

**“SPECIES COMPOSITION, REGENERATION AND
DIVERSITY OF TREE LAYER ALONG THE
DISTURBANCE GRADIENT IN TROPICAL DECIDUOUS
FOREST OF UDANTI WILD LIFE SANCTUARY”**

M.Sc. (Forestry) THESIS

by

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INDIRA GANDHI AGRICULTURAL UNIVERSITY
RAIPUR (C.G.)**

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CERTIFICATE – I

This is to certify that the thesis entitled **“SPECIES COMPOSITION, REGENERATION AND DIVERSITY OF TREE LAYER ALONG THE DISTURBANCE GRADIENT IN TROPICAL DECIDUOUS FOREST OF UDANTI WILD LIFE SANCTUARY”** submitted in partial fulfilment of the requirements 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 **DEEPAK M.S.** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

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

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CERTIFICATE - II

This is to certify that the thesis entitled “**SPECIES COMPOSITION, REGENERATION AND DIVERSITY OF TREE LAYER ALONG THE DISTURBANCE GRADIENT IN TROPICAL DECIDUOUS FOREST OF UDANTI WILD LIFE SANCTUARY**” submitted by **DEEPAK M.S.** to the Indira Gandhi Agricultural University, Raipur in partial fulfilment of the requirements for the degree of **M.Sc. (Forestry)** in the **DEPARTMENT OF FORESTRY** has been approved by the Student's Advisory Committee after an oral examination in collaboration with the external examiner.

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LIST OF ABBREVIATIONS

Abbreviations	Description
%	Per cent
^o C	Degree Celsius
Cm	Centimeter
<i>et al.</i>	And others/ co-workers
Fig.	Figure
N	Nitrogen
P	Phosphorus
ha ⁻¹	per hectare
i.e.	That is
K	Potassium
GPS	Global Positioning System
m ²	Square meter
CG	Chhattisgarh
DBH	Diameter at breast height
∑	Summation
<i>viz.</i>	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). Political and scientific concerns have been raised as we are experiencing an increase in species extinction rates caused by anthropogenic activities (Ehrich and Wilson, 1991). Many kinds of environmental changes influence or determine process that can both augment and erode diversity (Sheil, 1999). 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).

Sheil (1999) opined that the disturbance of a suitable intensity would increase species richness in old growth communities in consonance with intermediate disturbance hypothesis of Connell (1978), however, others believed that disturbance can not increase diversity in genuine old growth forest (e.g. Phillips *et al.*, 1997). The diversity disturbance debate need future work. Information along disturbance gradient on species distribution, dispersion, stand structure and species diversity in dry tropical forest is lacking.

Prior to forest management operations, biodiversity inventory 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).

The dry tropical forest accounts for 38.2% of the total forest cover of India (MoEF, 1999), which is largely threatened by lopping, burning, overgrazing and clearing for cultivation (Jha and Singh, 1990). Because of these threats since past several decades the dry deciduous forest in most part of the central India is being converted into dry deciduous scrub, savanna and grasslands which are progressively species poor (Champion and Seth, 1968).

India has a total land cover of 329 million ha of which 43% is under cropping and 23% is classified under forests (Ministry of Environmental and forest 1999). Barren lands, land under non-agricultural use, and cultivable wastelands constitute 74.8 million ha. The National forest policy of India (1952) stipulated that India as a whole should aim at maintaining one third of its total land area under forest for securing ecological stability, but forest cover at present is 67.5 million ha, or only 22.55% of the land area (Forest Survey of India 2001).

Most forests in India have been disturbed significantly through logging, clear felling, grazing, fire, and the collection of fuel wood, fodder and non timer forest products. Thus most remaining forests in India are secondary, primarily post-extraction secondary forests arise after significant disturbance through large scale and small scale extractive activities. Post-extraction secondary forests are

defined here as “forests regenerating largely through natural process after significant reduction in the original forest vegetation through tree extraction at a single point in time or over an extended period and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites” (Chokkalingam *et al.*, 2000).

Also, large scale plantation or rehabilitation programmes were undertaken in the recent past allowing for natural regeneration and have resulted in an increase in the area of rehabilitated secondary forests. Rehabilitated secondary forests are defined as “forest regenerated largely through natural processes on degraded lands, often aided by rehabilitation efforts or the facilitation of natural regeneration through measures such as protection from chronic disturbances, site stabilization, water management and planting (Chokkalingam *et al.*, 2000). It is estimated that secondary forest occupies about 32 million ha land constitute about 45.8% of the forest area of the country (Chaturvedi 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% of the world’s land area and 1.8% of the global forest area, but supports 15.6% of the world’s human population and 14% of the livestock population. It has large rural population of nearly 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 forest are very important for the supply of fuel wood raw materials for rural hand crafts 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.

With the passing of forest conservation act of 1980, which banned forest clearing, forest conservation pressures for agriculture and other infrastructural facilities were reduced. However, remaining natural forest (mostly secondary) continued to be subject to increasing local extraction pressure with growing population and growing industrial and urban demand for forest products. Large forest cover are degraded and converted into barren land as a result (Ravindranath & hall 1994). In the recent past, India has launched a massive afforestation programme, one of the largest in the tropics (Ravindranath & Hall 1995), which has led to increased secondary forest formation through the promotion of natural regeneration in plantation and community controlled areas.

Forest structure, composition and regeneration are strongly correlated with environmental factors, such as climate, topography and biotic factors. Studying the composition and diversity of tropical deciduous forests and its habitat and comparing with similar habitat types, perhaps becomes the yardstick to judge the level of adaptation to the environment and the ecological significance.

This will enable the development of appropriate management strategies to reduce the pressure and sustainable use of the remaining natural forests and to recover and maintain the country's environmental health and ecological stability through the reforestation of degraded lands.

Presently there is dearth of information on quantitative and qualitative pattern of forest communities as well as impact of human influence on vegetation status of tropical deciduous forest in Chhattisgarh.

No reports are available on structure, composition, regeneration and diversity, and no attempt was initiated to understand the variation due to human disturbance on vegetation in tropical deciduous forests. In view of this the present study entitled “Species Composition, Regeneration and Diversity of tree layer along the disturbance gradient in tropical deciduous forest of Udanti wildlife sanctuary”, was under taken to quantify the variation in composition, regeneration and diversity of trees in different forest types. Attempt were also made to determine the effect of human disturbance on composition, regeneration and diversity of trees.

The study was carried with following objectives:

1. To study the tree diversity in Udanti wildlife sanctuary.
2. To study the human interference in forest of Udanti wildlife sanctuary.

CHAPTER-II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work done on Species composition, Regeneration and Diversity of tree layer in tropical deciduous forest. The variation in composition, regeneration and diversity in tropical forest due to human disturbance were also reviewed. Due to lack of sufficient information on few aspects, the similar types of studies carried in other forest ecosystem are also cited. The literature is broadly reviewed under the following major aspects.

1. Composition, regeneration and diversity in forest
2. Variation in diversity due to human disturbance.

2.1 Composition, regeneration and diversity in forest

Danseroan *et al.* (1968) defines vegetation structure as the organisation in space of the individuals that form a stand (and by extension of a vegetation type or plant association) and he stated that primary elements of structure are growth form, stratification and coverage. The structural attributes of plant community can be expressed both in qualitative and quantitative characters. The qualitative characters are physiognomy, phenology. Stratification, abundance, dispersion, sociability, vitality and life form whereas quantitative characters include density, frequency, dominance and basal area (Odum, 1983). These quantitative primary variables are used for deriving secondary variables and Importance Value Index (IVI) of a species in a given community.

Champion & Seth (1968) identified five major forest groups in India viz. tropical, subtropical, Montane temperate, sub alpine and alpine vegetation, which are further divided into forest types and sub type based on the ecological and bioclimatic characteristics. These vegetation types have a characteristic physiognomy, density, phenology, stratification etc. However, the structural heterogeneity at type level needs further characterization in terms of community pattern, species diversity and density, when the process level understanding is required at patch or landscape levels. According to him 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.

In group 3:

- (i) 3B / C1c slightly moist teak forests
- (ii) 3C /C2e moist peninsular sal forests
- (iii) 3C/C3 moist mixed deciduous forest

In group 5

- (i) 5 B/C1C dry peninsular sal forest
- (ii) SB/C2 northern dry mixed deciduous forest.

In group 8

- (i) 8A/C3 Central Indian sub tropical hill forest.

Chhattisgarh is second densely forested state of the country after Assam since as it has 46 per cent of forest cover of its total area which is more than 33 per cent of forest cover as recommended by National Forest policy. The state is well known in the country for its sal forests which occupy nearly 36 per cent of

total forest cover. Teak forests are also abundant but mainly in western and southern parts of the state (Kumar, 2003).

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 45000 species which accounts for 15 per cent of the known world plants. Of the 15,000 species of flowering plant 35 per cent are endemic and located in 26 endemic centers. Among the Monocotyledons, out of 588 genera occurring in the country, 22 are strictly endemic (Agrawal, 2000).

In Chhattisgarh, so far only four species are endemic e.g. *Stauragyne perpusilla* (Henry and Balakr), *Maytenus bailadillana* (Narayan & Mooney), *Eriocaulon rajendrababui* Ansari and Balakr and *E. raipurensis* Khanna, An analysis has pointed out that about 480 taxa are rare in the state (Jha, 2003).

Singh and Singh (1991) studied the species composition and diversity index in mixed dry deciduous forests of Vindhyan region. The basal cover of vegetation varied from 3.8 to 10.4 m² ha⁻¹ for trees and 3.1 to 7.8 m² ha⁻¹ for shrubs. Shannon and Weiner index and concentration of dominance ranged between 1.93 to 2.18 and 0.18 to 0.38, respectively. The beta diversity was 3.1

Topographic factors modify the microclimate and edaphic conditions of a site and responsible for determining the status of vegetation in a given habitat (Cook *et al.* 1989). Kusum Latha and Bisht (1991) reported that phytosociological characters differ among aspect and position even in the same vegetation type. They observed 0.22 to 0.58 concentration of dominance in oak forests and from

0.21 to 0.26 in Chirpine forests in different aspects of Himalayas. Dhanai and Panwar (1999) reported the marked effect on species diversity in *Quercus floribunda* forest of Garhwal Himalaya, India. It was observed that highest diversity (0.52) in tree layer was found in slopes. Similarly, the effect of slope on structure and diversity of vegetation was also quantified by several workers (Joshi & Tiwari, 1990; Singh *et al.*, 1991; Swamy, 1998; Jha, 2001). 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 different distances from habitation in sal and teak forest in four districts of Madhya Pradesh, India. The forest with in 0.5 km radius of habitation recorded lower diversity and dominance compared to forest with in 5 km radius of habitation.

Verghese and Menon (1998) conducted studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India through quadrat sampling method. The stand density, species density and basal area of these forests were 535 trees/ha, 12 species per 0.1 ha and 26.57 /ha, 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.

Shi and Singh (2002) assessed the status of worlds remaining closed forest population distribution and protected areas in global biodiversity hot spots. They estimated the worlds remaining closed forests were 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 spots 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, Srilanka, Polynesia and Micronesia, Philippines and Caribbean hot spots.

Jha and Singh (1990) analysed the dry tropical forests of India and recognized five predominant plant communities. The environmental relationships of these community types were analysed through discriminate analysis. The study showed the importance of soil texture in determining the distribution of these communities.

Dry deciduous type of vegetation is made up of a small distinctive set of species. Many of them are exclusive to this type. Some of the species characteristic of this type includes *Anogeissus latifolia*, *Lannea coromandeica* and *Lagerstroemia parviflora*. This type of vegetation is characterized by lowest tree densities, lowest levels of diversities, highest levels of distinctiveness and lowest levels of hospitality and ubiquity. The unfavorable dry and hot climate permits only a limited number of trees species to co-exist. The species that inhabit this zone are all well adapted to harsh environment and hence in all probably co-evolved over long time periods (Homji, 1989).

