biomass (113.44 t ha^{-1}) followed by *Madhuca indica* (62.50 t ha^{-1}) and *Anogeissus latifolia* (59.62) which constituted 24.21, 13.34 and 12.72 % of the total biomass. However, lowest biomass was recorded in *Shorea assamica* (0.07 t ha^{-1}) and *Holoptelea integrifolia* (0.07 t ha^{-1}).

4.2.2 RAVAN RANGE:

The total biomass recorded in Ravan Range was 316.5 t ha⁻¹ of which 273.88 t ha⁻¹ was above ground biomass and 42.62 t ha⁻¹ below ground. The distribution of biomass in the different components was as follows 104.13 t ha⁻¹ in bole, 158.05 t ha⁻¹ in branch, 11.70 t ha⁻¹ in leaf and 42.62 t ha⁻¹ in root. The bole, branch, leaf and root biomass constituted 32.90, 49.94, 3.69 and 13.46 %, respectively of the total biomass. Among the species *Anogeissus latifolia* constituted the highest biomass (58.48 t ha⁻¹) followed by *Cleisthenus collinus* (50.74 t ha⁻¹) and *Terminalia tomentosa* (48.64 t ha⁻¹), which constituted 18.47, 16.03 and 15.36 % of the total biomass. However, lowest biomass was recorded in *Syzygium cumini* (0.07 t ha⁻¹).

4.2.3 SHIV TARAI RANGE:

The total biomass recorded in Shiv Tarai Range was 90.38 t ha⁻¹ of which 78.38 t ha⁻¹ was above ground biomass and 11.99 t ha⁻¹ was below ground biomass. The distribution of biomass in the different components was as follows 33.10 t ha⁻¹ in bole, 42.22 t ha⁻¹ in branch, 3.07 t ha⁻¹ in leaf and 11.99 t ha⁻¹ in root. The bole, branch, leaf and root biomass constituted 36.62, 46.71, 3.39 and 13.26 %, respectively of the total biomass. Among the individual species *Diospyros melanoxylon* constituted the highest biomass (29.01 t ha⁻¹) followed by *Bombax malabaricum* (16.28 t ha⁻¹) and *Semicarpus anacardium* (13.78 t ha⁻¹) which constituted 32.09, 18.01 and 15.25 % of the total biomass, respectively. However, lowest biomass was recorded for *Tectona grandis* (0.05 t ha⁻¹).

4.2.4 LAVAN RANGE:

The total biomass recorded in Lavan Range was 242.42 t ha⁻¹ of which 207.13 t ha⁻¹ was above ground biomass and 35.28 t ha⁻¹ was below ground biomass. The distribution of biomass in the different components was as follows 87.21 t ha⁻¹ in bole, 111.22 t ha⁻¹ in branch, 8.70 t ha⁻¹ in leaf and 35.28 t ha⁻¹ in root. The bole, branch, leaf and root biomass constituted 35.97, 45.88, 3.58 and 14.55 %, respectively of the total biomass. Among the individual species *Ougeinia oojeinensis* constituted the highest biomass (80.88 t ha⁻¹) followed by *Diospyros melanoxylon* (58.34 t ha⁻¹) and *Lagerstroemia parviflora* (53.66 t ha⁻¹), which constituted 33.36, 24.06 and 22.13 % of the total biomass. However, lowest biomass was recorded in *Limonia acidissima* (0.98 t ha⁻¹).

4.2.5 GAME RANGE:

The total biomass recorded in Game Range was 317.83 t ha⁻¹ of which 277.05 t ha⁻¹ was above ground and 40.76 t ha⁻¹ below ground. The distribution of biomass in the different components was as follows 106.33 t ha⁻¹ in bole, 159.92 t ha⁻¹ in branch, 10.80 t ha⁻¹ in leaf and 40.76 t ha⁻¹ in root. The bole, branch, leaf and root biomass constituted 33.45, 50.31, 3.39 and 12.82 % respectively of the total biomass. Among the individual species *Shorea robusta* constituted the highest biomass (218.79 t ha⁻¹) followed by *Terminalia tomentosa* (31.17 t ha⁻¹) and *Miliusa tomentosa*, which constituted 68.83, 9.80 and 3.69 %, of the total biomass. However, lowest biomass was recorded in *Cassia fistula*, *Zizyphus xylopyra* and *Semicarpus anacardium* (0.01 t ha⁻¹).

