

BIOMASS PRODUCTION AND VEGETATION ANALYSIS OF CHILAPATTA RESERVE FOREST ECOSYSTEM OF WEST BENGAL

Thesis

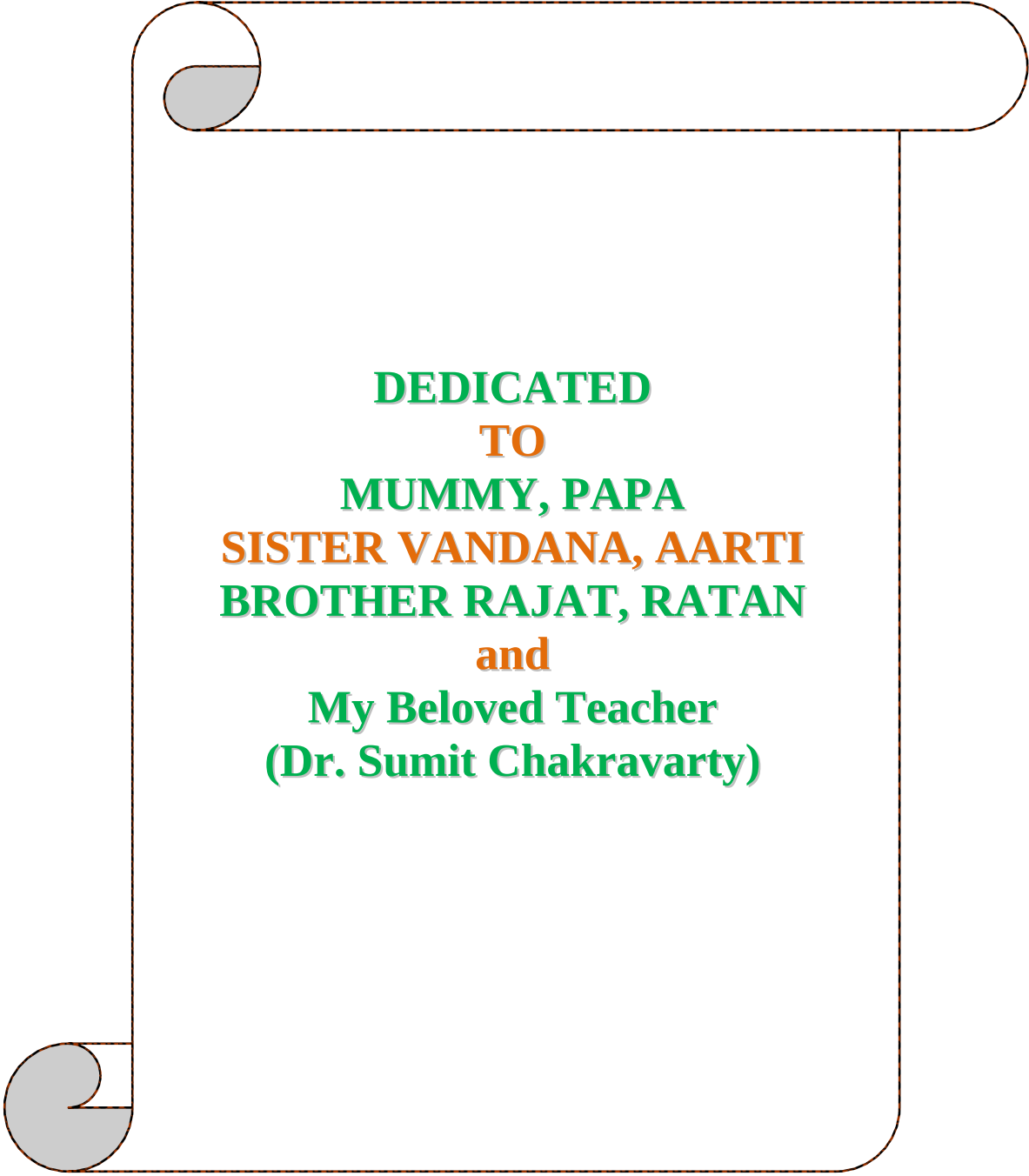
*Submitted to the
Uttar Banga Krishi Viswavidyalaya
in partial fulfillment of
the requirements for the degree of*

*Doctor of Philosophy
in
Forestry*

By
Gopal Shukla
(H-2006-12-D)



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2010**



**DEDICATED
TO
MUMMY, PAPA
SISTER VANDANA, AARTI
BROTHER RAJAT, RATAN
and
My Beloved Teacher
(Dr. Sumit Chakravarty)**

UTTAR BANGA KRISHI VISWAVIDYALAYA



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CERTIFICATE- I

This is to certify that the work recorded in the thesis entitled **“Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal”** submitted by **MR. GOPAL SHUKLA (H-2006-12-D)** in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Forestry of the Uttar Banga Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other degree or diploma. The assistance and help received from various sources during the course of investigation have been duly acknowledged.