According to UNESCO classification system moist deciduous forest is forest with moderate, 10-20 m tall trees, closed but not very dense canopy (40-70%), 0 to 40 per cent trees are evergreen. The deciduous tree mostly shed their leaves earliest. The leaves are mostly thin, pale green, undergrowth contains many herbaceous species sometimes, once encounters extensive growth of weed like Lantana, Eupatorium, lianas are very few.

Heinrich (2000) analysed the plant species diversity and composition of life form categories in tropical dry forest in Northwestern Costa Rica. Where the

different ages of secondary regeneration ranging from recently cleared and burned to more than 50 year of regrowth. All vascular plant species encountered were recorded during 30 months. The results documented great changes in species diversity and composition of plant form categories during regeneration. 328 plant species in 79 families & 247 genera of grasses, herbs, shrubs lianas and trees were, encountered. Species richness was greatest after 15 years and decreased significantly in older plots. The number of non-woody species was highest after 3 years of succession. Minimum of woody plant species was after one year and increased significantly after 5 years. Maximum was in the 15 years plots with a slight decrease.

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 groves where he recorded 33 plant species from 251 genera belonging to 110 families. In which 108 belonging to angiosperms and two to gymnosperms. Forest was rich with 139 sp of trees, 95 shrubs, 79 herbs and 16 lianas and climbers. 54 species are listed rare, endemic and threatened.

Negi (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 were 1010-1230 stems ha^{-1} in different compartment. Total basal covers of tree species ranged from 49.39 m^2/ha to 64.74 m^2/ha across compartment. Density of sapling ranges between 690-770 saplings/ha. 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. The value of Beta diversity was 1.42, 1.32, 1.16 and 1.30 for trees, saplings, seedlings and shrub layer, respectively.

Pande (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 Western Himalayan forests of Chakrate forest division (Uttaranchal). The density of the forest range for tree species (plant 100 m⁻²) was 4.51-6.64 for shrubs, 23.56-41.62 and 7280-11920 for herbaceous species, while the range for total basal cover 0.332-0.938 (m² 100 m⁻²) for trees; 9.50-18.81 cm²/100 m² for shrubs and 235-323 cm²/100 m² 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 and it 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, 3.8 and 1.2 for herbs.

In several temperate forests the value of total basal cover and density were 0.15-0.6 m²/100m² and 3.2-20.8 tree/100 m², respectively (Saxena and Singh 1982, Ralthan *et al.*, 1982, Singh *et al.*, 1997). The same ranges from 0.11-0.68 m²/100m² and from 5.5-18 trees/100m² for tropical forests (Visalakshi 1995, Parthasarathy *et al.*, 1992). The diversity values reported in temperate forest were between 1.16-3.4 by many workers.

Khanduri conducted study on forest composition and socio economic status of villages of Garhwal Himalayas. The rate of exploitation of forest

resources was verified by vegetation analysis where no regeneration has been recorded from all the adjacent forests for the selected villages. The total basal cover of all the species was 76.47 m²/ha as highest and lowest as 46.94 m²/ha. The values of diversity vary from 0.33-2.95. The value recorded for concentration of dominance were 0.14 to 0.56. It is apparent that the diversity increased with increased in species richness. The CD value for oak forest from Kumaun Himalaya was reported as 0.11-0.93 in the tree layer (Tiwari and Singh, 1985).

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, 114 to 714.95 for shrubs and 15905 to 102078 plant ha⁻¹ for herbs layer. Whereas the range for dominance was 9570 to 217333 cm²/ha for trees, 2912 to 32462 cm²/ha for shrubs and 1304 to 218468 cm²/ha for herbs.

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 in 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 and 10000 to 45000 cm²/ha respectively (Mosang, 1991), Pandey (2001) reported density and dominance (cm²/ha) as 690-1630 and 95643-155480 for closed canopy tropical dry deciduous teak forests of Satpura plateau.

Shannon Wiener diversity indices are generally higher for tropical forests, that ranges between 0.81-4.1 for the Indian sub continent (Singh *et al.*, 1984, Parthasarathy *et al.*, 1992, Visalakshi, 1995, Pande 1999, 2001). Vishalakshi (1995) reported Shannon Wiener diversity ranged between 0.83 and 2.43 for

Marakkanam reserve forest in south India. The value reported by Rajarathnam (1990) and 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 1.19-1.89 for shrubs. The value of concentration of dominance (Cd) for tropical forest lie with in the range of 0.21 to 0.92 (Bisht, 1989, Parthasarathy *et al.*, 1992; Visalakashi, 1995). Pandey (2005) analysed the vegetation in nine forest villages in M.P. where highest tree diversity was recorded (1.19) at highly disturbed site, concentration of dominate showed reverse trend to diversity index concluded that disturbances adversely affect of the regeneration and composition of different tree species at different sites. Tripathi (2004) studied the distribution and community characteristics in subtropical pine forests of Meghalaya. Altogether 174 species belonging to 139 genera and 77 families were recorded in different altitudes. The species rich ness (7.69), diversity (4.13) and evenness indices (0.26) of the three life forms (Tree, shrub, herbs) were maximum in the high elevation stand and minimum in the low-elevation stand. Species diversity in the stand was positively correlated ($r = 0.92$, $P = 0.001$) with annual rainfall and negatively ($r = -0.93$, $P = 0.001$) related to the temperature. The dominance of pine was positively correlated ($r = 0.89$, $p = 0.001$) with temperature but negatively correlated ($r = -0.89$, $P = 0.01$) with mean annual rainfall. The tree density varied between 810 and 1050 stem ha^{-1} and basal covers from 28.9 to 37.4 $\text{m}^2 \text{ha}^{-1}$.

Behera *et al.* (2002) compared the structure and composition of subtropical pine with subalpine coniferous forests. The study revealed that the total numbers of species, genera and families observed for subalpine coniferous

forest was found to be higher than that for subtropical pine forest. In case of subalpine coniferous forest a total of 40 species belong to 22 families and 32 genera and in subtropical pine forest, a total of only 23 species belong to 18 families and 19 genera were found. Margalef's index for species richness showed higher value (43.21) for subalpine coniferous forest. Simpson's index was higher (0.78) for subtropical pine forest in comparison with subalpine forest. Shannon-weaver index of species diversity was higher for subalpine forest (5.82) in comparison to subtropical pine forest (3.25).

Ipor (2002) investigated the floristic composition of mixed Dipterocarp forest of Mahua crockar Range National park. The species composition was moderately diverse. It has a total of 44 species where importance value of tree species revealed that *Duabanga molukana* (24.54), *Knlma ashtonii* (14.87), *Agathis lanecolata* (12.68), *Lithrocarpus cantleyannur* (12.3) and *Litsea ochracea* (9.9) were dominant species and *Shorea maxwelliana*, *Alseodaphne inignis*, *Litsa resinsa*, *Litsea Malchilifolar* and *Alseodephne foxiana* were found to be endangered.

2.2.1 Variation in diversity due to human disturbance

There is an alarming threat to life supporting 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. During last few decades the tropical ecosystem have severely affected by the anthropogenic disturbances like large scale deforestation and demonstration, resulting in fragmentation of habitats and loss of rich diversity (Stoms and Estes, 1993). Sal (*Shorea robusta*

Gaertn.f. family Dipterocarpaceae) forms most extensive forests in the Central and Northern parts of India. Occupying about 116000 km² or about 14.2 per cent of the total forest in India. It is regarded as the climax species in several regions (Champion and Seth, 1968). India depends largely on fuel wood for meeting domestic energy needs. In India Fuel wood are expected to increase from the previous figure of 250 million m³ to 310 million m³ by the year 2010 (Ministry of environment and forest 1999). Nearly 35 million ha of forests experience annual burning in India. Most states experience fire on nearly 50 per cent of their forest area (Ministry of Environment and forest 1999). Fires are mostly low intensity ground fires causing little or no damage to trees or the canopy and thus not giving rise to dense forest there, whereas low intensity fires affect the regeneration of forests and lead to forest degradation (Bhat, 2001).

India has the largest livestock population in the world, estimated at 445 million in 1990. It is estimated that in 2010 it would exceed 5 million, of these 270 million cattle grazed on forestland, leads to its degradation.

Encroachment and its legalisation have been major problems in India. It is estimated that 1.5 million ha of forestland has been encroached since 1997 (Forest Survey of India, 1999).

Jons (1997) indicated that the human influence is spreading comprehensively and simultaneously in virtually all forests. The greatest impact has been in forest clearing, both to create new agricultural lands and to harvest valuable timber. Studies on the impact of logging practices on tropical forest ecosystems and biodiversity indicated that logging of mature forest commonly leads to a local increase in species diversity as structural and associated

microclimate that changes create patches of habitat and food resources attractive to species typically live in secondary forest and on forest edges. Population of many species that typically live in the forest understory markedly decline and remain locally low or absent for many years. (Johns, 1997). The most appropriate way to manage tropical forests for producing timber, without losing other values, is to have small undisturbed forest areas preserved within a larger matrix of production forest.

Conserving forest biodiversity at the ecosystem level helps to support services such as maintain the balance of atmospheric gases, recycling nutrients, regulating climate, maintaining hydrological cycles and creating soil (Daily, 1997) 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 adopt to changing conditions (Jonson *et al.*, 1996).

Scheffer (2001) indicated that even gradual changes in climate, the flow of nutrients extraction of natural resources and habitat fragmentation could lead to sudden drastic switches in the character of a forest ecosystem. Many different factors can lead to such shifts; a critical factor is a loss of Resilience (the ability to recover from external events) through declining biodiversity at ecosystem level.

McNeely (2002) showed evidence which indicate all forests on the planet have been substantially influenced by humans, most for at least several thousands years. Studies by foresters, ecologists, historians and anthropologists on forests in

tropical, temperate & boreal regions conclude that forests and people have evolved together over thousands of years, with people planting the trees they prefer, using fire to burn forest to improve hunting conditions and managing forest fallows to maintain their agricultural fields. Forest is part of the human landscape.

In Northern Alberta, regularly and systematically burned habitats influences the local distribution and relative abundance of plant and animal resources, which created an overall fire mosaic that characterizes the northern boreal forests (Lewis and Ferguson, 1988).

Density of trees and their regeneration in the forest are largely dependent on the response of the seedling and saplings to the forest microenvironment and interactive influence of an array of biotic and abiotic factors (Umashankar 2001, Mishra *et al.*, 2003).

The absence of young tree in the stand could be attributed to their cutting by local inhabitants for firewood. Where chopping, annual surface fire and trampling by grazing cattle were major biotic stress. The regeneration was poor due to the absence of both seedling and saplings. The keen competition offered to seedlings by the overhead broad leaved tree for light and by the dense undergrowth for nutrients appears to be the main reason for the absence of shade intolerant saplings.

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 is 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 turnover of tree species was recorded between site I and III (5) and lowest at site II & V (0.25). The range for turnover of shrub layer was 0.60 (site II & IV) – 3.33 (site I & III) while herbs were ranged between (I-V) to 6.5 (site IV & V). He noticed that not only disturbance and stand age affect the sal regeneration due to invasion of new competitors at seedling and sampling 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.

Pascal (1988) analyse the Kan forest of Karnataka plateau for floristic composition and noticed structure change due to exploitation. The diversity of the forest range for the tree species was 40.6 – 70 m²/ha. The number of species varies from 480-960/ha. Simpson's index varies from 0.86 to 0.92. Shannon Wiener's index of diversity values varies from 3.5 to 3.82.

Gupta (1991) analysed the forest vegetation of Gorakhpur division consists of mainly sal plantations. Basal covers of the trees species varied from 52.0 to 50.0 m²/ha, 1.2-1.4 m²/ha for shrubs and 0.04 to 0.006 m²/ha for herbs, and density varies from 12.9 to 19.1 for trees, 16.9-20.3 for shrubs and 17 to 46 for

herbs. Species diversity index (H) varies from 1.02-1.2 and dominance varies from 0.067-0.13.