Table 4.6: Biomass (t ha⁻¹) of different components in Bar Range

Species	Bole	Branch	Leaf	Root	Total
<i>Terminalia tomentosa</i>	38.53	56.63	3.82	14.46	113.44
<i>Buchanania lanzan</i>	6.32	6.82	0.90	1.88	15.92
<i>Anogeissus latifolia</i>	11.37	37.83	2.33	8.10	59.62
<i>Lagerstroemia parviflora</i>	6.97	7.41	0.89	3.82	19.09
<i>Zizyphus xylopyra</i>	0.64	0.56	0.08	0.24	1.51
<i>Grewia tiliaefolia</i>	4.69	5.04	0.44	1.64	11.81
<i>Andidesma acidum</i>	1.63	1.55	0.19	0.61	3.99
<i>Ficus hispida</i>	1.31	1.69	0.13	0.49	3.63
<i>Aegle marmelos</i>	0.34	0.25	0.04	0.13	0.75
<i>Holoptelea integrifolia</i>	0.03	0.01	0.01	0.01	0.07
<i>Garuga pinnata</i>	7.16	8.47	0.76	2.68	19.07
<i>Madhuca indica</i>	20.39	32.51	1.95	7.66	62.50
<i>Terminalia chebula</i>	10.50	18.73	0.96	3.95	34.14
<i>Tectona grandis</i>	0.53	0.17	0.13	0.24	1.06
<i>Bridelia retusa</i>	6.01	7.67	0.62	2.26	16.57
<i>Cassia fistula</i>	0.07	0.03	0.01	0.02	0.13
<i>Bauhinia variegata</i>	2.66	3.76	0.26	1.00	7.68
<i>Cleisthenus collinus</i>	19.15	21.67	2.09	7.18	50.09
<i>Zizyphus mauritiana</i>	0.87	0.73	0.10	0.32	2.03
<i>Emblica officinalis</i>	11.92	17.61	1.02	3.89	34.43
<i>Butea monosperma</i>	0.64	0.56	0.08	0.24	1.51
<i>Diospyros melanoxylon</i>	0.72	0.45	0.07	0.28	1.53
<i>Careya arborea</i>	2.56	3.19	0.27	0.96	6.98
<i>Shorea assamica</i>	0.03	0.01	0.01	0.01	0.07
<i>Delomix regia</i>	0.41	0.38	0.05	0.15	0.98
Total	155.44	233.74	17.20	62.22	468.58

Table 4.7: Biomass (t ha⁻¹) of different components in Ravan Range

Species	Bole	Branch	Leaf	Root	Total
<i>Mangifera indica</i>	1.69	1.61	0.19	0.63	4.13
<i>Cleisthenus collinus</i>	20.87	19.62	2.45	7.81	50.74
<i>Lagerstroemia parviflora</i>	6.95	5.85	0.98	3.20	16.99
<i>Syzygium cumini</i>	0.03	0.01	0.01	0.01	0.07
<i>Lannea coromandellica</i>	5.30	8.05	0.52	1.99	15.86
<i>Gmelina arborea</i>	0.72	0.55	0.09	0.27	1.63
<i>Zizyphus xylopyra</i>	0.91	0.87	0.10	0.34	2.22
<i>Bridelia retusa</i>	0.23	0.18	0.03	0.09	0.52
<i>Diospyros melanoxylon</i>	16.60	20.80	1.16	5.67	44.23
<i>Chloroxylon swietenia</i>	4.29	4.98	0.46	1.61	11.35
<i>Tectona grandis</i>	0.90	0.37	0.20	0.31	1.79
<i>Semicarpus anacardium</i>	0.14	0.08	0.02	0.05	0.29
<i>Sterculia urens</i>	0.55	0.46	0.07	0.20	1.28
<i>Madhuca indica</i>	12.91	24.94	1.14	4.85	43.84
<i>Anogeissus latifolia</i>	10.69	37.74	2.27	7.78	58.48
<i>Terminalia tomentosa</i>	15.89	25.27	1.52	5.97	48.64
<i>Pterocarpus marsupium</i>	1.44	1.36	0.09	0.38	3.27
<i>Cordia dichotoma</i>	0.14	0.08	0.02	0.05	0.29
<i>Embllica officinalis</i>	1.20	1.58	0.11	0.41	3.30
<i>Dalbergia paniculata</i>	2.25	3.39	0.22	0.85	6.70
<i>Buchanania lanzan</i>	0.19	.08	0.03	0.06	0.36

<i>Andidesma acidum</i>	0.23	0.18	0.03	0.09	0.52
Total	104.13	158.05	11.70	42.62	316.5

Table 4.8: Biomass (t ha⁻¹) of different components in Shiv Tarai Range

Species	Bole	Branch	Leaf	Root]	Total
<i>Anogeissus latifolia</i>	0.60	1.60	0.11	0.40	2.70
<i>Terminalia tomentosa</i>	3.73	4.03	0.41	1.40	9.56
<i>Butea monosperma</i>	1.31	1.69	0.13	0.49	3.63
<i>Pterocarpus marsupium</i>	1.73	1.44	0.12	0.45	3.74
<i>Tectona grandis</i>	0.03	0.01	0.01	0.01	0.05
<i>Diospyros melanoxylon</i>	11.35	12.89	0.83	3.94	29.01
<i>Bombax malabaricum</i>	5.16	8.70	0.48	1.94	16.28
<i>Buchanania lanzan</i>	1.45	0.42	0.22	0.45	2.54
<i>Emblica officinalis</i>	0.58	0.65	0.06	0.22	1.52
<i>Madhuca indica</i>	2.94	3.19	0.32	1.10	7.56
<i>Semicarpus anacardium</i>	4.22	7.59	0.38	1.59	13.78
Total	33.10	42.22	3.07	11.99	90.38