Place: *Pundibari*
Date: *19.02.2010*


(Sumit Chakravarty)
Chairman
Advisory Committee

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	ABSTRACT

The study entitled, “**Biomass production and vegetation analysis of Chilapatta Reserve Forest Ecosystem of West Bengal**”, was conducted at Chilapatta Reserve Forest, Cooch Behar Wildlife Division during April 2007 to March 2009 to document the floristic, production and carbon storage status of the forest. Stratified random nested quadrat sampling method was adopted for analyzing the qualitative and quantitative character or phytosociology. The life forms were trees, shrubs, lianas, climbers, ferns, herbs, and epiphytes. A total of 100 species were very less present, 165 were less frequent and 46 were often present. All the shrubs, herbs, climbers and lianas were evergreen but mostly trees were deciduous. The species growing intermixed were only the trees (36.98 %), 23.47 % in patches, 23.15 % in colonies and 16.40 % grown singly. Medium/small leaf species dominated the forest while maximum species had membranous leaf. Most of the canopies were continuously covered. Overall intercepted PAR by the forest strata was more than 98 %. A total of 311 species of plants were recorded but 52 of these species could not be identified. The identified species were represented by 85 families and 167 genera. The number of species representing the trees, shrubs, herbs, climbers, lianas, and ferns were 160, 36, 49, 44, 4 and 19, respectively. The Menhinick's index and concentration of dominance were 2.20 and 0.0072, respectively. Shannon and Wiener index was high with 4.70. High index values suggest the community to be more diverse and stable. The species are more or less evenly distributed. Frequency of species in the forest ranged from 1.73 to 54.39 % while relative chance of occurrence ranged from 0.01 to 12.25 %. Density, relative density, abundance, relative abundance and IVI ranged from 0.44 to 13,403.51 plants ha⁻¹; 0.005-15.59 %, 0.80 to 17.83, 0.12-10.11 % and 0.13-37.94, respectively. The tree, shrub, liana, climber, fern and herb density in the forest was 2,615; 8,512; 775; 7,628; 1, 06,667 and 2, 18,982 plants ha⁻¹, respectively. The species were grouped into three frequency classes of A, B and C having 77.49, 20.90 and 1.61 % of the total species, respectively. About half of the species were regularly distributed. The basal area of trees species in the forest ranged from 0.25-41.60 m² ha⁻¹. The total basal area of trees estimated was 522.91 m² ha⁻¹ which is far greater than the other tropical forests. The total biomass accumulated was 1995.98 Mg ha⁻¹. Almost all this biomass was contributed by the trees. The total biomass stored in the forest was 4391191 Mg. The litter production was 5.37 Mgha⁻¹. The turnover rate of litter decomposition was only 12 months. The soils of the forest up to 30 cm were acidic with electrical conductivity of 0.069 m mhos cm⁻¹ and had 34.61 % moisture while available NPK was 261.89, 108.73 and 152.22 Kg ha⁻¹. The total available NPK reserve in the soil was 561.77, 237.67 and 334.87 Mg, respectively. The NPK content in fresh litter of forest was recorded as 1.58, 0.42 and 1.12 %, respectively. The return of available NPK from litter through decomposition was 0.084, 0.023 and 0.060 Mgha⁻¹, respectively. The total carbon storage in the soil was 75.83 Mgha⁻¹ while the total carbon pool of the forest in its soil, live and organic biomass was 973.65 Mgha⁻¹. Almost all of this carbon was contributed by the trees. The total carbon stored in the forest was 2142030 Mg.

(Gopal Shukla)

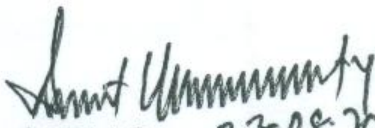
(Sumit Chakravarty)

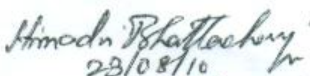
CERTIFICATE –II

This is to certify that the thesis entitled “**Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal**”, submitted by **Mr. GOPAL SHUKLA** (H-2006-12-D) to the Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the subject of Forestry has been approved today the 23rd day of August 2010 by the student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.


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*I express my deepest sense of gratitude and veneration to my chairman, Advisory committee **Dr. Sumit Chakravarty**, Assistant Professor, Department of Forestry, Uttar Banga Krishi Viswavidyalaya Cooch Behar for his meticulous guidance, constructive suggestions, and sustained interest and patience throughout the present investigation.*

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Today the world is concerned over identification, conservation and sustainable utilization of biodiversity especially those found in natural forests because it is essential for human survival, socio-economic well being and for ecosystem function and stability (Singh, 2002). Natural forests, one of the most magnificent terrestrial ecosystems and living treasures of the world is now not only regarded as the most important life support system for innumerable number of living creatures but also as a system that maintains and establish environmental harmony (Behera *et al.*, 2000; Nagendra and Gadgil, 1999). The diversity of trees provides resources and habitat for almost all other life forms of the forest (Huston, 1994; Cannon *et al.*, 1998). Tree species diversity in tropical areas varies greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Whittaker, 1972). In today's context of population explosion coupled with pollution, environmental degradation and climate change, the main concern is protection and production of bio-resources world-wide. The concern grew on paramount after the constitution of World Commission on Environment and Development by the General Assembly of the United Nations because they endorses the need of conserving the world's rich biodiversity particularly those in the tropical areas.

The Earth Summit of 1992 particularly laid stress on the integration, conservation and sustainable use of biodiversity. India along with 125 countries is a signatory to Convention on Biological Diversity (CBD) and therefore is committed to carry out identification and monitoring of the components of biological diversity for their proficient conservation and sustainable utilization (Gadgil, 1994). Biodiversity has attracted the attention of people in general and scientist community in particular because of increasing awareness of its importance on the one hand and the anticipated massive reduction on the other hand. About 20 % of all species are expected to be vanished within 30 years and 50 % or more by the end of 21st century (Myers, 1993) and mostly these losses are associated with the destruction of forests particularly the tropical forests. Duars region of West Bengal is one of the most biodiversity rich areas in India and Chilapatta Reserve Forest is one of the major diversity rich areas of the Duars (Anon., 2001_a). The forest type ranges from tropical wet evergreen to tropical moist deciduous forest (Champion and Seth, 1968).