Visalakshi (1995) analysed 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 2 stands was 280 ha⁻¹ in RF and basal area 11.0 m²/ha. In SG stand density was 1130 stems/ha and basal area 36.9 m²/ha. The Shannon Wiener index for RF & SG site was 2.19 and 1.78, respectively.

Panchal (2004) analysed the total tree vegetation of Rampare forest in which the total tree cover ranged from 180 to 3326 cm³/ha. The composition of tree and shrub layers was markedly similar among various sites. Site I supported the largest shrub population while site II was the poorest in this regard. Site I on density basis and site II on cover and IVI basis has maximum diversity of tree species on the whole.

Singh *et al.*, (2005) have compared the diversity and dominance of pure sal and degraded moist forest of Achankmar wild life sanctuary. The pure sal forest was characterized by high trees (1233 stems ha⁻¹) and under story vegetation densities (1575 stems ha⁻¹) as well as basal cover (36.36 m² ha⁻¹, under story 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 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 (richness index) and 0.78 (equitability index).

In many ways the open evergreen vegetation type resembles the semi evergreen. This is related to the fact that most of the open evergreen forests are the result of selective logging a few decades ago (Pascal 1988 and Chandran, 1993). Hence, it shows a few large openings in the canopy, extensive in earlier canopy gaps and scarcity of trees with large girth. The vigorous colonization of once logged evergreen forests by pioneer species, including a few deciduous ones, are lead to a higher level of packing of species, several of which do not co-occur normally. This results in the high hospitality and observed ubiquity is rather low as the species mostly belong to those of evergreen forests with narrow distribution. As Chandran (1993) and Pasal (1988) have shown, this forest may later progress towards more stable, less diverse composition. Species characteristic of this type include *Artocarpus hirsutus*, *Hopea pariflora* and *Holigarna arnottiana*.

Rawat (1999) compared the woody vegetation structure and composition of forests across the Shivaliks, Doonvally and outer Himalaya in Dehradun District. North West India was studied using stratified random plots. The richness of woody species was highest in Shivaliks (62) followed by Doonvally (56) and outer Himalaya (54). The pole size (10-20 cm) girth class formed about 4 per cent of the population. Outer Himalaya had significantly higher density of sal saplings (<10 cm girth class) compared to Shivaliks (paired $t=2.62$) and Doonvally ($t=2.29$) but the rest two zones were similar in sapling density. Sal

attain highest girth in Doonvalley ($X=126.2 \pm 12.3$ cm) and lowest in the outer Himalaya ($X=56 \pm 6.4$ cm), with in Shivaliks. The tree density varied among 254 - 253.9 ha^{-1} and outer Himalayas 643.7 - 257.7 ha^{-1} . Areas disturbed due to lopping and cutting particularly in Doonvalley, diversity index was 1.39. Outer Himalayas were dominated by *Lantana camara*. Though it seem to protect sal seedling from forest and other injuries.

Kadavul (1999) studied the species richness, density and population structure of all trees inventoried in four 1 ha plots of semi-evergreen forest 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 sp/ha. Shannon index from 2.31 to 2.87 and stand density from 367 to 667 stems/ha, mean stand basal area was 33.6 m^2/ha . *Nothopegia heyneana* and *Celtis philippines* were dominated and contributing 50 per cent of total density. Species richness and density decreased with increasing tree girth.

Bhygan (2001) investigated four stands of tropical wet evergreen forest in Arunachal Pradesh. The forest 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 indiaca*, *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, whereas no regeneration was recorded in the highly disturbed stand.

Elouard (1997) established a permanent experimental station in a dense moist evergreen forest of Western Ghats. Two forest compartment of 28 ha each were monitored to study the impact of selective logging in the once logged compartment and the forest structure and dynamics in the other undisturbed compartment. The density (635 trees > 30 cm gbh/ha) basal area (39.7 m²/ha) and diversity (Simpson's D=0.92 and Shannon H¹=4.56) and degree of endemism (48%) were high.

Brokaw (1997) distinguish 73 different species in 31 families among the 359 trees in 1 ha plot in the Duebrade de ore valley, Central America, where 0.0359 stems per square meter was obtained. Total basal area of these trees was 32.81m²/ha.

Gunasekara (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.

Rao (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 (955cm) was found in core zone where as highest regeneration was found in periphery zone.

Shrestha (2000) analyse the vegetation of natural and degraded forests in Chir pine in Siwalik region of Central Nepal. Where a total number of species vary from 39, 10 and 15 for Natural forest, degraded forest and regenerating mixed forest, respectively. Where the density of natural forest was high (264 /ha) compared to the degraded forest (23/ha). Basal area of natural forest was 59.6 m²/ha and degraded forest was 11.4 m²/ha. Seedling density reported high in natural forest was 8649 ha⁻¹ compared to degraded 1830 ha⁻¹.

Adhikari (1991) studied the high altitude forest communities distributed within 2150-2500 m elevation in Kuman Himalaya. Total density and basal area for three layer varied from 320 to 1600 stems/ha and 44 to 98 m²/ha, respectively where *Chimonobambosa falcate* was dominant shrub species in most of the stands. Diversity for tree layer and shrub layer ranged from 0.81 to 3.55 and 0.05 to 1.33 respectively.

CHAPTER – III

MATERIALS AND METHODS

The study on “Species composition, regeneration and diversity of tree layer along the disturbance gradient in tropical deciduous forest of Udanti Wild Life Sanctuary” was carried out at Garhiaband Forest Division in Raipur district (C.G.) during 2004-2005. The details of the study site, climate, geology, soil, forest, flora, fauna & other features of land along with the methodologies adopted for the above mentioned studies are described below.

3.1 Study Site

The Forest types of the area represent tropical deciduous forest on Udanti river, situated about 160 km from Raipur on Orissa border. It was notified as Wild Life Sanctuary in the year 1985 with an area of 247.28 sq. km. More than 80% area is covered by different forest types.

3.1.1 Geographical location and physiography

The study was conducted in Udanti Wildlife Sanctuary situated in Raipur district, Chhattisgarh. It is located in Central India between longitude 80° 30' East to 82° 0' East and latitude 20° 01' North to 20° 15' North. The forest type is tropical dry deciduous comprised of *Shorea robusta*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Cleistanthus collinus* and other associated species. It falls in biogeographic zone 6 E of Rodgers and Panwar (1988). The location of study area and base map showing important places and road network are depicted in Figs 3.1 and 3.2.

The general topography reveals that most of the peripheral area of the Sanctuary is Hilly, while the middle area has plain to gentle slope to undulating slopes. The area is comprised of rock out crops in some places also. The study area is comprised of deciduous forests, grasslands, agriculture lands and human habitations. All villages in the forest are categorised as forest villages and majority of them are accessible through Kaccha roads, which is motorable only in dry season. Road network is absent in few hill tracts, which are inaccessible due to steep slopes and wetlands.

3.2 Climate

The climate of study area is tropical. Total annual rainfall is 1402 mm. More than 80 per cent of the rainfall occurs during monsoon season from mid June to September. Number of rainy days varies from 80 to 90 with an occasional rainfall during October to February. Mean monthly minimum and maximum temperature varies from 11.5 °C and 41.1 °C. The maximum temperature goes beyond 45 °C in May and minimum below 10 °C in December. Relative humidity is generally higher (82 %) in July and August whereas, minimum (29 %) in May.

3.3 Geology

The main composition of the study area has Dolestic Sand stone, lime stone and Conglomerates Granite type. In some places near the village Pahelikand valuable diamond mineral deposit is also reported.

3.4 Soils

Soils is mostly sandy loam, which is deep at valley and shallow on slope. Murrum soil is found only in patches in plain areas of the sanctuary. Soil erosion and gully formation at various places especially in plain area is usually common.

The soil colour varies from black, grey to reddish. On the other hand, this soil having good water holding capacity and supporting rich vegetation. Some of these lands are utilized for cultivation of Agricultural crops.

3.5 Water resources

The channels are more or less filled during the monsoon season. The majority of bigger channels flow from south west direction to north east direction. The hilly terrain of study area forms few important catchments. The water from different catchments collects in the Udanti river, which ultimately joins in Mahanadi river. Many village made ponds and natural ponds do exist.

3.6 Forest Types and Flora

Different types of forest vegetation occurs in the study area. Champion and Seth (1968) have classified the forest vegetation of the area into two major forest types viz., (1) Dry Peninsular Sal forest (5 B/c Ic (iv)), (2) Northern Dry mixed deciduous forest (5 b/c 2(ii)). The predominant woody flora found in these forests are *Shorea robusta*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Cleistanthus collinus*, *Tectona grandis*, *Boswellia serrata*, *Buchanania lanzan*, *Dalbergia paniculata*, *Diospyros melanoxylon*, *Emblica officinalis*, *Bauhinia vahlii* etc. In understorey *Woodfordia fruticosa*, *Ziziphus sp.*, *Phoenix acaulis*, *Nyctanthes arbortristis* are commonly found. Among Poaceae many important grasses of 26 types are present. Forest mainly contains 85 tree species. 28 species of climbers, 28 species of shrubs and herbs, 26 grasses and bamboos. Several Ferns, Bryophytes and algae have also been observed in the study area.

3.7 Fauna

Different species of mammals, birds, reptiles along with scores of amphibians, insects and other organisms are found in the study area. The important fauna are Indian wild buffalo, guar, spotted deer, sambar, barking deer, wild boar, chausingha, nilgai, monkey, hare, tiger and large number of birds and reptiles are commonly seen and most common among them are peacock, jungle fowls, bulbul, wood pecker, iora, myna, roller, hoopoe and kite etc. Reptiles like snakes, cobras, kraits, blind snakes, rat snakes and python are commonly found and a large number of amphibians like toads, frogs also occur in these forests. Among fishes, common carp, grass carp, rohu, catla, mruigal etc are found in the seasonal and perennial water bodies.

3.8 Other land use practices

3.8.1 Agricultural crops

There are more than 20 villages in the vicinity of the forest. These villages are named as forest villages, out of 20 villages 3 villages were taken for study. They are Jugad, Dejaramli and Pahelikand. Principle agricultural crops cultivated in the study area are paddy and *Lathyrus*. Gram is also sown in few patches. Paddy is grown extensively during rainy season (June-October), while *Lathyrus* is taken as relay crop by using residual moisture leftover after the harvest of paddy. Besides gram, other pulses like arhar, green gram and mung are cultivated in marginal lands and paddy field bunds. Among vegetables the prominent crops grown in this area are brinjal, raddish, beans, tomato etc.

3.8.2 Grasslands

Grasslands are also found in patches in open areas, occasionally occur as under storey in mixed deciduous forests and also on hill plateaus. Biotic

interferences coupled with edaphic factors helped in the perpetuation of grass lands are also found with *Phoenix* sp. in the forest.

3.9 Sampling

The study on species composition, regeneration and diversity of tree layer along the disturbance gradient in tropical deciduous forest was conducted after reconnaissance survey of Udanti Wildlife Sanctuary. The villages chosen for the present study represent the general situations for other villages of the Sanctuary area. Three sites, namely Jugad, Dejaramli and Pahelikand, were selected for the study (Fig 3.2).

The possible impacted sites were therefore chosen at varying distance from villages. Site I is those area which surrounded villages in a radius of up to 1 km. Forest between 1-5 km from village boundaries were chosen as site II. For site III, the forest situated at distance of over 5 km were selected. The choice was limited because many a times there were other villages falling with in 5 km distance.