Table 4.9: Biomass (t ha⁻¹) of different components in Lavan Range

Species	Bole	Branch	Leaf	Root	Total
<i>Cleistenthus collinus</i>	9.94	10.97	1.09	3.73	25.73
<i>Terminalia tomentosa</i>	1.31	1.69	0.13	0.49	3.63
<i>Diospyros melanoxylon</i>	22.10	27.05	1.58	7.61	58.34
<i>Lagerstroemia parviflora</i>	19.86	20.56	2.55	10.69	53.66
<i>Lxora arborea</i>	0.85	0.69	0.10	0.32	1.96
<i>Ougeinia oojeinensis</i>	26.80	41.43	2.59	10.06	80.88
<i>Delomix regia</i>	3.72	6.12	0.35	1.40	11.58
<i>Lannea coromandellica</i>	0.87	0.86	0.10	0.33	2.16
<i>Zizyphus mauritiana</i>	1.35	1.48	0.15	0.51	3.49
<i>Limonia acidissima</i>	0.41	0.38	0.05	0.15	0.98
Total	87.21	111.22	8.70	35.28	242.42

Table 4.10: Biomass (t ha⁻¹) of different components in Game Range

Species	Bole	Branch	Leaf	Root	Total
<i>Miliusa tomentosa</i>	4.25	5.45	0.44	1.60	11.73
<i>Shorea robusta</i>	69.43	116.36	6.64	26.36	218.79
<i>Diospyros melanoxylon</i>	2.31	1.64	0.22	0.89	5.06
<i>Lannea grandis</i>	3.24	3.93	0.34	1.21	8.73
<i>Schleichera oleosa</i>	1.05	1.18	0.11	0.39	2.74
<i>Caesalpinia sepiaria</i>	0.30	0.13	0.05	0.12	0.60
<i>Ventilago clayculata</i>	0.03	0.01	0.01	0.01	0.06
<i>Anogeissus latifolia</i>	1.43	3.30	0.23	0.90	5.86
<i>Emblica officinalis</i>	1.25	1.02	0.19	0.56	3.03
<i>Casearia graveolena</i>	0.21	0.11	0.03	0.09	0.44

<i>Mitragyna parviflora</i>	0.62	0.51	0.08	0.24	1.45
<i>Ougeinia oojeinensis</i>	1.59	1.79	0.17	0.60	4.14
<i>Woodfordia fruticosa</i>	0.01	0.00	0.00	0.03	0.04
<i>Semicarpus anacardium</i>	0.00	0.00	0.00	0.01	0.01
<i>Terminalia tomentosa</i>	11.37	14.36	1.18	4.26	31.17
<i>Butea monosperma</i>	1.42	1.76	0.15	0.53	3.85
<i>Zizyphus xylopyra</i>	0.00	0.00	0.00	0.01	0.01
<i>Buchanania lanzan</i>	1.91	1.54	0.28	0.58	4.31
<i>Garuga pinnata</i>	1.75	2.44	0.17	0.66	5.02
<i>Syzygium cumini</i>	0.18	0.10	0.03	0.08	0.38
<i>Lagerstroemia parviflora</i>	1.62	1.38	0.23	0.75	3.97
<i>Cassia fistula</i>	0.00	0.00	0.00	0.01	0.01
<i>Bauhinia racemosa</i>	0.41	0.38	0.05	0.15	0.98
<i>Eugenia heyneana</i>	0.10	0.04	0.02	0.04	0.19
<i>Madhuca indica</i>	1.85	2.51	0.19	0.69	5.24
TOTAL	106.33	159.92	10.80	40.76	317.83

4.2.6 Biomass of various forest fragments are as follows:

Bar Range (468.58 t ha⁻¹) > Game Range (317.83 t ha⁻¹) > Ravan Range (316.5 t ha⁻¹) > Lavan Range (242.42 t ha⁻¹) > Shiv Tarai Range (90.38 t ha⁻¹).

The total biomass (t ha⁻¹) recorded among the different forest fragments was maximum in Bar Range (468.58) followed by Game Range (317.83), Ravan Range (316.5) and Lavan Range (242.42) and minimum in Shiv Tarai Range (90.38). The higher proportion of above ground biomass was allocated to branch followed by bole and leaf in different forest fragments. The above ground biomass in different forest fragments ranged between 78.38 to 406.38 t ha⁻¹ with the highest in Bar Range and lowest in Shiv Tarai Range. The below ground biomass in different forest fragments varied from 11.99 to 62.22 t ha⁻¹ and was highest in Bar Range and lowest in Shiv Tarai Range.