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Tropical forests are one of the most structurally and functionally complex systems on earth. Knowledge of flora and fauna of any region is essential for the study of biodiversity and environment. A comprehensive and up to date knowledge of flora is essential for the study of plants of any area and their utility. More over preparation of herbarium of the floras of smaller areas like protected areas is a prerequisite for protection and proper management of biodiversity. Plants offer better protection to the soil and water regimes. But forests are degrading day by day and Chilapatta forest is no exception. Large scale destruction of forests in many sectors of Himalayas and its foot hills especially in the duars and Chilapatta has resulted in several environmental problems. The study of natural plant community is thus basic and prerequisite for understanding the structural and functional attributes specific to locate for better land scape management.

A vital characteristic of ecosystem function is the continuous flow the nutrients and energy through various components of ecosystem. Soil and vegetation has a complex interrelationship. Soil properties influence the vegetation and vice-versa. Selective absorption of nutrients by different tree species and their capacity to return these to the soil brings about changes in chemical and physical soil properties (Rawat, 2005). Biomass production is also directly and indirectly related to availability of plant nutrients besides the inherent growth capacity of the species. An understanding of nutrient flux and cycling in individual ecosystem is of fundamental importance to understand the large biogeochemical cycle of a forest ecosystem. This is because, in a forest ecosystem, a large amount of organic matter returns to the forest floor by way of litter fall and forms a major fraction of total net production. The dead organic matter upon decomposition renders essential nutrients for the growth and development of a forest stand. Thus it is necessary to understand litter and its nutrient dynamics of the forest by analyzing the mode and magnitude of litter fall and its subsequent decomposition along with estimation of the floor nutrient dynamics in terms of return, release and accumulation.

Tropical forest plays an important role in reducing atmospheric CO₂ which continues to contribute to global warming of the earth surface. Studies on biomass of forest vegetation are essential for determining storage of the carbon in the dominant tree component and computing the carbon cycling at a regional as well as global level. Moreover soil is one of the main sinks of carbon on earth especially forest soil because these soils have normally higher soil organic matter (Jha *et al.*, 2003;

Hashimoto *et al.*, 2009). Soil organic carbon store has great importance to conserve carbon and restrict the carbon emission while quantification of soil carbon store is useful to know the total soil carbon sink and to formulate future strategies not only to conserve this sink but also to increase it by bringing more and more wasteland, degraded land and other unusable land under afforestation programme.

The scientific management of the forest in India especially in Chilapatta has become difficult due to lack of proper understanding of structural and functional relationships of forest ecosystem (Pande, 2001). Unfortunately, careful and systematic studies on the floristic, qualitative and quantitative analysis of these climax evergreen vegetation fragment of Chilapatta is lacking. Such an understanding is very important for developing natural resources management and conservation ideas for such a rich floristic patches of the Chilapatta Reserve forest. Keeping this in view the present study entitled **“Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal”** was undertaken with the following objectives:

- To study the plant community characters of the forest.
- To estimate the biomass along with N, P, K and C stored in the forest.
- To prepare herbaria of the floras collected from the study site.

Forestry has social and economic benefits which range from maintenance of biodiversity and endangered habitats to provide sources of sustainably harvested forest products or employment for forest communities. Forest cover and land use change directly impact biological diversity worldwide, contribute to climate change and affect the ability of biological systems to support human needs by altering ecosystem service. Change in forest land use may significantly affect ecosystem processes and service (Raumann and Cablk, 2008). Ecosystem service represents those functions of ecosystem that maintain the earth's life support system which maintains and sustains all the living organisms on this earth. These benefits include nutrient cycling, carbon sequestration, air and water filtration and flood amelioration (Costanza *et al.*, 1997). The diversity of tree provides resources and habitat for almost all other life forms of the forest (Huston, 1994; Cannon *et al.*, 1998).

Today the whole world is concern over biodiversity identification, conservation and sustainable utilization of biodiversity because it is essential for human survival, socio-economic well being and for the ecosystem function and stability (Singh, 2002). Biodiversity is the core of the sustainable development and productivity of ecosystems, and is the source from which human race depends for food, fodder, fuel, fiber and raw material for industrial goods to meet his ever changing and ever increasing demand (Chen, 1993; Ye *et al.*, 2006; Gao *et al.*, 2007).

World forests especially the tropical and particularly the Asian tropical forests are being lost at an alarming pace (Laurance, 2007). Much of the surviving forest cover is already fragmented or degraded (Stibig *et al.*, 2007). At present rates of conversion, perhaps only a tenth of the original forest will survive by the year 2100, mostly within protected areas (Sodhi *et al.*, 2006_a). Laurance (2007) evaluated the forest loss, population size, economic growth and corruption within 12 nations that contain the large bulk of Asian tropical forests and compared these with the trends occurring elsewhere in the tropics. The author reported that total forest cover is already low in a number of tropical Asian nations, even when logged, secondary and plantation forests are included.

Bangladesh has just a tenth (10.2 %) of its estimated original cover, where as the Philippines (19.4 %) and India (21.6 %) each have just two-tenths. Thailand (28.9 %), Sri Lanka (30.0 %) and Vietnam (30.2 %) each have about three-tenths of their original cover. Forest cover is higher in Myanmar (52.3 %), Cambodia (52.9 %), Laos (54.4 %), Indonesia (58.0 %), Malaysia (58.7 %) and Papua New Guinea (67.6 %). There is some tendency for the most forest-rich nations to experience the highest relative rates of forest loss and vice-versa. Forest-poor Bangladesh, India and Vietnam with net annual changes of +1.3 %, +0.1 % and +0.5 % respectively are either gaining forest cover or remaining roughly stable. Forest cover is declining in all other Asian tropical nations. Forest-rich Indonesia and Malaysia are rapidly losing their forests (both -1.2 %/year) as in Sri Lanka (-1.6 % /year) and Myanmar (-1.4 % /year). The situation is especially alarming in the Philippine a forest-poor country with rapid forest loss (-1.4 % / year). Forest loss is intermediate in Thailand (-0.7 % / year) and Cambodia (-0.6 % / year) and lowest in Laos and Papua New Guinea (both 0.4 % / year). Overall the correlation between total forest cover and relative forest loss for the 12 Asian tropical nations is negative but nonsignificant ($r = 0.420$, $P = 0.17$; Pearson correlation).