3.10 Method

At each of these villages, one hectare permanent plots were established, each plot was sampled for ten quadrat, each 10x10 m² in size. In each quadrat, dbh (diameter at breast height) of each adult individual (≥ 9.6 cm dbh) were measured. In the center of each 10x10 m² quadrat, 2x2 m² quadrat area was marked for enumeration of sapling (individuals 3.2 cm to < 9.6 cm dbh) and seedling (individuals, 3.2 cm diameter but ≥ 30 cm height). Stem diameter of adult & sapling individual was measured at 1.37 m from ground level and for

seedlings it was measured at 10 cm above the ground. Thus all individuals were enumerated by species and the diameter of all the individuals was measured.

The vegetation data were quantitatively analysed for frequency, density and abundance following (Curtis and Mc Intosh, 1950).

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates studied}} \times 100$$

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

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

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

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

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

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

The importance value index (IVI) was determined as the sum of relative frequency, relative density and relative dominance (Phillips, 1959).

$$\text{Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RBA}$$

Species diversity parameters for three layer were determined using basal cover values. Shannon-Wiener information function (Shannon-Wiener,1963) was used for species diversity:

$$H^1 = - P_i \log_2 P_i$$

Where P_i , is the proportion of total stand basal cover represented by the i th species. The working formula given by Smit (1974) was used here.

$$H^1 = 3.3219 \left[\log_{10} N - \left\{ \frac{\sum Ni \log_{10} Ni}{N} \right\} \right]$$

Where N_i was the total basal cover of species i and N was the total basal cover of all the species. The factor 3.3219 was used to convert the index value to \log_2 .

Concentration of dominance was measured by Simpson's index (Simpson, 1949)

$$Cd = \sum \left[\frac{Ni}{N} \right]^2$$

Where N_i and N were same as described above.

Beta diversity was calculated according to the formula given by Whittaker (1972)

$$Bd = \frac{Sc}{\bar{s}}$$

where Sc = total number of species in the number of sites studied and \bar{s} = average number of species per site.

The data generated from above equation was assessed on the scale of disturbance gradient. Soil samples were collected from representative forest sites and was analysed for physicochemical properties (particle size distribution i.e. texture analysis) by pipette method (Piper 1950). Total N was measured by Kelplus (Pelican equipment) based on micro Kjeldhal principle. Organic C of the

soil was determined by Walkley and Black's method and total P was measured after HClO₄ digestion (Jackson, 1958) and that was correlated with forest diversity.

CHAPTER IV

RESULT AND DICUSSION

The results on “Species composition, Regeneration and diversity of tree layer along the disturbance gradient in tropical deciduous forest of Udanti Wild life Sanctuary”, 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 composition, dominance and diversity of trees in the forest vegetation and second part comprised the impact of human disturbance on diversity in the forest of Udanti Wild Life Sanctuary.

PART I

4.1 Composition, Dominance and Diversity of Trees in the Forest.

In the present forest a total of 980 trees, 734 saplings and 3075 seedlings, representing 36 species, 34 genera and 21 families were encountered. The most diverse families were Leguminaceae (5), Euphorbiaceae (3), Combretaceae (3) Anacardiaceae (3) and Malvaceae (2). The Dipterocarpaceae family was represented by 150 individual followed by Combretaceae (134), Fabaceae (116) in tree layer. In sapling Combretaceae family represented 143 individuals followed by Dipterocarpaceae (110). In seedling highest density was observed in Dipterocarpaceae (5450) followed by Combretaceae (5250).

The forest under study was rich in species with 36 species per ha. The richness was greater than that of Sal forest in Corbett (Singh *et al.* 1997), Gorakhpur (Shukla and Pandey, 1999), Mandla (Prasad and Pandey, 1989). But lower than Doona valley, Siwaliks (Rawat and Bhainsara 1999), Mahenada

Sanctuary Darjeeling (Umashankar, 2001), B.R. Hills (Murali, *et al* 1998.) and Madhumali (Sukumaran *et al.* 2000). This indicate that the forest cover occupied by sal mixed forest showed higher diversity compared to others.

Results of structural analysis of forest vegetation are given in table 4.1. *Shorea robusta* is most dominant in tree layer followed by *Madhuca longifolia* and *Terminalia tomentosa*. Highest density was observed in *Shorea robusta* followed by *Cleistanthus collinus*, *Terminalia tomentosa* and *Madhuca longifolia*. Lowest density was observed in case of *Bridelia retusa* followed by *Cassia fistula*, *Salmalia malabarica* and *Bauhinia malabarica*. Highest basal area was observed in sal followed by *Madhuca longifolia*, *Terminalia tomentosa*, *Tectona grandis* and *Diospyros melanoxylon*. Lowest basal area was observed in *Bauhinia malabarica* followed by *Cassia fistula*. *Shorea robusta* showed highest basal area and density in seedling and sapling layer. In Tree layer, basal area and density of individual species varies from 0.013 m² /ha to 9.67 m² /ha and 1 to 149 respectively. In sapling layer (Table 4.2) *Shorea robusta* showed highest value of IVI (47.5) followed by *Terminalia tomentosa* (31.27) and *Diospyros melanoxylon* (20.65).

In seedling layer (Table 4.3) IVI was highest for *Diospyros melanoxylon* followed by *Ziziphus xylopyrus* and *Anogeissus latifolia*. Because *Diospyros melanoxylon* and *Ziziphus xylopyrus* fruits were edible by animals and birds. The seed dispersal and its germination was higher than other species.

The overall density of tree was 980 followed by 733 and 3075 for sapling and seedling, respectively. The basal area was 34.85, 2.99 and 7.84 m²/ha for tree, sapling and seedling, respectively. The sapling layer density was poorly

developed and this could be due to severe competition with tree and sapling for light and nutrients in under canopy environment (Singh and Singh, 1987).

Similar observations on the basis of quantitative information were made by Champion and Seth (1968). Fire, logging and grazing were the most important factors in declining of density and basal area of forest near villages. Hunting could lead to forest ecosystems that are virtually empty of wild life populations which play essential roles in pollination, seed dispersal and nutrient cycling (Redford, 1992). In the Atlantic forest of Brazil about 70 per cent of the tree species are dispersed by vertebrates mostly birds and mammals (Silva and Taballi, 2000).

Small fragment of forest villages have very different ecosystem characteristics than large forest fragments, supporting more light loving species, more tree with wind or water dispersed seeds and relatively few understory species (Laurence, 1999). Conservation strategies need to ensure the preservation and restoration of large, unfragmented forest habitats in each region (Robison *et al.*, 1995; Aksins, 1995) and to support greater efforts to build linkages between ecosystems at the landscape level (Bennet and Wit, 2001).

PART II

4.2 Impact of Human disturbance on diversity in the forest of Udanti wild life sanctuary.

Dejaramli Forest Village

The Dejaramli is a forest village situated in predominantly Sal forest. Perusal of data of this area showed that the density of tree species (about > 9.2 cm DBH) was comparatively less at site I being 720 tree/ha of 18 species. The sites, which were away from habitation showed higher tree density. The density of tree species were found to be 1030 /ha comprised of 23 species at site II and 1200/ha of 20 species at site III, respectively (Table 4.4).

Contribution of species in tree layers at three different sites of the study area indicated that sal occurred to the extent of 200 tree /ha at sited I, 150/ha at site II and 310/ha at site III, respectively. Frequency and basal area of tree species at three sites were also found in increasing order with increased distance from habitation. At site I, the area covered by 720 individuals of 17 species was found to be 22 m² /ha (basal area), contributing 2.25 % of tree zones. At site III & site II which were away from habitation, the basal cover of tree was higher being 30 m²/ha (3%) and 19.6 m²/ha (1.9%), respectively (Table 4.4).

Association of tree species of different diameter classes (DBH class) indicated that the forest of the study area was composed of young aged trees. The maximum density of trees attained the basal growth between 10-20 cm DBH class at all three sites (I, II & III) being 61 tree/ha, 89 tree/ha and 97 tree/ha, respectively. The density of higher dbh classes (30-40 cm and above) was found to be negligible at all the sites. However, in middle age class (20-30cm) the

density of tree was minimum at site I (50 tree /ha) than site II (120 tree/ha) and site III (160/ha).

IVI of various tree species at different site of the study area showed that *Shorea robusta* was a dominant species having maximum IVI of 100.9 at site I, and 45.2 at site II and however, at site III shows maximum IVI of 75.6. The status of sal at all the three sites was observed to be very significant. Species diversity and distribution of tree species at different sites of the same study area showed that the tree species were not evenly distributed.

Diospyros melanoxylon was the co-dominant species having IVI and density values of respectively, 45.21 and 90 tree/ha at site II. At site III 80 tree/ha and at site I very less density of 10 tree/ha was found. More than 30 per cent of the species present at site II was fruit bearing and are edible to wild animals, such as, *Embllica officinalis*, *Ziziphus xylopyrus*, *Terminalia chebula*, *Buchanania lanzan* and *Semecarpus anacardium*.

It appears that variation in intensity of biotic disturbance are operating differently at different sites. For example, site I which was very close to habitation represented highly degraded forests of the locality. Some species at site II indicated preferential treatment in favors of certain species. Protection of fruit bearings trees by inhabitants also explains high IVI values of a group of species over other at site II. However, at the site III and II the species having lower IVI values of fruit bearing trees.

Dewalt *et al.* (2003) reported that the density of plants producing fleshy fruits was highest in the young secondary forest. Higher density and cover at site

I and II obviously indicated that these areas are least affected by human disturbance.

Jugad Forest Village

Quality sal forests were found in northeastern part of the Jugad village. While good teak forest occur in southern part of the village. The village was easily accessible to state highway. As compared to teak forests, the sal forest of this area was found to be better as for the biotic pressure was concerned.

The density of various trees were found to be 550 tree /ha of 17 species at site I, 950 tree/ha of 23 species at site II and 1100 tree /ha of 22 species at site III, respectively. The basal area of the tree stand showed same trend 18.7, 28.3 and 28.58 m²/ ha at site I, II and III, respectively. (Table 4.5). The growth and composition of trees at three locations indicated that the forest away from habitation were able to regenerate better than the forest in the near vicinity of habitation (Site I). The tree attaining growth in various DBH classes showed that maximum number of trees (880 tree/ha) of 21 species representing young age (10-20cm DBH) class were found at site III than site II, 710 tree/ha of 23 species and at site I, 410 tree/ha of 17 species. Similarly the basal area of young age class also showed same trend i.e. 6.1, 9.4 and 12.3 m²/ha at site I, site II and site III, respectively. The sapling (DBH class < 9.6 - >3.2cm) was found to be almost lesser in all the three sites.

Composition and distribution of various tree species were different from site to site. At site I and site III *Shorea robusta* was dominant and its IVI were 78.81 and 77.67, respectively. But at site II teak was dominant (38.94). Co-dominant species at sites III was *Terminalia tomentosa* (35.22), followed by

Diospyros melanoxylon (19.64) and *Pterocarpus marsupium* (16.89). *Madhuca longifolia* (31.25) and *Tectona grandis* (24.94) were co-dominant at site I and site II followed by *Cleistanthus collinus* (27.27) and *Madhuca longifolia* (22.72.)

Pahelikand Forest Village

The Pahelikand, a study site in this area belongs to mixed deciduous forest type, was dominated by *Cleistanthus collinus*. The density of various trees were found to be 450 tree/ha of 23 species at site I, 600 tree /ha of 22 species at site II and 740 tree/ha of 22 species at site III, respectively (Table 4.6).