The above values are comparable with the estimates made by many workers (Murphy and Lugo, 1986; Singh and Singh, 1991; Roy and Ravan, 1996; Haripriya, 2000). The comparative account of biomass of important tropical forests is presented in table 4.11 and 4.12. Singh and Mishra (1979) reported 77 Mg ha⁻¹ and Singh and Singh (1991) reported 42-78 Mg ha⁻¹ biomass in dry tropical forests of U.P., India. Roy and Ravan (1996) estimated the biomass of tropical dry deciduous forests of Madhav National Park, Madhya Pradesh, India. Total biomass of the different forest communities ranged from 7.42 to 52.41 t ha⁻¹. Hall and Uhling (1991) estimated the biomass density of

Table 4.11: Comparative account of stand biomass of certain tropical forests of the

Forests	Location	Stand biomass			Source
		Above ground	Below ground	Total	
Tropical lower montane Rain	New Guinea	310	39	349	Edward and Grubb (1977)
Tropical wet	Cambodia	322	60	382	Hozumi <i>et al.</i> (1969)
Tropical wet	Global pattern	213-1173	11-135	269-1186	Murphy and Lugo (1986b)
Tropical Rain	Sarawak			210-650	Proctor <i>et al.</i> (1983b)
	India	420-649	14-20	434-669	Rai and Proctor (1986a)
	Thailand	295-371	31-33	326-404	Ogawa <i>et al.</i> (1965)
	Ghana	233	54	287	Greenland and Kowal (1960)
Tropical montane wet	Venezuela	347	73	420	Brun (1976)
Tropical Moist	San Carlos	340	56	396	Brunig <i>et al.</i> (1979)
		326	55	381	Folster <i>et al.</i> (1976)
	Global	316	11	327	Golley <i>et al.</i> (1975)
	Brazil Amazonia	377	104	481	Klinge and Herrera (1978)
	Ivory Coast	243	48	291	Muller and Nielson (1965)
Tropical Plantations	Puerto Rica	-	-	0.4-506	Lugo <i>et al.</i> (1988)
Tropical premontane Moist	Papua- New Guinea	286	46	332	Enright (1979)
	Zaire	320	51	371	Freson <i>et al.</i> (1974)
	Ivory Coast	431	24	455	Huttel and Bernhard-Reversat (1975)
Sub-tropical lower montane wet	Jamaica	279	65	344	Tanner (1980)
Sub-tropical wet	Eleverde Puerto Rico	237	116	353	Crow (1980)
	Global pattern	228	89	317	Jordan (1971a)
		198	73	271	Odum (1970)
Sub-tropical Moist	Thailand	253	10	263	Drew <i>et al.</i> (1978)
Sub-tropical Dry	Senegal	82	58	140	Jung (1969)
	Thailand	69	10	79	Ogawa <i>et al.</i> (1965)
	India	28	12	40	Vyas <i>et al.</i> (1977)
	Puerto Rico Guanica	53	45	98	Murphy and Lugo (1986a)
Tropical Dry	Global pattern	30-273	10-45	78-320	Murphy and Lugo (1986b)
	India	77	20	97	Singh and Mishra (1979)
	India	42-78	9-16	53-94	Singh and Singh (1991)
	India	78.38-406.38	11.99-66.22	90.38-468.58	Present study

Table 4.12: Comparative account of distribution of aboveground biomass in different tree components in certain forests

Forests	Location	Above ground biomass	Percentage distribution			Source
			Bole	Branch	Foliage	
Dry Sal	India	70.2	44	51	5	Singh, R.P. (1979)
Moist Sal	India	561	77	20	3	Singh and Singh (1989)
Tropical wet	Global pattern	216-1173	98.8*		1	Murphy and Lugo (1986b)
Tropical dry	Global pattern	30-273	97*		3	Murphy and Lugo (1986b)
Tropical dry deciduous	India	77	42	51	7	Singh and Mishra (1979)
Tropical dry	India	21-63	43-46	49-53	4-7	Singh and Singh (1991)
Tropical dry deciduous	India	78.38-406.38	32.90-36.62	45.88-50.31	3.39-3.69	Present study
Central Himalayan pine	India	113-283	76	19	5	Chaturvedi and Singh (1987c)
Central Himalayan oak	India	302	51	44	5	Rawat and Singh (1988a)

* Stems and branches are combined.