The fear whether the protected areas in tropical Asia can sustain biodiversity is justified because tropical Asia has less remaining forests, higher rates of deforestation, logging and higher population densities than do other major tropical regions coupled with the situation that conservation in the Asian continent is highly uncertain. Asian nations like India, China and Vietnam have stabilized their forest area during the period 2000-2005 (Vincent, 2009) while tropical countries like Cambodia, Indonesia, Laos, the Philippines and Thailand have nominally protected at least 10 per cent of their original forest cover but still many protected areas in these countries are isolated (DeFries *et al.*, 2005) and degraded by illegal logging, hunting and other forms of encroachment (Curran *et al.*, 2004; MacKinnon, 2006), while some reserves have already collapsed ecologically (Smith *et al.*, 2003_a; Curran *et al.*, 2004; MacKinnon, 2006; Wright *et al.*, 2007). Protected areas in peninsular Malaysia and Java are relatively stable but many in Cambodia, Vietnam, Laos, the Philippines and Indonesian Borneo are seriously imperiled (Smith *et al.*, 2003; Curran *et al.*, 2004; MacKinnon, 2006; Wright *et al.*, 2007).

Similar situation of conservation for protected areas prevails in the Indian subcontinent also. Such a situation of biodiversity damage due to forest cover loss will be crucial to bolster and expand the current protected area network in tropical Asia and to manage off-park lands more sustainably. The heart of Borneo initiatives, for example, which seeks to maintain ecological connectivity among 22 protected areas across parts of Kalimantan, Sarawak, Sabah and Brunei (Anon., 2006) could potentially limit the deleterious impacts of reserve isolation and overhunting on biodiversity (Laurance *et al.*, 2002; Brook *et al.*, 2003; Sodhi *et al.*, 2006_{a & b}). Ecological restoration will also help to increase the viability of certain degraded reserves (Lamb *et al.*, 2005). The future of biodiversity conservation thus will depend upon the success or failure of such a noble initiatives.

The diversity of biological communities has never been more appreciated globally and particularly in Asia than they are now as they become ever more threatened by the environmental crises. Because of its remarkably high species richness and endemism, the rapid loss and degradation of forests will likely have serious impacts on Asian biodiversity (Laurance, 2007). The previous studies on biological diversity were descriptive and concentrated at higher spatial scales i.e. regional, national and global (Raven, 1987; May, 1988; Groombridge, 1992; Daily, 1995; Heywood, 1995). A great deal of time and expertise has been meager also (Southwood, 1978). However now the focus of such studies has changed from higher spatial scales to locally convenient landscapes at which land use decisions and management policies are frequently implemented (Rickklef and Schluter, 1993; Nagendra and Gadgil, 1999; Negi, 1999). In Indian forestry so far production values have not included anything more than stem and branch wood. Even in other countries forestry practices have been based on production value of bole wood only. It is only for last few decades that in some developed countries, attempt have been made to quantify total above the ground production though root production still largely estimated (Lal, 1992). Perusal of literature on this aspect reveals neither much work has been done to estimate net primary productivity in Indian forests nor there have been comprehensive studies to estimate standing crop in various forest ecosystems in India. Fortunately, scattered literature those are available indicates

initiation of some systematic work but unfortunately these are not on detail and full scale basis. Therefore a systematic attempt was made in the present study entitled **“Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal”** in light of similar results collected from the available literature which are presented under the following heads:

1. Floristic composition
2. Production, decomposition and nutrient dynamics
3. Carbon sequestration

2.1 FLORISTIC COMPOSITION

Species diversity is a comprehensive reflection of species richness, distribution and evenness and embodies community structure types, organization levels, development stages, stability and habitat difference. Biodiversity reflects not only the heterogeneity of a community in its composition, structure, function and dynamic, but also the relationship between different conditions of physical geography and communities (Wu, 1998; Ovington, 1999; Ai, 2006). Species diversity varies greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Whittaker, 1972). There is significant correlation of species diversity with species evenness and species richness while significant negative correlation exists between species diversity, concentration of dominance, beta diversity and maturity index (Dash *et al.*, 2009). The studies of tree spatial patterns in forest stands have become a relevant tool in the analysis of the structure and dynamics of forest communities and provide a measure of habitat quality (Pommerening, 2002).

Recent research comparing the spatial variability among natural and managed stands of boreal, tropical and southern hemisphere deciduous forests (Kuuluvainen, *et al.*, 1996; Batista and Maguire, 1998; Fajardo and Alaback, 2005_a) suggest that natural forests are likely to host the highest amount of structural and biological diversity. Spatial stand structure has an important role in determining habitat and species diversity and can be quantified to assess habitat quality for conservation purpose (Pommerening, 2002;

Skov and Svenning, 2003). Understanding the causes, patterns and consequences of biodiversity is critical to protect biodiversity and to understand the consequences of changing diversity. For example, in arctic region the species diversity is primarily influenced by the energy availability (summer temperature) and habitat variability (Rannie, 1986; Edlund and Alt, 1989; Walker, 1995).