The structure of the forest vegetation of 3 location showed that the forest away from habitation were able to regenerate better than forest in the vicinity of habitat and other abiotic factors also played a major role in species distribution, germination and its survival. Because of heavy terrain and rocky structures the density of the tree was very less. The dominance of the species varies from site to site. The trees at old age class (>40 cm) was absent at site III. Rockiness of that area may be one of the reason for absence of old age class tree. Minimum density was observed in rest 2 sites. Composition and distribution of various tree species were different from site I to site III, *Cleistanthus collinus* and *Anogeissus latifolia* were the dominant and co dominant species at site III. The IVI of *C. collinus* and *A. latifolia* were 50.5 and 27.2, respectively at site III. At site II, *Ziziphus xylopyrus* and *Terminalia tomentosa* were the dominant and co dominant species and its IVI were 28.2 and 27.7, respectively. At site I *Mitragyna parviflora* (IVI, 27.12) *Ziziphus xylopyrus* (IVI, 26.19) and *Cleistanthus collinus* (IVI, 24.91) were dominant species.

Species such as *Pterocarpus marsupium*, *Buchanania lanzan*, *Shorea robusta*, *Terminalia tomentosa*, *Madhuca longifolia*, *Cleistanthus collinus*, *Terminalia chebula*, *Ziziphus xylopyrus*, *Anogeissus latifolia*, *Dalbergia paniculata*, *Cochlospermum religiosum*, *Mitragyna parviflora* and *Lagerstroemia parviflora* were observed to be common to all sites. Moreover, density of trees were low in all the sites. However, impact of human disturbance also observed for decline in basal area and density in all the three sites and it may be attributed to steep terrains and rocky pan cover in all around the forest.

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 (Sheil, 1994). Disturbance such as logging usually causes an immediate decline in biodiversity followed by a recovery, although not necessarily of the same species (Noble and Dirz, 1997). Species richness of the site experiencing disturbance, therefore, will be cumulative outcome of differential responses of species to disturbance. Some species may tolerate the disturbance and the others may disappear.

The presence of maximum number of species with only one or 1-10 individuals at 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 per cent. Black *et al.* (1950) in Amazonia rain forests found that among trees of at least 10 cm dbh, over one-third of the species were represented by single individual. Soil N is supposed to be the most limiting nutrient in a majority of terrestrial ecosystems (Fenn *et al.*, 1998). Many study suggested that the heterogeneity of the

environment as well as disturbance are the prime cause for patch formation in forest (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 practices of grazing and trampling may change the habitat fitness for many species (Pandey and Sukla, 1990). Occurrence of *Shorea robusta*, *Ziziphus xylopyrus*, *Anogeissus latifolia* and *D. melanoxylon* at all the sample locations along the disturbance gradient suggests their tolerance to biotic pressure and wide ecological amplitude. Clumping in these species may be due to coppice forming habit, and patchy distribution of microhabitats suitable for plant growth in tropical forest soils (Roy and Singh, 1994). According to Odum (1991), 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 (Ashton, 1969; Richards, 1996), or when death of tree creates a large gap encouraging recruitment and growth of numerous saplings (Armesto *et al.*, 1986; Newbery *et al.*, 1988; Richard, 1996). Vegetative reproduction by suckers and coppice also encourages clumpiness (Lieberman, 1979). *A. latifolia*, *Diospyros melanoxylon*, *Lagerstroemia parviflora*, *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 *A. latifolia* and *S. robusta* are able to tolerate high degree of disturbance.

Connell (1971) suggested that the uniform dispersion patterns 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 higher on the more disturbed sites. Uniform dispersion of species is possible in case of edible fruits by animals and birds. Eg. *Ziziphus xylopyrus*, *D. melanoxylon*, *B. lanzan*, *Grewia tiliifolia*, *T. chebula* etc.

The study of Ramirez-Marcial *et al.* (2001) showed decreasing density and basal area with disturbance intensity. Smiet (1992) correlated the basal area with the disturbance. Current study also indicated that 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 timber, insect attack, and rotting of boles.

Regeneration status

The renewal of the tree crop by natural means in the form of crop is the indication of the health of site, recruitment and establishment of regenerating plants of tree species of various sites indicated that the forest near habitation were severely impacted by prevailing biotic factors in the sal forest. The density of seedlings (Table 4.10) was found to be 8453 /ha of 8 species at site I, 17240 /ha of 9 species at site II and 22990/ha of 10 species at site III in Dejaramli forest area. Similarly density of sapling (Table 4.7) was found to be 440 /ha of 14

species at site I. 543/ha of 17 species at site II and 654 /ha of 16 species at site III were observed in the same study site.

Similarly in Jugad forest village area the density (Table 4.11) of seedlings was found to be 7998/ha of 8 species at site I, 11810 plants /ha of 9 species at site II and 15110 plants of 7 species at site III. Sapling density (Table 4.8) in site I, site II and site III was found to be 328 /ha of 15 species, 497.9/ha of 19 species and 636.8 /ha 23 species, respectively. This shows poor sapling status in Jugad area than Dejaramli forest.

The basal area of seedling was 0.84, 3.1 and 4.8 m²/ha at site I, site II and site III respectively. Similarly in sapling layer was found to be 1.98, 2.57 and 2.85 m²/ha at site I, site II and site III, respectively.

Sapling density and basal area were lesser than the seedling and trees. It was due to heavy exploitation for firewood, small timber, browsing and forest fire.

At Pahelikand, seedling density (Table 4.12) and basal area was high at site III, 15113/ha and 2.2 m²/ha, respectively followed by site II and site I. Where the density and basal area were 11810/ha, 2.21 m² /ha and 7998/ha, 0.32/ha respectively.

In sapling layer density and basal area was 636.8/ha and 2.8 m²/ha, 4.97 /ha and 2.45 m² /ha, 328.3 /ha and 1.43 m²/ha at site III, site II and site I, respectively, (Table 4.9).

In all these sites density of species in sapling layer was minimum because of high temperature, and drought during summer. Many of the saplings were dead during rainy season due to water logging and could be the reason for absence of

many species in sapling layer. Due to wild and domestic browsing also the development of saplings gets altered /affected. However, because of preferential browsing of wild and domestic animals many species were absent in the three sites.

Change in density and basal area of both seedling and saplings shows that prevailing biotic factors such as exploitation of forest to meet daily requirements of fuel wood, wood for agricultural implements and house 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 forests get degraded 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 the tree species at different sites in the forest indicate the complex plant succession resulting from varying degree of pressures at different sites. It is also interesting to note that teak forest of Jugad village shows no regeneration of teak and many other species. The density was lower than the sal forest of other sites.

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 is not a good sign for better growth of forest of any area. In sal forest area species diversity (H') was observed to be variable from site to site in the study area of Dejaramli forest village. Values of it was 2.66 at site I, 3.65 at site II and 3.18 at site III,

exhibiting decreasing diversity trend towards the forest away from habitation. Similarly in saplings and seedlings values were 3.52 and 2.8 at site I, 3.80 and 2.8 at site II and 3.67 and 2.74 at site III, respectively exhibiting increasing diversity trend towards the forest away from habitation. Similarly in the second study area of Jugad, species diversity index (H'), showed similar trend but the values were higher than Dejaramli forest viz., 3.19, 3.71 and 3.31 at site I, II and III, respectively. For sapling and seedling layer values were 3.40 and 2.89 at site I, 4.04 and 3.00 at site II and 4.2 and 2.98 for site III, respectively. For Pahelikand forest village in tree layer, Shannon index varies from 3.41 at site I, 3.96 at site II and 3.62 at site III, respectively. In seedling layer, increasing trend in diversity was observed from 2.26 at site I, 2.54 at site II and 2.74 at site III, respectively. For sapling it was 3.54, 3.90 and 4.16 for site I, site II and site III, respectively. The values for concentration of dominance for overall forest were ranging from 0.074 to 0.321, 0.0718 to 0.684 and 0.138 to 0.218 for trees, saplings and seedlings, respectively.

Concentration of dominance

In Dejaramli forest village highest Cd value for tree layer was observed at site I followed by site III and site II. The Cd values were 0.321, 0.180 and 0.126, respectively. The sapling layer also showed same trend at site I, site III and site II and it was 0.103, 0.097 and 0.081, respectively. In sapling layer very little variation were observed i.e. 0.158, 0.154 and 0.151 for site I, site II and site III, respectively.

In Jugad forest village highest values were observed under tree layer and were 0.166, 0.112 and 0.167 for site I, site II and site III, respectively. For sapling

layer the values were 0.086, 0.075 and 0.0718 for site I, site II and site III, respectively. For sapling layer lowest values were observed at site II (0.1385) followed by (0.142) at site I and site III (0.1424).

In Pahelikand highest value for concentration of dominance at tree layer was observed at site III followed by site II and site I i.e. 0.113, 0.077 and 0.074, respectively. For sapling layer it was 0.104, 0.079 and 0.6844, respectively for site I, site II and site III.

Beta diversity

Beta diversity for Dejaramli village was 4.74, 4.03 and 3.50 for tree layer at site I, site II and site III, respectively. For seedling layer the beta diversity ranged from 2.61 on site I to 1.70 on site III. For sapling it was 3.61, 2.72 and 2.43 for site I, site II and site III, respectively. For Jugad village the highest value was found at site I followed by site III and site II. The values were 5.48, 3.38 and 2.40, respectively. For sapling layer it varies from 4.21 for site I and 3.08 for site III, respectively. For seedling layer beta diversity was 1.97, 1.05 and 1.15 for site I, site II and site III, respectively.

In Pahelikand, tree layer beta diversity showed highest value of 6.38 at site I, 4.68 at site II and 4.49 for site III, respectively.

In general at all sites beta diversity showed decreasing trend from site I to site III. For seedling layer it varies from 1.99 to 1.87 for site I to site II, respectively; for sapling layer it varies from 3.28 for site I and 2.06 for site III, respectively.

Results of diversity parameter revealed that the Shannon index values in different forest types ranged from 2.26 to 4.16, Cd value from 0.071 to 0.684 and

beta diversity from 1 to 5.77. The diversity parameters of these forest are comparable with the diversity indices reported in different tropical forests (Singh and Singh, 1991).

Prasad and Pandey (1992); Ravan (1994); Verghese and Menon (1998); Singh and Singh (1991) 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 Vindhya region in India. Prasad and Pandey (1992) in sal and teak forest of Madhya Pradesh found species diversity 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 district of Madhya Pradesh, India. The forest within habitation recorded lower diversity and dominance compared to forests away from habitation.

The Shannon index values of dry tropical forests in study area were comparatively lower than those reported by Singh *et al.*, (1984) and Swamy (1998) for other 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, the higher diversity was found in those forests. It is also evident from the results that Shannon index values were higher than concentration of dominance for different site of forest. The inverse relationship was found between Shannon index and

Simpson index. These results are in agreement with earlier findings of Singh and Singh (1991) and Swamy (1998).

Among different forest types, the mixed forest showed higher diversity and lower dominance, while teak forest showed poor diversity and higher concentration of dominance. The higher diversity in mixed forest is attributed to the presence of higher number of species (26), while the higher concentration of dominance in sal forest were attributed to higher relative proportion of sal in these forest types compared to other species. The beta diversity was found to be highest for mixed forests and lowest for sal forests, shows that higher rate of species turnover in former type compared other forest type. The higher beta diversity represents the higher niche diversification in mixed forests compared to degraded forests. The results also showed that disturbance significantly influenced the basal area, tree density and species diversity, concentration of dominance and beta diversity in the forest.

Effect of site quality on Diversity and structure

Correlation analysis was performed between soil and diversity parameter of tropical deciduous forest and results are presented in Table 4.14. It is evident from the result that per cent clay was negatively correlate with Shannon index, whereas concentration dominance exhibited positive correlation with per cent clay and negatively correlated to total K. There was strong positive correlation between density and per cent organic carbon, and basal area was negatively correlated with Total N. No significant correlations were observed among other relations.

Above results revealed that diversity of forest decreased with per cent clay because during rainy season water logging decreases the root aeration and due to this many of the non tolerant species may vanish. Some species of trees like *Casurina equisetifolia*, *Butea monosperma*, *Acacia nilotica* shows preference to grow in clay soil. Whereas sal and teak trees shows absence in clay soils. Generally total K increased with forest fire which may kill seedling and sapling of the forest. Only fire resistant species may regenerate properly and rest of the species will vanish. If forest fire were very low which may help in regeneration and health of the forest and thereby increase the species diversity.