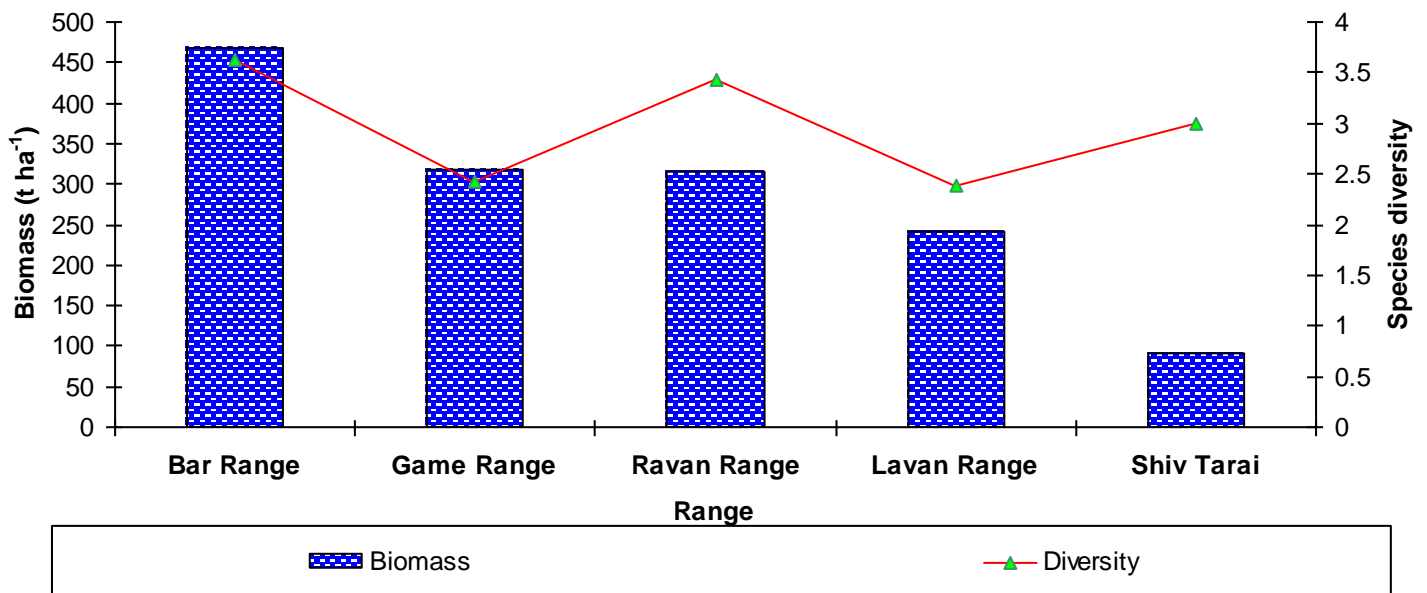


Fig. 4.2 : Relationship between biomass and species diversity

Table 4.13: Chemical properties of soil in various forest fragments

	Bar range	Ravan range	Lavan range	Game range	Shiv Tarai range
% Organic carbon	1.28	1.20	1.03	1.78	0.98
Available N (kg/ha)	165.0	155.0	128.0	364.08	260.0
Available P (kg/ha)	12.03	11.04	10.06	15.8	9.6
Available K (kg/ha)	206.0	198.01	170.02	620.0	430

forests in South and South east Asia using the volume estimates and biomass expansion factors derived from Brown *et al.*, (1989). Their biomass estimates for India ranged from 116 Mg ha⁻¹ for forest undisturbed for 60-80 years and 35, 66 and 84 Mg ha⁻¹ for logged, unproductive and managed forests, respectively. However, the present estimates were comparable to Murphy and Lugo (1986), where they reported 30 to 276 Mg ha⁻¹ above ground biomass for variety of dry tropical forests of the world. Tiwari (1994) reported average total above ground biomass density in different forest types of Rajaji National Park, Dehradun, India ranged between 52.36 t ha⁻¹ (Plantations) and 371.08 t ha⁻¹ (Sal forest).

CHAPTER-V

SUMMARY CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

Study on “Effect of forest fragments on species composition, species diversity and biomass in dry deciduous forest” was carried out in various forest fragments of 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 and Achanakmar-Amarkantak Biosphere Reserve (Achanakmar, Bilaspur Forest Division) which lies between 22⁰ 15' to 22⁰ 58' North latitude and 81⁰ 25' to 82⁰ 5' East longitude, having an area 3835.51 km², during the year 2005-2006.

The composition, structure and diversity of different forest fragments was conducted by randomly laying sample plots of 10 x 10 m² in size. Randomly 10 sample plots were down in each forest fragment. In each quadrat GBH (Girth At Breast Height) of each adult individual (> or = 9.6 cm gbh) were measured.

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 fragment. Biomass for each forest fragment was estimated using allometric equations based on the relationship between girth

of a tree and dry weight of component. The salient findings on effect of forest fragmentation on species composition, species diversity and biomass in dry deciduous forest are summarized below:

- A total of 8120 trees in all the forest fragments ha^{-1} representing 50 species and 23 families were encountered.
- BAR RANGE
- In Bar range *Terminalia tomentosa* was recognized as dominant plant species and *Cleisthenus collinus* as co dominant plant species.
- Maximum density was observed for *Cleisthenus collinus* (410 stems ha^{-1}) followed by *Terminalia tomentosa* (310 stems ha^{-1}) and *Lagerstroemia parviflora* (200 stems ha^{-1}).
- Maximum basal cover was observed for *Terminalia tomentosa* ($12.72 \text{ m}^2 \text{ ha}^{-1}$) followed by *Cleisthenus collinus* ($7.25 \text{ m}^2 \text{ ha}^{-1}$) and *Anogeissus latifolia* ($4.51 \text{ m}^2 \text{ ha}^{-1}$).
- Basal area and density of individual tree species varied between $0.02 \text{ m}^2 \text{ ha}^{-1}$ and $12.72 \text{ m}^2 \text{ ha}^{-1}$ and 10 and 410 stems ha^{-1} , respectively.
- Highest value of IVI was recorded for *Terminalia tomentosa* (53.67) followed by *Cleisthenus collinus* (40.72) and *Lagerstroemia parviflora* (23.29).
- The total density and basal area of Bar range was 2130 stems ha^{-1} and $50.90 \text{ m}^2 \text{ ha}^{-1}$.
- RAVAN RANGE
- In Ravan range *Cleisthenus collinus* was recognized as dominant plant species and *Diospyros melanoxylon* as co dominant plant species.

- Maximum density was observed for *Cleistenthus collinus* (850 stems ha⁻¹) followed by *Lagerstroemia parviflora* (280 stems ha⁻¹) and *Diospyros melanoxylon* (160 stems ha⁻¹).
- Maximum basal cover was observed for *Cleistenthus collinus* (8.54 m² ha⁻¹) followed by *Terminalia tomentosa* (4.99 m² ha⁻¹) and *Diospyros melanoxylon* (4.91 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.02 m² ha⁻¹ to 8.54 m² ha⁻¹ and 10 to 850 stems ha⁻¹, respectively.
- Highest value of IVI was recorded for *Cleistenthus collinus* (81.69) followed by *Diospyros melanoxylon* (33.24) and *Lagerstroemia parviflora* (27.29).
- The total density and basal area of Ravan range was 1930 stems ha⁻¹ and 37.21 m² ha⁻¹.
- LAVAN RANGE
- In Lavan range *Lagerstroemia parviflora* was recognized as dominant plant species and *Ougeinia oojeinensis* as co dominant plant species.
- Maximum density was observed for *Lagerstroemia parviflora* (340 stems ha⁻¹) followed by *Cleistenthus collinus* (200 stems ha⁻¹) and *Diospyros melanoxylon* (200 stems ha⁻¹).
- Maximum basal cover was observed for *Ougeinia oojeinensis* (8.76 m² ha⁻¹) followed by *Lagerstroemia parviflora* (7.76 m² ha⁻¹) and *Diospyros melanoxylon* (6.99 m² ha⁻¹).
- Basal area and density of individual tree species varied between 0.17 m² ha⁻¹ and 8.76 m² ha⁻¹ and 10 and 340 stems ha⁻¹, respectively.

- Highest value of IVI was recorded for *Lagerstroemia parviflora* (81.58) followed by *Ougeinia oojeinensis* (63.87) and *Diospyros melanoxylon* (63.15).
- The total density and basal area of Lavan range was 1030 stems ha⁻¹ and 30.02 m² ha⁻¹.
- GAME RANGE
- In Game range *Shorea robusta* was recognized as dominant plant species and *Terminalia tomentosa* as co dominant plant species.
- Maximum density was observed for *Shorea robusta* (1460 stems ha⁻¹) followed by *Diospyros melanoxylon* (150 stems ha⁻¹), *Terminalia tomentosa* (110 stems ha⁻¹) and *Caesalpinia sepiaria* (110 stems ha⁻¹).
- Maximum basal cover was observed for *Shorea robusta* (22.77 m² ha⁻¹) followed by *Terminalia tomentosa* (4.21 m² ha⁻¹) and *Miliusa tomentosa* (1.53 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.01 m² ha⁻¹ to 22.77 m² ha⁻¹ and 10 to 1460 stems ha⁻¹ respectively.
- Highest value of IVI was recorded for *Shorea robusta* (128.23) followed by *Terminalia tomentosa* (21.63) and *Miliusa tomentosa* (13.4).
- The total density and basal area of Game range was recorded 2640 stems ha⁻¹ and 37.75 m² ha⁻¹.
- SHIV TARAI
- In Shiv Tarai range *Diospyros melanoxylon* was recognized as dominant plant species and *Terminalia tomentosa* as co dominant plant species.

- Maximum density was observed for *Diospyros melanoxylon* (100 stems ha⁻¹) followed by *Buchanania lanzan* (80 stems ha⁻¹) and *Terminalia tomentosa* (70 stems ha⁻¹).
- Maximum basal cover was observed for *Diospyros melanoxylon* (3.43 m² ha⁻¹) followed by *Terminalia tomentosa* (1.47 m² ha⁻¹) and *Semicarpus anacardium* (1.30 m² ha⁻¹).
- Basal area and density of individual tree species varied from 0.01 m² ha⁻¹ to 3.43 m² ha⁻¹ and 10 to 100 stems ha⁻¹, respectively.
- Highest value of IVI was recorded for *Diospyros melanoxylon* (73.93) followed by *Terminalia tomentosa* (51.75) and *Buchanania lanzan* (47.25).
- The total density and basal area of Shiv Tarai range was 390 stems ha⁻¹ and 10.61 m² ha⁻¹.
- Density of trees in different forest fragments ranged between 390 and 2640 stems ha⁻¹. The over all density of trees was highest in Game Range followed by Bar Range, Ravan Range and Lavan Range. However, lowest density was recorded in Shiv Tarai Range.
- The basal area in different forest fragments ranged between 10.61 and 50.90 m² ha⁻¹. The highest basal area was recorded in Bar Range followed by Game Range, Ravan Range and Lavan Range. However, lowest basal area was recorded in Shiv Tarai Range.
- SPECIES DIVERSITY
- Shannon index in different forest fragments ranged between 2.39 and 3.62 and was highest in Bar Range and lowest in Lavan Range.