Gould and Walker (1996) examined the correlation between species richness, mean July temperature and landscape heterogeneity along the Hood river area of the Central Canadian Arctic Coast in order to determine the relative influence of temperatures and physical landscape on an observable gradient in species richness. The workers reported 201 species of vascular flora which includes 103 forbs, 71 grasses and sedges, 19 deciduous woody shrubs and 8 evergreen woody shrubs. Species richness at each site ranged from 70 to 109 vascular plant species. Sites with lowest species richness were those in the upper portion of the river with diversity generally increasing towards the coast. Villa *et al.* (2003) recorded 71-78 species on 0.1 ha from forest-grassland mosaic in Southern Spain. Kawada *et al.* (2005) recoded 46, 37, 40 and 45 species in *Stipa capillata* stand, *Medicago romanica* stand, *Poa angustifolia* stand and *Inula ensifolia* stand respectively from plant communities in Kharkiv, Ukraine.

Rainforest occupy only 7 % of the earth dry surface area and accommodate 70 % of animal and plant species in world ecosystems (Lovejoy, 1997) and the range of tree species vary from 20 – 223/ha (Whitmore, 1984), a value that is much higher than that of species found in temperate forests. Abundant lianas are a conspicuous feature of tropical forests (Molina-Freaner *et al.*, 2004) and make a substantial contribution to the overall plant diversity (Nabe-Nielsen, 2001). Lianas constitute about 25 % of the woody stem density and species diversity in tropical forests (Gentry, 1991). Lianas also play an important role in forest regeneration, composition and ecosystem level process particularly in the tropics (Schnitzer and Bongers, 2002). Richness and abundance of liana differ greatly from one forest to another and between forests locations (Reddy and Parthasarathy, 2003).

Bunker *et al.* (2005) recorded 227 tree species from tropical forest in Panama. Derwisch *et al.* (2009) observed that tree density declined from 1,079 trees/ha (one year old teak plantation) to 383 trees/ha (ten year old teak plantation) and mean tree height increased from 2.1 m to 20.5 m in Western Panama. Galanes and Thomlinson (2009) reported total number of woody plant species in the 12 forest patches (γ diversity) was 69 and average species richness for each patch (α -diversity) was 21 species from northeastern Puerto Rico. The per cent of native species was 80 % with an abundance of 92 %. The woody plant Shannon diversity and species richness were higher in larger patches which is consistent with results from European landscapes (Honnay *et al.*, 1999; Krauss *et al.*, 2004; Okland *et al.*, 2006).

Species richness and density of forest woody species decreased progressively from 32 to 7 species and from 152 to 16 individuals per 50 m² due to successive farming of rice fields over a period from 5-20 years in a rice-pasture sequence clearing the Brazilian primary rain forest area at Amazonian pioneer front (Mitja *et al.*, 2008). Pereira and Eskinazi (1999) studied a vascular and nonvascular aquatic floras from northeast Brazil where various types of vegetation in this region viz. mangrove, seagrass meadow and many species of algae. But the region mostly dominated by aquatic vegetation i.e. mangroves (*Rhizophora mangle*, *Avicennia schaueriana*, *Laguncularia racemosa* and *Conocarpus erectus*), seagrass (*Halodule wrightii*, *Halophila decipiens*, *H. bailloni* and *Ruppia maritima*), 113 macroalgae and 192 microalgae species, confirming the high vegetation diversity.

Relationship between vegetation structure, physiognomy and biodiversity were analyzed for the dry lands at Falcon State of Venezuela by Matteucci *et al.* (1999). The workers found 41 physiognomic vegetation types with 974 plant species. Forest inventory project were carried out by Lentz *et al.* (2002) in conjunction with archaeological observations at Dos Hombres, an ancient Maya site located in the Rio Bravo reserved of the Orange walk district of Belize. The transitional forest away from the ancient Maya occupation contained 406 species belonging from 54 genera and 30 families. The Dos

Hombres contained 38 species belonging to 17 families. The Shannon Weiner Index of biodiversity was slightly lower at Dos Hombres.

A preliminary analysis of forest biodiversity of four provinces along the middle and lower reaches of the Changjiang River in China were studied by Fang and Yu (1999). The authors recorded nearly 10,000 species of higher plants including various endemic and rare species. Structure and dynamics of natural populations of the endangered plant *Euryodendron excelsum* was studied by Shen *et al.* (2009) at Bajia region of China. The workers reported that the species is restricted to one remnant population with less than 200 individuals in the region. Investigations of forest plant biodiversity were conducted at Liangshui Nature Reserve in Ziaoxing'an Mountains of eastern Heilongjiang Province, China by Wanli (1999_a). Plant biodiversity varied with season and growth form. Suo *et al.* (2009) recorded 69 plant species belonging to 26 families in natural forests of seabuckthorn at southern Ningxia, China. The families include Compositae (13 species), Rosaceae (8 species), Leguminosae (6 species), Ranunculaceae (5 species) and remaining from other families. Relationship between community type of wetland plants and site elevation on sandbars of the east Dongting Lake, China was studied by Jing-ming *et al.* (2009_a) by categorizing the study site with three groups on the basis of their species diversity. The author observed that the group I showed Shannon-Wiener index below 1.0 while second group with a Shannon-Wiener index 1.0-1.6 and third group had Shannon-Wiener index over 2.0. Yi, *et al.* (2005) surveyed the current status of tree communities of urban green areas at Bautou city of China. The result show that the only 81 species of trees are in urban green area. About 85 % of the total amounts of the trees in Bautou city belong to only 10 species. The structure of the community is very simple. Yao-qin *et al.* (2008) recorded 544 plant species in the built-up areas of Beijing belonging to 102 families. Out of these 146 are tree species, 86 are shrub species and 312 are herb species including liana.