Organic C is generally influenced by climate, natural vegetation, texture and cropping and crop sequences (Brandy, 1984). Temperature and rainfall also exert a dominant influence on the amount of organic matter in the soil (Jenny, 1941). Soil moisture, also exerts a positive control upon accumulation of organic C in soils. It is evident from table 4.15 that has related with % organic carbon.

CHAPTER V

SUMMARY, CONCLUSIONS AND SUGGESTION

FOR FUTURE WORK

The study on “Species composition, regeneration and diversity of tree layer along the disturbance gradient in tropical deciduous forest of Udanti Wildlife Sanctuary” were carried out in three forest villages in Garhiabandh forest division in Chhattisgarh, India during 2004-2005. Udanti Wildlife Sanctuary covers an area of 247.28 sq. km of which more than 70 per cent is under forest cover. The study area is located between 82°30’ to 82°00’E longitude and 20°0 to 20°15’ N latitudes.

The composition, structure, diversity and disturbance study were conducted by establishing one-hectare permanent plots at different forest villages. Ten plots of 10 x 10 m² in area were laid to study the vegetation changes along human disturbance. The extent of biotic impacts on natural forest was conducted near habitation (village), i.e. less than 1 km radius area from villages (Site I), 1-5 km from the villages (site II) and more than 5 km from villages (site III).

Regeneration status and successional trends were studied at all the three sites in the sampling plot of 2 x 2 m². The structural analysis was done by determining primary variables (density, basal area and frequency). Subsequently secondary variables (relative density, relative frequency, relative basal area and IVI) were computed from primary data. The diversity parameters *viz.* Shannon index, Simpson index and beta diversity were also calculated for

each plot. The salient findings on forest composition, regeneration, structure and diversity are summarized below.

- *Shorea robusta*, *Madhuca longifolia*, *Terminalia tomentosa* and *Cleistanthus collinus* associations were recognized as pre dominant plant species in deciduous forest, sapling layer was dominated by *Shorea robusta*, *Terminalia tomentosa* and *Diospyros melanoxylon*.
- In seedling layer *Diospyros melanoxylon* *Ziziphus xylopyrus* and *Anogeissus latifolia* was observed predominant community.
- In tree layer maximum density was observed for sal (149.8) followed by *Cleistanthus collinus* (83) and *Terminalia tomentosa* (79.4).
- Maximum basal cover for trees were observed for sal (9.6) followed by *Madhuca longifolia* (3.03) and *Terminalia tomentosa* (2.40 m² ha⁻¹), respectively.
- In different site, density of trees ranged from 450-1200 tree/ha along sal forest to mixed deciduous forest and basal area ranges from 15.8 –34.85 m²/ha. The mean density was 980 trees/ha.
- Shannon index for tree layer along different representative sites ranged from 2.43-4.164.
- In Dejaramli forest village at site I the predominant species was sal (IVI 78), mahuva (31.25), teak (24.94) and *Caryota urence* (24.42). In saplings it was sal (53.4) followed by *Diospyros melanoxylon* (31.13) and *Cleistanthus collinus* (29.48). Where as, in seedling layer dominance was shared by sal (79.1) followed by *Ziziphus xylopyrus* (47.4) and *Anogeissus latifolia* (41.4).

- The density of tree species were found to be 1030 /ha comprised of 23 species at site II and 1200/ha of 20 species at site III, Overall density of trees were 550 stems ha⁻¹ and basal area was 18.7 m² ha⁻¹. In sapling and seedling layers the density and basal area were 5480 ha⁻¹, 0.84 m² ha⁻¹ and 380 ha⁻¹ and 1.98 m² ha⁻¹, respectively.
- Shannon index and Simpson index was 2.66 and 0.321 at site I, 3.65 and 0.126 at site II and 3.18 and 0.180 at site III, respectively. Beta diversity was 4.74, 4.03 and 3.50 for tree layer at site I, site II and site III, respectively. For seedling layer the beta diversity ranged from 2.61 on site I to 1.70 on site III. For sapling it was 3.61, 2.72 and 2.43 for site I, site II and site III, respectively.
- For Jugad Forest Village, the density of trees was 550 tree /ha of 17 species at site I, 950 tree/ha of 23 species at site II and 1100 tree /ha of 22 species at site III, respectively. The basal area of the tree stand was 18.7, 28.3 and 28.58 m²/ ha at site I, II and III, respectively. I and site III *Shorea robusta* was dominant followed by *Terminalia tomentosa*, *Diospyros melanoxylon*. and *Pterocarpus marsupium*. *Madhuca longifolia*, *Tectona grandis*, were co-dominant at site I. Density of seedlings was found to be 7998/ha of 8 species at site I, 11810 plants /ha of 9 species at site II and 15110 plants of 7 species at site III. Sapling density in site I, II and III was 328 /ha of 15 species, 497.9/ha of 19 species and 636.8 /ha 23 species, respectively.
- Shannon index for tree layer was 3.19, 3.71 and 3.31 at site I, II and III, respectively. For sapling and seedling layer values were 3.40 and 2.89 at site I, 4.04 and 3.00 at site II and 4.2 and 2.98 for site III, respectively. Simpson

index for tree layer was 0.166, 0.112 and 0.167 for site I, II and III, respectively. For sapling layer the values were 0.086, 0.075 and 0.0718 for site I, II and III, respectively. Beta diversity was highest at site I followed by site III and site II for sapling and seedling layer, respectively.

- For Pahelikand forest village the density of trees was 450 tree/ha of 23 species at site I, 600 tree /ha of 22 species at site II and 740 tree/ha of 22 species at site III, respectively. Seedling and sapling density and basal area was high at site III followed by site II and site I.
- Shannon index for tree layer was 3.19, 3.71 and 3.31 at site I, II and III, respectively. For sapling and seedling layer values were 3.40 and 2.89 at site I, 4.04 and 3.00 at site II and 4.2 and 2.98 for site III. Concentration of dominance at tree layer was observed at site III followed by site II and site I. Beta diversity was decreasing from site I to site III, in all the three layers.
- Correlation analysis was performed between soil and diversity parameter. Percent clay was negatively correlated with Shannon index, whereas concentration of dominance exhibited positive correlation with percent clay and negatively correlated to total K. There was strong positive correlation between density and percent organic carbon and basal area was negatively correlated with Total N. No significant correlations were observed among other relations.

Conclusion and suggestions for future work

The study proved that disturbance had significantly influenced the structure, composition and diversity of forest. It reflects that sal deciduous forests of Chhattisgarh are ecologically rich 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 the intensive-conservation measures especially in degraded areas of the forest.

The perennial grasses, hardy trees and shrubs should be planted on steep slopes to reduce runoff, control erosion and also to stabilize the degraded slopes. In order to encourage and improve sal regeneration in sal mixed forests, the temporary closure has to be made for at least for a period of 5 to 10 years. The silvi-pastoral system should be developed in natural open 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 grass lands

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 deciduous forests of Chhattisgarh.

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

“Species composition, regeneration and diversity of tree layer along the disturbance gradient in tropical deciduous forest of Udanti Wild life Sanctuary”.

by

Deepak M.S.

ABSTRACT

The present study was carried out to compare the species composition, regeneration and diversity of the tree layer along the disturbance gradient in tropical deciduous forest of Udanti wild life sanctuary, situated at Garhiaband forest division in Raipur district (C.G.) during the year 2004-05. Three forest village were taken for study, were categorized on the basis of relative impact of composite elements of disturbance and phytosociological study conducted near habitation (village) about less than 1 km radius from villages (Site I), about 1-5 km from village (site II) and more than 5 km from village (Site III). These sites were chosen in sal and mixed deciduous forests of the Sanctuary. A total of 36 species, 34 genera and 21 families of tree occurred in the study area. Phytosociological analysis at different forest village revealed that both biotic and abiotic factors also significantly influenced the structure, regeneration and diversity of forests. In different sites the density ranged from 450 to 1200 trees ha^{-1} , basal area from 15.8 to 30.2 $\text{m}^2 \text{ha}^{-1}$ and number of species from 17 to 26. Similarly, the diversity ranged from 2.61 to 3.96, concentration of dominance from 0.032 to 0.180 and beta diversity from 2.4 to 6.38. It was observed that the forests close to habitation were more severely affected by prevailing biotic factors than the distant forest areas even in the sal and mixed deciduous forests. The mean stem density was highest (933 stem/ha) at least disturbed site and lowest (596 stems /ha) at highly disturbed site and for basal area the highest value (25.18 $\text{m}^2 \text{ha}^{-1}$) was for the second moderately disturbed forest site and lowest value (19.58 $\text{m}^2 \text{ha}^{-1}$) was for most disturbed site.

In all the three village forest diversity index was highest at Site II (Shannon index). Highest Betadiversity (6.38) was found at Site I highly disturbed forest village, lowest (3.5) at Site III of least disturbed site. Highest density and Basal area found at Site III of the least disturbed forest village. Sapling density and basal area was highest at moderately disturbed forest (Site II), lowest at (Site I) highly disturbed forest village. Density of seedling were higher in least disturbed forest village (Site III). Highest Basal area and diversity was found at moderately disturbed forest (Site III) and (Site II) respectively.

From these observation, it is evident that with increasing pressure of human population and their increasing demand for fuel wood, fodder, timber and many other non wood forests products, Efforts need to be made to regulate the 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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- **Table 4.1: Phyto sociological analysis of tree layer at Udanti wild life sanctuary**

Name of the species	Basal Area (m ² ha ⁻¹)	Density stems ha ⁻¹	IVI
<i>Emblica officinalis</i>	0.2351	25.60	5.87
<i>Bauhinia malabarica</i>	0.0133	1.20	0.28
<i>Pterocarpus marsupium</i>	1.5279	62.70	16.90
<i>Semecarpus anacardium</i>	0.3787	19.60	5.92
<i>Kydia calycina</i>	0.3124	15.40	4.93
<i>Bombax ceiba</i>	0.1322	2.10	0.72
<i>Cassia fistula</i>	0.0531	1.20	0.40
<i>Buchanania lanzan</i>	1.4141	39.10	14.00
<i>Grewia tiliifolia</i>	0.5648	26.40	6.77
<i>Anogeissus latifolia</i>	0.7591	29.60	7.17
<i>Dalbergia paniculata</i>	1.4346	42.60	12.20
<i>Adina cordifolia</i>	0.5011	28.60	6.08
<i>Cochlospermum religiosum</i>	0.2229	7.30	2.37
<i>Ziziphus xylopyrus</i>	1.2333	61.90	17.50
<i>Terminalia chebula</i>	0.6452	24.70	6.83
<i>Syzygium cumini</i>	0.2140	5.40	1.66
<i>Flacourtia ramontchi</i>	0.1322	11.30	3.01
<i>Cleistanthus collinus</i>	1.6869	83.00	20.00
<i>Bridelia retusa</i>	0.0154	1.00	0.27
<i>Dillenia aurea</i>	0.2153	7.00	1.95
<i>Sterculia urens</i>	0.1018	6.00	1.64
<i>Schleichera oleosa</i>	0.0157	2.00	0.50
<i>Lannea grandis</i>	0.4273	27.00	8.66
<i>Madhuca longifolia</i>	3.0309	72.40	24.00
<i>Mitragyna parviflora</i>	0.8373	24.60	8.36
<i>Terminalia tomentosa</i>	2.4119	79.40	22.40
<i>Shorea robusta</i>	9.6652	149.80	54.30
<i>Boswellia serrata</i>	0.9280	12.30	5.27
<i>Careya arborea</i>	0.0380	3.80	0.99
<i>Lagerstroemia parviflora</i>	0.7563	34.70	8.91
<i>Salmalia malabarica</i>	0.0227	1.20	0.31
<i>Tectona grandis</i>	2.1846	12.40	9.01
<i>Wrightia tinctoria</i>	0.6554	3.60	2.99
<i>Diospyros melanoxylon</i>	1.9692	46.50	16.10
<i>Ougeinia oojeinensis</i>	0.1163	8.60	1.95
Total	34.852	980.00	300.00