- Equitability (e) values ranged from 0.75 to 1.25, respectively in various forest fragments and was recorded highest in Shiv Tarai Range and lowest in Game Range.
- Species richness in various forest fragments ranged from 2.65 to 6.61 and was recorded highest in Game Range (6.61) and lowest in Lavan Range (2.65).
- Beta diversity values in various forest fragments ranged from 6.02 to 20.0 and was recorded highest in Shiv Tarai Range (20.0) and lowest in Bar Range (6.02).
- Concentration of dominance ranged between 0.12 to 1.0 and was highest in Bar and Game Range (1.0) and lowest in Ravan Range.
- BIOMASS
- The total biomass recorded in Bar Range was 468.58 t ha⁻¹ of which 406.38 t ha⁻¹ was above ground and 62.22 t ha⁻¹ below ground.
- Highest biomass was constituted by branch (233.74 t ha⁻¹) followed by bole (155.44 t ha⁻¹) and root (62.22 t ha⁻¹).
- Lowest biomass was constituted by leaf (17.20 t ha⁻¹).
- The bole, branch, leaf and root biomass constituted 33.17, 49.88, 3.67 and 13.28 %, respectively of the total biomass.
- The total biomass recorded in Ravan Range was 316.5 t ha⁻¹ of which 273.88 t ha⁻¹ was above ground biomass and 42.62 t ha⁻¹ below ground.
- Highest biomass was constituted by branch (158.05 t ha⁻¹) followed by bole (104.13 t ha⁻¹) and root (42.62 t ha⁻¹).
- Lowest biomass was constituted by leaf (11.70 t ha⁻¹).

- The bole, branch, leaf and root biomass constituted 32.90, 49.94, 3.69 and 13.46 %, respectively of the total biomass.
- The total biomass recorded in Shiv Tarai Range was 90.38 t ha⁻¹ of which 78.38 t ha⁻¹ was above ground and 11.99 t ha⁻¹ was below ground biomass.
- Highest biomass was constituted by branch (42.22 t ha⁻¹) followed by bole (33.10 t ha⁻¹) and root (11.99 t ha⁻¹).
- Lowest biomass was constituted by leaf (3.07 t ha⁻¹).
- The bole, branch, leaf and root biomass constituted 36.62, 46.71, 3.39 and 13.26 %, respectively of the total biomass.
- The total biomass recorded in Lavan Range was 242.42 t ha⁻¹ of which 207.13 t ha⁻¹ was above ground and 35.28 t ha⁻¹ was below ground biomass.
- Highest biomass was constituted by branch (111.22 t ha⁻¹) followed by bole (87.21 t ha⁻¹) and root (35.28 t ha⁻¹).
- Lowest biomass was constituted by leaf (8.70 t ha⁻¹).
- The bole, branch, leaf and root biomass constituted 35.97, 45.88, 3.58 and 14.55 %, respectively of the total biomass.
- The total biomass recorded in Game Range was 317.83 t ha⁻¹ of which 277.05 t ha⁻¹ was above ground biomass and 40.76 t ha⁻¹ below ground biomass.
- Highest biomass was constituted by branch (159.92 t ha⁻¹) followed by bole (106.33 t ha⁻¹) and root (40.76 t ha⁻¹).
- Lowest biomass was constituted by leaf (10.80 t ha⁻¹).
- The bole, branch, leaf and root biomass constituted 33.45, 50.31, 3.39 and 12.82 % respectively of the total biomass.

- Available N in various forest fragments ranged from 281.01 to 140 kg ha⁻¹.
- Available P in various forest fragments ranged from 5.13 to 14.8 kg ha⁻¹.
- Available K in various forest fragments ranged from 120.0 to 370.11 kg ha⁻¹.

The present study proved that forest fragmentation caused due to the disturbance created in the forest had significantly influenced the structure, composition, diversity and biomass status of dry deciduous forest. It reflects that dry deciduous forests of Chhattisgarh are ecologically rich as compared to other tropical forests of the world in terms of structure, composition and diversity. The increasing biotic interferences are degrading these forests and resulting in poor density, basal area and diversity. The study recommends adopting intensive conservation measures especially in degraded areas of the forest.