Cloud forests include all forests in the humid tropics that are frequently covered by clouds or mist and covered only 2.5 % of the total area of the world's tropical forests (Bubb *et al.*, 2004). These ecosystems typically harbor a high proportion of endemic

species (Foster, 2001; Hilbert, *et al.*, 2001). Floristic composition of the cloud forests are mainly comprised of Fagaceae, Ericaceae, Vacciniaceae, Aceraceae, Magnoliaceae, Theaceae, Aquifoliaceae, Illiciaceae, Lauraceae and Rosaceae (Shi and Zhu, 2009) from the tropical mountain cloud forest in Yunnan, southwestern China. Authors also reported that the number of vascular species ranged from 57 to 110, Simpson's diversity index varies from 0.7719 to 0.9544, Shannon-Winner's diversity index from 1.8251 to 3.2905 and Pielou's evenness index from 0.5836 to 0.8982 for trees. Moreover evergreen species make up more than 75 % of the total tree and shrub species. The forest structure, floristic composition and physiognomy of the cloud forest in Yunnan are more closely related to the upper montane forest of Mount Kinabalu, Borneo (Aiba and Kitayama, 1999).

A total of 165 liana species representing 44 families with diversity varying from 15 to 41 species in a plot of 0.25 ha were recorded from a tropical forest of southern Yunnan, south-western China (Zhu, 2008). The author also studied the floristic composition of the forest and observed the families leguminosae with 20 species followed by Annonaceae and Vitaceae with 12 species each, Apocynaceae with 10 species and Rubiaceae with 8 species while 13 families having single species. Similar results were also reported from various other locations also viz. Malaysia (Putz and Chai, 1987; Appanah *et al.*, 1993), Costa Rica (Nabe-Nielsen, 2001), Yasuni National Park, Ecuador (Burnham, 2002), Southern India (Parthasarathy *et al.*, 2004), afro-montane rain forests (Sembeta *et al.*, 2005) and tropical Africa (Hemp, 2006).

The community types were spruce (*Picea jezoensis*) forests, linden (*Tilia amurensis*), Korean pine (*Pinus koraiensis*) forests, Birch (*Betula costata*)/ Korean pine forest, Oak (*Quercus mongolica*)/ Korean pine forest and artificial plantation forests of Korean pine and larch (*Larix gmelinii*). Generally the highest diversity values occurred in spring and herbaceous species had a richer diversity than shrub species and tree species. Similar study conducted at natural secondary forests on Mao'er Mountains by Wangli, (1999_b) in a 6 different forest communities i.e. oak (*Quercus*), poplar (*Populus*), mixed and broadleaved (hardwood) forests, Korean pine (*Pinus koraiensis*) and larch (*Larix*) plantation. The author reported that the forest plant biodiversity varied with season as

well as forest type. Tree species showed highest species richness and diversity in the poplar forest followed by the mixed forest and larch plantation while least tree species richness and diversity was found in the broadleaved community. The similar trend was followed in case of shrubs. Herbaceous species richness and diversity was the highest in the mixed forest and lowest in the Korean plantation. Species evenness followed a different pattern in the different communities. 136 woody species belonging to 44 families was recorded by Larpkern *et al.* (2009) from bamboo-deciduous forest in northeastern Thailand. Euphorbiaceae represented 15 species followed by Fabaceae (13) and Rubiaceae with 8. Maxwell (2008) reported 1,013 species belonging to 170 families from mixed forests of Doi Tung, Chang Rai Province in northern Thailand. The author recorded 742 species representing 111 families from Dicotyledonae (Angiospermae), 176 species representing 17 families from Monocotyledonae (Angiospermae), two species representing two families from Gymnospermae, 71 species representing 22 families from Bryophyta.

Plant species diversity in a managed forest landscape composed of *Larix kaempferi* plantations and abandoned coppice forests in central Japan were studied by Nagaike *et al.* (2006). The authors observed that all species diversity indices were significantly higher in plantation than in secondary forests. Moreover, the number of species in secondary forests was lower than that in younger plantations. The relative frequency of occurrence and the number of species of fern, vine and annuals were significantly higher in plantations than in secondary forests while number of tall tree species was lower in plantations than in secondary forests. Various workers also reported that the comparisons of plant species diversity and richness between plantations and other forest type varied from place to place (Kirby, 1988; Qian, *et al.*, 1997; Stapanin and Cassell, 1999; VanWesenbeeck *et al.*, 2003).

Structure, species composition and soil properties of a subtropical evergreen broad-leaved forest in Okinawa, Japan were examined by Xiao-niu *et al.* (2008). The workers reported 80 tree species belonging to 31 families. The Diversity index (H'), Equitability index (J') and Species richness index (S') worked out were 3.36, 0.71 and

4.72, respectively and all of these strongly declined with the increase of importance value of the dominant. Moreover the mean canopy height for this forest was 10 m and stands contained an average of 5400 stems/ha of which about 36 % of these stems were larger than 10 cm dbh while the total basal area was 54.4 m²/ha. This result was similar to the dominated species in warm temperate evergreen broad-leaved forests in the mainland Japan (Iehara *et al.*, 1983; Takyu and Ohsawa, 1997) and is high in comparison to the subtropical evergreen forests in Taiwan (Hara *et al.*, 1997) and tropical rainforests in Amazon (Mori *et al.*, 1983; Milliken, 1998). Jing, *et al.* (2009) carried out a study in three different forest types (natural forests, plantations and regenerated forest after fire) at Aershan in Inner Mongolia and recorded 95 plant species belonging to 19 families and 50 genera. Out of these 9, 6 and 80 species were arbors, shrubs and herbs, respectively. However natural forests showed highest IVI for the total number of species followed by plantations and regenerated forest after fire. All the three diversity indices (Simpson's, Shannon-wiener and Pielou's indices) indicate a similar trend in all forest types.