• **Table 4.2:Phyto sociological analysis of sapling layer at Udanti wild life sanctuary**

Name of species	Density stems ha⁻¹	Basal Area (m²ha⁻¹)	IVI
<i>Adina cordifolia</i>	12.6	0.05	5.3154
<i>Anogeissus latifolia</i>	44.3	0.11	16.821
<i>Bauhinia malabarica</i>	5.7	0.02	2.3129
<i>Boswellia serrata</i>	7.6	0.02	2.7135
<i>Buchanania lanzan</i>	24.4	0.10	10.871
<i>Careya arborea</i>	4.6	0.01	1.6765
<i>Cassia fistula</i>	11.3	0.05	5.1586
<i>Cleistanthus collinus</i>	44.7	0.18	19.913
<i>Dalbergia paniculata</i>	24.5	0.11	11.436
<i>Dillenia aurea</i>	5.4	0.03	2.8904
<i>Diospyros melanoxylon</i>	50	0.20	20.654
<i>Emblica officinalis</i>	42.6	0.16	12.663
<i>Flacourtia ramontchi</i>	30.1	0.10	11.676
<i>Kydia calycina</i>	5.4	0.01	2.0397
<i>Lagerstroemia parviflora</i>	27.6	0.12	12.902
<i>Lannea grandis</i>	7.6	0.06	5.3783
<i>Madhuca longifolia</i>	19.4	0.06	7.1857
<i>Ougeinia oojeinensis</i>	19.8	0.09	9.6831
<i>Pterocarpus marsupium</i>	29.1	0.10	11.0000
<i>Schleichera oleosa</i>	15.1	0.08	8.2004
<i>Semecarpus anacardium</i>	18.4	0.05	6.0227
<i>Shorea robusta</i>	109.7	0.65	47.58
<i>Tectona grandis</i>	49.1	0.13	17.02
<i>Terminalia chebula</i>	19.1	0.08	7.3161
<i>Terminalia tomentosa</i>	79.4	0.29	31.271
<i>Woodfordia fruticosa</i>	5.9	0.02	2.0704
<i>Ziziphus xylopyrus</i>	20.4	0.08	8.2304
	733.8	2.99	300

Table 4.3 : Phyto sociological analysis of seedling layer at Udanti wild life sanctuary

Name of the species	Density stems ha⁻¹	Basal Area (m²ha⁻¹)	IVI
<i>Anogeissus latifolia</i>	349.5	0.0891	39.232
<i>Cleistanthus collinus</i>	149.9	0.0382	17.75
<i>Diospyros melanoxylon</i>	394.0	0.1005	42.127
<i>Dalbergia paniculata</i>	173.0	0.0441	19.252
<i>Emblica officinalis</i>	181.0	0.0462	19.773
<i>Lagerstroemia parviflora</i>	381.0	0.0972	32.781
<i>Ougeinia oojeinensis</i>	349.0	0.089	30.7
<i>Shorea robusta</i>	545.0	0.139	37.948
<i>Terminalia tomentosa</i>	176.0	0.0449	19.448
<i>Ziziphus xylopyrus</i>	376.5	0.096	40.989
Total	3074.9	0.7842	300

Table 4.4 : Species structure of tree layer at Dejaranli village near Udanti wildlife sanctuary

Name of the species	Dejaranli					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Emblica officinalis</i>	0.3142	20	6.87	0.1131	110	20.0
<i>Pterocarpus marsupium</i>	0.7857	50	18.53	1.6445	90	24.0
<i>Semecarpus anacardium</i>	0.3912	30	11.30	0.3143	30	9.7
<i>Kydia calycina</i>	0.4525	40	12.96			
<i>Buchanania lanzan</i>	1.005	20	12.64	0.5657	40	12.0
<i>Grewia tiliifolia</i>	0.2797	20	6.72	0.1131	20	6.0
<i>Anogeissus latifolia</i>				1.2721	50	14.8
<i>Dalbergia paniculata</i>	0.6458	30	9.73	1.3467	20	10.5
<i>Adina cordifolia</i>	0.6199	60	16.48	0.7488	50	12.0
<i>Ziziphus xylopyrus</i>	0.7857	50	18.53	0.3599	20	7.2
<i>Terminalia chebula</i>				0.1131	20	4.2
<i>Flacourtia ramontchi</i>	0.1131	10	4.59			
<i>Sterculia urens</i>	0.4714	30	14.36			
<i>Cleistanthus collinus</i>	0.3535	20	7.04	0.7119	130	25.0
<i>Dillenia aurea</i>				0.6946	20	7.2
<i>Schleichera oleosa</i>						
<i>Lannea grandis</i>	0.2011	10	4.98	0.0786	10	4.8
<i>Madhuca longifolia</i>	2.9951	80	35.20	1.5699	60	20.8
<i>Mitragyna parviflora</i>	0.2011	10	4.98	0.2011	10	3.7
<i>Nyctanthes arbortristis</i>				0.1540	10	5.2
<i>Chloroxylon swietenia</i>				0.0786	10	3.1
<i>Terminalia tomentosa</i>	0.5806	30	9.44	0.6042	40	12.2
<i>Shorea robusta</i>	12.2367	200	100.96	1.6924	150	33.0
<i>Boswellia serrata</i>				0.9625	20	8.6
<i>Lagerstroemia parviflora</i>				0.3968	20	5.7
<i>Wrightia tinctoria</i>				0.0951	10	3.2
<i>Diospyros melanoxylon</i>	0.1131	10	4.59	5.7766	90	45.0
<i>Ougeinia oojeinensis</i>						
Total	22.5469	720	300	19.608	1030	300

* : (m²ha⁻¹); ** : stems ha⁻¹

Table 4.5 : Species structure of tree layer at Jugad village near Udanti wildlife sanctuary.

Name of the species	Jugad					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Emblca officinalis</i>	0.1901	20	7.98	1.1314	100	21.0
<i>Bauhinia malabarica</i>		0		0.1327	10	3.3
<i>Pterocarpus marsupium</i>	0.5201	30	14.90	2.0750	70	21.3
<i>Semecarpus anacardium</i>	0.2797	20	8.46	0.4274	30	10.9
<i>Kydia calycina</i>	0.2262	20	8.17			
<i>Caryota urence</i>	1.3372	40	24.42			
<i>Buchanania lanzan</i>				0.6097	30	10.9
<i>Bauhinia varigata</i>	0.6419	30	12.21			
<i>Grewia tiliifolia</i>				1.5730	40	13.3
<i>Anogeissus latifolia</i>				1.4787	50	14.4
<i>Dalbergia paniculata</i>	0.6458	30	12.24			
<i>Adina cordifolia</i>	0.3394	30	10.60	1.1510	50	12.2
<i>Ziziphus xylopyrus</i>	0.5625	30	11.79	0.3598	20	6.9
<i>Terminalia chebula</i>				0.2655	20	6.6
<i>Flacourtia ramontchi</i>	0.1131	10	5.75			
<i>Cleistanthus collinus</i>	0.3535	20	8.85	1.6209	120	27.7
<i>Dillenia aura</i>						
<i>Sterculia urens</i>	0.3928	20	12.40			
<i>Schleichera oleosa</i>						
<i>Lamea grandis</i>				0.0785	10	4.9
<i>Madhuca longifolia</i>	2.2754	50	31.25	2.6266	60	22.7
<i>Mitragyna parviflora</i>	0.2011	10	6.22	0.2011	10	3.5
<i>Lamea grandis</i>				0.1540	10	5.1
<i>Randia dioca</i>				0.6160	10	5.0
<i>Shorea robusta</i>	6.2401	140	78.81	2.6541	130	31.9
<i>Boswellia serrata</i>				2.2392	30	14.4
<i>Terminalia tomentosa</i>				0.7566	30	9.3
<i>Lagerstroemia parviflora</i>				0.3967	20	5.2
<i>Tectona grandis</i>	2.7382	20	24.94	7.4344	70	38.8
<i>Wrightia tinctoria</i>				0.0950	10	3.1
<i>Diospyros melanoxylon</i>	1.6484	30	20.93	0.2797	20	6.6
<i>Ougeinia oojeinensis</i>						
Total	18.7060	550	300	28.3580	950	300

* : (m²ha⁻¹); ** : stems ha⁻¹

Table 4.6: Species structure of tree layer at Pahelikand village near Udanti wildlife sanctuary.

Name of the species	Pahelikand					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Bauhinia malabarica</i>						
<i>Chloroxylon swietenia</i>	0.2545	10	8.79			
<i>Pterocarpus marsupium</i>				0.2011	20	8.7
<i>Semecarpus anacardium</i>				0.3121	10	4.4
<i>Kydia calycina</i>				0.1540	10	6.8
<i>Cassia fistula</i>	0.5311	10	8.09	1.0453	10	20
<i>Caryota urence</i>		10	6.93			
<i>Buchanania lanzan</i>	0.154	10	6.04	1.4174	50	24.
<i>Grewia tiliifolia</i>						
<i>Anogeissus latifolia</i>	0.585	20	14.45	0.4525	10	5.6
<i>Dalbergia paniculata</i>	1.0410	50	25.87	0.3677	20	7.8
<i>Cochlospermum religiosum</i>	0.2545	10	7.168	0.7071	20	10.
<i>Ziziphus xylopyrus</i>	0.5814	50	29.62	1.1180	70	31.
<i>Terminalia chebula</i>	0.616	10	8.328	0.4022	20	8.0
<i>Syzygium cumini</i>	0.8430	20	12.52	0.2270	10	5.0
<i>Flacourtia ramontchi</i>	0.113	10	6.471	0.950	10	2.5
<i>Cleistanthus collinus</i>	1.1848	40	24.05	1.1337	60	22.
<i>Bridelia retusa</i>	0.154	10	6.70			
<i>Sterculia urens</i>	0.4231	10	9.0451			
<i>Lannea grandis</i>				0.3314	20	9.6
<i>Madhuca latifolia</i>	0.9625	10	11.13	3.0320	40	24.
<i>Nyctanthes arbortristis</i>	1.5352	40	27.12	1.661	40	19.
<i>Terminalia tomentosa</i>	1.265	30	23.20	2.431	40	24.
<i>Shorea robusta</i>	2.3807	30	24.50	0.9617	40	18.
<i>Boswellia serrata</i>				1.6625	20	13.
<i>Careya arborea</i>	0.3983	10	6.35			
<i>Lagerstroemia parviflora</i>	0.0950	30	5.67	1.3354	50	23.
<i>Salmalia malabarica</i>	0.227	10	6.50			
<i>Tectona grandis</i>				1.6325	10	12.
Total	15.8871	450	300	24.5323	590	300

* : (m²ha⁻¹); ** : stems ha⁻¹

Table 4.7: Species structure of sapling layer in village Dejaramli near Udanti wildlife sanctuary.