Perennial grasses, hardy trees and shrubs should be planted on steep slopes to reduce surface runoff, control soil erosion and to stabilize the degraded slopes. In order to encourage and improve regeneration in forests, the temporary closure is to be made at least for a period of 5-10 years. The silvipastoral system should be developed in open natural grasslands by planting MPTs and other palatable grasses to protect the forest area from overgrazing and browsing. The rotational grazing practices should be adopted in regenerating grasslands.

It is also suggested to practice alternate system of land management / agri-silvicultural practices in marginal, degraded and agricultural lands, which are accurately under utilized. These strategies will help in reducing the biotic

pressure and also restoring and conserving the fragile tropical dry deciduous forests of Chhattisgarh.

Therefore, the study suggests developing remote sensing and spectral response models for estimating structural attributes, basal area and biomass for local and regional scale applications. The use of Global Positioning System (GPS) for better understanding of forest dynamics at large spatial scale is recommended.

“Effect of Forest Fragments on Species Composition, Species Diversity and Biomass in Dry Deciduous Forest”

by

Dhiraj Kumar Yadav

ABSTRACT

In the present study an attempt was made to investigate the effect of forest fragments on species composition, species diversity and biomass in dry deciduous forest during the year 2005–2006. The study sites were located in Barnawapara wildlife sanctuary (North Raipur Forest Division) and Achanakmar-Amarkantak Biosphere Reserve (Achanakmar, Bilaspur Forest Division). The study was conducted in five different forest fragments of dry deciduous forest. The variation in composition, structure, diversity and biomass in different forest fragments were quantified. Biomass for each forest fragment was estimated using allometric equations based on the relationship between girth of a tree and dry weight of component. Trees in the sampling quadrates in each forest fragments were enumerated for their GBH.

A total of 8120 trees ha⁻¹ representing 50 species and 23 families were encountered in the study area. Phytosociological analysis in different forest fragments revealed that both biotic and abiotic factors significantly influenced the composition, structure, diversity and biomass of the forests. Density of trees in different forest fragments ranged from 390 to 2640 stems ha⁻¹. The over all density of trees were highest in Game Range followed by Bar Range, Ravan Range and Lavan Range. However, lowest density was recorded in Shiv Tarai Range. The basal area in different forest fragments ranged from 10.61 to 50.90 m² ha⁻¹. The highest basal area was recorded in Bar Range followed by Game Range, Ravan Range and Lavan Range. However, lowest basal area was recorded in Shiv Tarai Range.

Shannon index in different forest fragments ranged from 2.39 to 3.62 and was highest in Bar Range and lowest in Lavan Range. Equitability (e) values ranged from 0.75 to 1.25 respectively, in various forest fragments and was recorded highest in Shiv Tarai Range and lowest in Game Range. Species richness in various forest fragments ranged from 2.65 to 6.61 and was recorded highest in Game Range (6.61) and lowest in Lavan Range (2.65). Beta diversity

values in various forest fragments ranged from 6.02 to 20.0 and was recorded highest in Shiv Tarai Range (20.0) (highly disturbed) and lowest in Bar Range (6.02) (least disturbed). Concentration of dominance ranged between 0.12 to 1.0 and was highest in Bar and Game Range (1.0) and lowest in Ravan Range. It was observed that the forests close to habitation were more severely affected by the prevailing biotic factors than the forests located at distant areas, thus resulting in fragmentation of forests. The stem density was highest (2640) at least disturbed site and lowest (390) at highly disturbed site.

The total biomass ($t\ ha^{-1}$) recorded among the different forest fragments was maximum in Bar Range (468.58) followed by Game Range (317.83), Ravan Range (316.5) and Lavan Range (242.42) and minimum in Shiv Tarai Range (90.38). The higher proportion of above ground biomass was allocated to branch followed by bole and leaf in different forest fragments. The above ground biomass in different forest fragments ranged between 78.38 to 406.38 $t\ ha^{-1}$ with highest in Bar Range and lowest in Shiv Tarai Range. The below ground biomass in different forest fragments varied from 11.99 to 62.22 $t\ ha^{-1}$ and was highest in Bar Range and lowest in Shiv Tarai Range.

% Organic carbon in various forest fragments ranged from 0.72 to 1.78 %. Available N ranged from 281.01 to 140 $kg\ ha^{-1}$. Available P ranged from 5.13 to 14.8 $kg\ ha^{-1}$. Available K ranged from 120.0 to 370.11 $kg\ ha^{-1}$.

From these observations, it is evident that as a result of fragmentation caused due to the increasing pressure of human population and their increasing demands for fuel wood, fodder, timber and various non-wood forest products there is a great impact on structure, composition, diversity and biomass of forests. Efforts are needed to regulate the biotic pressure in the vicinity of dwellings and protecting the forests would go a long way in rejuvenating the lost forest ecosystem.

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a



b

Plate 3.1: A view of mixed forest



a



b

Plate 3.2: A view of degraded forest



Plate 3.3 (a) : Dense mixed forest



Plate 3.3 (b) : Sal mixed forest