A list of flowering plants belonging to Augrabies National Park of South Africa compiled by Zietsman and Bezuidenhout (1999) enumerated a total of 364 species from 210 genera and 74 families. Out of these 76 are monocotyledons while 288 are dicotyledons. Springuel *et al.* (1997) recorded 78 plant species from four phytogeographic elements and four principal vegetation groups from Wadi Allaqi Biosphere Reserve Egypt. Onyekwelu, *et al.*, 2008 recorded a total of 31 families (26, 24 and 22 in Queen's, Oluwa and Elephant forests respectively) from rainforest ecosystems in south-western Nigeria. Species diversity index, species richness and species evenness were in the order Queen's > Oluwa > Elephant forests. Queen's, forests had the highest species diversity 51 followed by Oluwa 45 and Elephant forests 31. The trend of Shannon –Wiener diversity indices (H') showed that Queen's forest was the most diverse followed by Oluwa and Elephant Forests. The similar trend of Shannon –Wiener diversity indices (H') and species richness value were reported by Lowe (1997) and Adekunle (2006) from some other rainforest site in Nigeria.

Bahar (2001) recorded a total of 52 plant species under *Populus tremuloides* forest in North America. Of which 27, 18 and 15 plant species respectively were found at Utah, Idaho and South Dakota. The author found that variability in species diversity at these three sites was primarily influenced by stand density, topography, aspect and biotic pressure in the area. The lowest stand density of *P. tremuloides* at Utah enable more light radiation and rain to reach the ground floor which explain higher genetic diversity and plant population of undergrowth at Utah.

In Southeast Asia, the highest richness recorded so far is 225 species/ha by Whitmore (1984). Sheikh *et al.* (2002) reported 153 plant species belonging to 38 families and 113 genera from Naltar valley at northwestern Karakorums in Pakistan. The dominated families in this area were Asteraceae, Polygonaceae, Saxifragaceae and Rosaceae. Similarly, 32 tree species belonging to 20 families and 25 genera was recorded by Newaz (2006) in tropical forests of Chittagong, Bangladesh. The dominant family reported was Leguminosae with four species followed by Moraceae and Myrtaceae with three species each.

Sapkota *et al.* (2009) recorded 48 species from a mature seasonally dry *Shorea robusta* forest at Nawal Paransi district in Nepal. Among the 48 species, 43 and 37 species were recorded in the gap and intact vegetation environment. The majority of the species had few individuals and minority species had many individuals. However, many herbs and trees had low species abundance in the gap, while many shrubs with few individuals were found in the intact vegetation. The authors also reported that the various diversity indices for each growth form did not vary consistently between the gap and intact vegetation. For herbs and trees, the total number of species (S), species richness (D_{mg}) and Fisher diversity index (α) were slightly higher in the gap than in the intact vegetation. While the above three index for shrub were show reserve trends. The species turn-over rate, as measured by numerical species richness (S/N) was higher in the gap for herbs and intact vegetation for shrubs and approximately the same in both environments for tree. The Shannon-Wiener index (H), the component of Simpson's index (I -D) and the Shannon's measures of evenness (J) was slightly higher in the intact vegetation than

in the gap for shrubs and trees while nearly the same for herbs. Other workers like Runkle, 1982; Denslow, 1995; Pande, 1999; Zang and Wang, 2002; Li, *et al.*, 2005 reported that the tree species richness is higher in the gap than in the intact vegetation.

The Eastern Ghats constitute an important biodiversity area in India and have studied earlier mainly for floristic and that too confined to a few prioritized sites. A total of 175 climbing plant species belonging to 100 genera and 40 families were recorded from tropical forests of southern Eastern Ghats, Tamil Nadu (Muthumperumal and Parthasarathy, 2009). Species richness and stand density of all woody plants in a tropical dry evergreen forests at Kuzhanthaikuppam and Thirumanikkuzhi of Tamil Nadu was 42 and 38 species and 1367 and 974 individuals/ha, respectively (Parthasarathy and Karthikeyan, 1997). Thus a total of 54 species belonging to 47 genera and 31 families was recorded from both these sites. Lichen diversity and its distribution pattern in tropical dry evergreen forest of Guindy National Park, Chennai was studied by Balaji and Hariharan (2004). The workers recorded 31 lichens representing 26 genera, 19 families and 9 orders from 219 phorophytes in a 219 trees, 27 shrubs. Out of 19 families of lichens, the largest family being Physciaceae with 6 species and 10 lichen families possess single species each. The Guindy National Park also contains 350 species of flowering plants Santharam (1992).

Mohammed *et al.* (2008) recorded 250 wild and neutralized plant species belonging to 71 families from Ahobilam catchment area of the Nallamalais Reserve Forest of the Eastern Ghats. All the collected plants are highly endemic and used for medicinal purpose. In a tropical semi-evergreen forest of Shervarayan hills in Eastern Ghats, 80 species belonging to 71 genera and 44 families with a stand density 815/ha was recorded by Kadavul and Parthasarathy (1999). Moreover it was found that species richness was greatest in undisturbed site (50) and lowest (33) in the selectively felled site. The undisturbed site was also denser (986 stem/ha) and more voluminous (basal area 44.3 m²/ha) as compared to others site. *Chionanthus paniculata*, *Syzygium cumini*, *Canthium dicoccum* and *Ligustrum perrottetii* dominated the stand and collectively contributing to more than 50 % of the total density. Reddy *et al.* (2006) recorded 372 plant species

belonging to 262 genera under 100 families from Bhitarkanika National Park, Orissa. A total of 152 tree species belonging to 114 genera and 41 families were recorded from Niyamgiri Hill Ranges, Orissa by Dash *et al.* (2009).