Name of the species	Dejaramli					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Adina cordifolia</i>	0.0345	12.6	7.80	0.0345	12.6	6.4
<i>Anogeissus latifolia</i>	0.081	48.3	25.94	0.0810	28.3	17.
<i>Buchanania lanzan</i>				0.0910	24.4	13.
<i>Cleistanthus collinus</i>	0.0918	43.7	23.17	0.0918	43.7	18.
<i>Dalbergia paniculata</i>	0.0811	24.5	14.97	0.0811	24.5	12.
<i>Dillenia aurea</i>						
<i>Diospyros melanoxylon</i>				0.0719	40	22.
<i>Emblica officinalis</i>	0.0916	14.6	13.04	0.0916	34.6	14.
<i>Flacourtia ramontchi</i>	0.0979	35.1	20.60	0.0979	35.1	16.
<i>Lagerstroemia parviflora</i>				0.1248	27.6	15.
<i>Lanea grandis</i>	0.0584	9.6	6.87	0.0584	9.6	5.7
<i>Madhuca longifolia</i>	0.0644	19.4	11.95	0.0644	11.4	8.3
<i>Ougeinia oojeinensis</i>	0.0938	19.8	13.58			
<i>Pterocarpus marsupium</i>	0.1032	29.1	18.27	0.1032	20.1	13.
<i>Semecarpus anacardium</i>				0.0511	18.4	8.2
<i>Shorea robusta</i>						
<i>Schleichera oleosa</i>	0.0813	15.1	10.36			
<i>Terminalia chebula</i>				0.0826	19.1	10.
<i>Shorea robusta</i>	0.6496	87.7	73.07	0.6496	92.7	62.
<i>Terminalia tomentosa</i>	0.2936	60.4	47.67	0.2936	80.4	43.
<i>Ziziphus xylopyrus</i>	0.0837	20.4	12.63	0.0837	20.4	10.
Total	1.90658	440.3	300	2.1529	542.9	30

* : (m²ha⁻¹); ** : stems ha⁻¹

Table 4.8 : Species structure of sapling layer at village Jugad near Udanti wildlife sanctuary.

Name of the species	Jugad					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Adina cordifolia</i>	0.0451	10.6	8.00	0.0451	12.6	6.4
<i>Anogeissus latifolia</i>	0.0900	41.3	21.76	0.1080	43.3	18.9
<i>Bauhinia malabarica</i>	0.0189	5.7	3.45	0.0189	5.7	2.4
<i>Boswellia serrata</i>	0.0235	7.6	5.11	0.0235	7.6	3.7
<i>Buchanania lanzan</i>				0.1010	22.4	12.3
<i>Careya arborea</i>				0.0135	4.6	2.3
<i>Cassia fistula</i>						
<i>Cleistanthus collinus</i>	0.1816	37.7	29.48	0.1816	47.7	23.9
<i>Dalbergia paniculata</i>	0.1144	21.5	17.47	0.1145	21.5	12.3
<i>Dillenia aurea</i>				0.0312	5.4	3.5
<i>Diospyros melanoxylon</i>	0.1992	32	31.13	0.1992	52	26.9
<i>Emblica officinalis</i>	0.0716	19.6	11.67	0.0816	49.6	13.9
<i>Flacourtia ramontchi</i>	0.0979	30.1	21.23	0.0979	30.1	15.9
<i>Kydia calycina</i>						
<i>Lagerstroemia parviflora</i>						
<i>Lannea grandis</i>	0.0584	7.6	6.92	0.0584	7.6	5.1
<i>Madhuca longifolia</i>	0.0644	10.4	9.23	0.0644	19.4	8.3
<i>Ougeinia oojeinensis</i>	0.0938	19.8	15.08	0.0938	19.8	11.9
<i>Pterocarpus marsupium</i>	0.1032	14.1	12.17	0.0910	19.1	9.3
<i>Schleichera oleosa</i>				0.0813	15.1	8.5
<i>Semecarpus anacardium</i>				0.0511	18.4	8.1
<i>Shorea robusta</i>	0.3649	67.7	53.40	0.6496	97.7	55.9
<i>Terminalia chebula</i>	0.0826	19.1	13.38	0.0826	19.1	9.7
<i>Terminalia tomentosa</i>	0.2936	15.4	22.63	0.2936	59.4	32.9
<i>Ziziphus xylopyrus</i>	0.0837	20.4	15.32	0.0837	20.4	11.9
Total	1.9877	380.6	300	2.5664	598.5	300

* : ($m^2 ha^{-1}$); ** : stems ha^{-1}

Table 4.9: Species structure of sapling layer at village Pahelikand in Udanti wildlife sanctuary.

Name of the species	Pahelikand					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Adina cordifolia</i>	0.0451	18.6	13.41	0.0452	18.6	8.9
<i>Anogeissus latifolia</i>	0.0710	11.3	12.95	0.108	30.3	15.1
<i>Bauhinia malabarica</i>	0.0189	5.7	4.48	0.0189	5.7	2.3
<i>Boswellia serrata</i>	0.0235	3.6	3.68	0.0235	7.6	3.3
<i>Buchanania lanzan</i>	0.0710	12.4	13.46	0.1011	14.4	10.1
<i>Cassia fistula</i>				0.0511	10.3	6.1
<i>Cleistanthus collinus</i>	0.0318	12	9.96	0.1816	34.7	20.1
<i>Dalbergia paniculata</i>	0.1145	14.5	17.02	0.1145	24.5	14.1
<i>Diospyros melanoxylon</i>	0.1992	43	35.63	0.1992	43	27.1
<i>Emblica officinalis</i>						
<i>Flacourtia ramontchi</i>	0.0979	20.1	21.64	0.098	20.1	13.1
<i>Kydia calycina</i>						
<i>Lagerstroemia parviflora</i>				0.1248	27.6	14.1
<i>Lannea grandis</i>				0.0584	7.6	5.1
<i>Madhuca longifolia</i>	0.0644	9.4	10.22	0.0644	19.4	8.1
<i>Ougeinia oojeinensis</i>						
<i>Pterocarpus marsupium</i>	0.1032	29.1	22.58	0.1033	29.1	14.1
<i>Schleichera oleosa</i>						
<i>Semecarpus anacardium</i>				0.0511	18.4	9.1
<i>Shorea robusta</i>	0.3649	67.7	70.66	0.6496	67.7	55.1
<i>Terminalia chebula</i>	0.0826	19.1	17.56	0.0827	19.1	10.1
<i>Terminalia tomentosa</i>	0.0529	41.4	26.52	0.2937	79.4	45.1
<i>Ziziphus xylopyrus</i>	0.0837	20.4	20.16	0.0838	20.4	12.1
Total	1.4252	328.3	300	2.4529	497.9	300

* : ($m^2 ha^{-1}$); ** : stems ha^{-1}

Table 4.10: Species structure of seedling layer at village Dejaramli in Udanti wildlife sanctuary

Name of the species	Dejaramli					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Anogeissus latifolia</i>	0.0508	218.40	43.96	0.0609	209.5	36
<i>Cleistanthus collinus</i>	0.0211	127.70	22.44	0.0238	143.9	21
<i>Diospyros melanoxylon</i>	0.0471	213.00	32.76	0.0110	284	35
<i>Dalbergia paniculata</i>	0.0231	96	24.83	0.0441	193	28
<i>Emblica officinalis</i>	0.0232	164	21.01	0.0546	251	34
<i>Lagerstroemia parviflora</i>						
<i>Ougeinia oojeinensis</i>	0.0689	21.00	39.59	0.0890	28	26
<i>Shorea robusta</i>	0.0913	364.00	88.63	0.1039	465	73
<i>Terminalia tomentosa</i>	0.034	81.00	27.01	0.0248	97	17
<i>Ziziphus xylopyrus</i>	0.0500	76.50	20.75	0.0560	52.5	26
Total	0.4091	1361.6	300	0.4682	1723.9	300

Table 4.11: Species structure of seedling layer at village Jugad in Udanti wildlife sanctuary

Name of the species	Jugad					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Anogeissus latifolia</i>	0.0125	91	41.39	0.0256	101	29
<i>Cleistanthus collinus</i>	0.0031	92.3	31.71	0.0313	102.3	34
<i>Diospyros melanoxylon</i>	0.0012	85	22.78	0.0124	95	21
<i>Dalbergia paniculata</i>	0.0034	41	16.93	0.0344	141	37
<i>Emblica officinalis</i>	0.0052	51	25.35	0.0524	251	47
<i>Lagerstroemia parviflora</i>						
<i>Ougeinia oojeinensis</i>				0.0248	48	16
<i>Shorea robusta</i>	0.0291	99	79.08	0.0915	195	67
<i>Terminalia tomentosa</i>	0.0153	27	34.79	0.0232	107	29
<i>Ziziphus xylopyrus</i>	0.0136	61.5	47.92	0.0136	61.5	15
Total	0.0837	547.8	300	0.3095	1101.8	300

* : (m^2ha^{-1}); ** : stems ha^{-1}

Table 4.12: Species structure of seedling layer at village Pahelikand in Udanti wildlife sanctuary

Name of the species	Pahelikand					
	Site I			Site II		
	Basal Area*	Density**	IVI	Basal Area	Density	IVI
<i>Anogeissus latifolia</i>				0.0560	293.5	74
<i>Cleistanthus collinus</i>	0.0013	84.9	37.60	0.0338	344.9	70
<i>Diospyros melanoxylon</i>	0.0001	24	5.57	0.0001	20	3
<i>Dalbergia paniculata</i>	0.0004	61	25.46	0.0441	141	46
<i>Emblica officinalis</i>						
<i>Lagerstroemia parviflora</i>						
<i>Ougeinia oojeinensis</i>	0.0028	98	28.28	0.0289	148	31
<i>Shorea robusta</i>	0.00002	10.4	7.69	0.0015	15.4	7
<i>Terminalia tomentosa</i>	0.0023	157	42.11	0.0324	157	41
<i>Phoenix acaulis</i>	0.0012	103	36.35			
<i>Ziziphus xylopyrus</i>	0.0236	261.5	116.90	0.0236	61.5	24

Total	0.0318	799.8	300	0.2206	1181.3	3
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* : (m²ha⁻¹); ** : stems ha⁻¹

Table 4.13: Species diversity of different layers in different forest villages in Udanti wildlife sanctuary

Forest villages	Sites	Tree layer			Sapling layer		
		Shannon index	Beta diversity	CD	Shannon index	Beta diversity	CD
Dejaramli	Site 1	2.616	0.3208	4.74	3.521	0.1038	3.61
	Site 2	3.650	0.1262	4.03	3.600	0.0810	2.72
	Site 3	3.180	0.1800	3.50	3.673	0.0994	2.43
Jugad	Site 1	3.195	0.1660	5.48	3.464	0.0860	4.21
	Site 2	3.715	0.1120	2.40	4.045	0.0756	3.67
	Site 3	3.315	0.1669	3.38	4.179	0.0718	3.08
Pahelikand	Site 1	3.417	0.0740	6.38	3.548	0.1047	3.28
	Site 2	3.966	0.0770	4.68	3.930	0.0797	2.74
	Site 3	3.620	0.1126	4.49	4.165	0.6849	2.06

Table 4.14 : Important physical and chemical properties of soil at different forest villages

Forest villages	Sites	Sand (%)	Silt (%)	Clay (%)	OC (%)	Tot
Dejaramli	Site I	64.0	29.0	7.0	1.04	
	Site II	68.0	29.5	2.5	1.80	
	Site III	72.0	26.0	2.0	1.90	
Jugad	Site I	62.0	34.0	4.0	0.90	
	Site II	67.9	29.3	2.8	1.32	
	Site III	69.7	27.2	3.1	1.20	
Pahelikand	Site I	73.0	23.1	3.9	0.86	
	Site II	80.0	18.0	2.0	1.06	
	Site III	85.2	12.0	2.8	1.01	

Table 4.15: Correlations among site quality on diversity and structure

	Sand	Silt %	Clay %	OC%	N %	P %	K %
Shannon index	0.5917	-0.4670	-0.7973	0.0715	-0.1179	-0.4001	0.4960
Simpson index	-0.5567	0.4365	0.7628	0.0591	0.2964	0.4464	-0.6710
Beta diversity	0.0507	-0.1416	0.3744	-0.6091	-0.5009	0.2050	0.0359
Density	-0.1107	0.2086	-0.3787	0.8487	0.1717	-0.4778	-0.2144
Basal area	0.3523	-0.3548	-0.1407	0.3896	-0.6176	-0.1743	-0.1182