Plant diversity in the Western Ghats is correlated with seasonality and with higher level of alpha diversity towards the south (Pascal, 1988; Davidar, *et al.*, 2005). The flora of Western Ghats comprises about 12,000 species ranging from unicellular cyanobacteria to angiosperm (Nayar, 1996). In this spectrum of flowering plant constitutes about 27 % of Indian flora with 4,000 species of which about 1,500 species are endemic. Many of these species are traditional source of medicine. The bryophyte diversity of the Western Ghats is high with about 850-1000 species (Daniels and Vencatesan, 2004). Of these, 682 are mosses, 190 of which are endemic including one endemic genus *Nanothecium* (Vohra and Aziz, 1997). . In tropical rain forest of Western Ghats, India 312 species in 103 families were recorded (Muthuramkumar, *et al.*, 2006). Out of these 144 species are trees, 60 species lianas and 108 species understory plants. Ganesh *et al.* (1996) recorded 173 woody plant species belonging to 58 families including 90 species representing 35 families of understory trees from Kalakad-Mundanthurai tiger reserve, Western Ghats. Species diversity (H) was 4.87 recorded from this forest was higher than other similar sites in the Western Ghats. Stem density and basal area recorded was 727.34 and 42.03m²/ha respectively.

Biodiversity index, number of different species and total number of plants of forest ecosystem under different canopy density was measured by Jha and Nanduri (2003). The workers reported that these three attributes decreased with decrease in canopy density. *Myristica* swamp forest found in the southernmost part of Western Ghats showed stand density of 520 trees/ha, maturity index value of 18.33, species density of 18 species/ 0.1ha, diversity of 2.5 and concentration of dominance of 0.09 (Varghese and Menon, 1999). Similarly, Varghese (1997) reported stand density, basal area cover, maturity index value, species richness, diversity, concentration of dominance and evenness of other forest type found in Peppara Wildlife Sanctuary. As compared to other

forest types of Peppara Wildlife Sanctuary, *Myristica* swamp forest had very low species richness (4.3024) and species diversity (2.5097).

Singh (2004) recorded 515 plant species in Ratanmahals Wildlife Sanctuary at Malwa region of Gujarat. Out of which 124 species are trees, 31 species are shrubs, 241 species are herbs, 39 species are grasses, 72 species are climbers and 8 species are epiphytes. Amongst all the tree species, *Tectona grandis* was found to have the maximum density and comprised 19.60 % of the total tree cover composition. Out of 31 shrubs species recorded in the sanctuary, *Holarrhena antidysenterica* show a remarkable density of 76.60 %.

Raja Sekhar *et al.* (2008) recorded 19 mangroves and associated plant species belonging to 15 families from Bangarampalem mangrove swamp of Visakhapatnam district of Andhra Pradesh. Rao *et al.* (2005) reported 232 species of herbs, shrubs, ferns, climbers and orchids were distributed in 60 families from Linganamakki catchment area of Shimoga District in Karnataka. The workers reported that family Scrophulariaceae have the highest number of species (20), followed by Orchidaceae (18), Fabaceae & Rubiaceae (17), Acanthaceae (12), Lamiaceae, Asteraceae & Euphorbiaceae (8), Balsaminaceae & Gentianaceae (6), Malvaceae (5), Convolvulaceae & Liliaceae (4), Boraginaceae & Commelinaceae (3) and rest of the families with 1 or 2 species. Forest tree species of Shimoga District were first catalogued in 1888 by Lavery (1888) and subsequently by Fyson (1915), Cooke (1901-1908); Talbot (1909-1911); Gamble (1915-1936); Kadambi (1939 & 1941); Raghavan (1970); Saldanha and Nicolson (1976); Yoganarasimhan, *et al.* (1982); Raghavan (1983); Pascal (1988) and Ramasamy *et al.* (2001).

Saldanha (1984) reported 95 species in 41 genera of Orchidaceae from Hasan district in Karnataka while Sharma *et al.* (1984) reported 173 species of orchids in 51 genera from Karnataka. Jha (2003) reported a total number of 237 species belonging to 153 genera and representing 70 families from Lonar Crater in Buldhana Forest Division in Maharashtra. Out of these there are 128 herbs, 30 shrubs, 5 under-shrubs, 19 climbers and 57 trees. Similar species were also reported from Lonar Crater by Diwakar and

Ansari (1995). Three major tree communities recorded in the Satpura National Park, Madhya Pradesh were Chloroxylon-Terminalia, Shorea-Terminalia and Syzygium-Terminalia at < 900m (Lower hills), 900-1100m (Middle hills) and 1100-1350m elevation (Upper hills) respectively (Khatri *et al.*, 2004). The tree species richness and diversity index was 45 & 3.62, 29 & 2.71 and 31 & 3.02 respectively at these elevations, while the shrub species richness and diversity under Chloroxylon-Terminalia community was 29 & 3.85, 27 & 3.16 in Shorea-Terminalia community and 19 & 2.57 under Syzygium-Terminalia community. However, species richness and diversity index of herbs in these communities were 43 & 3.53, 40 & 3.44 and 37 & 3.26, respectively.

Khera *et al.* (2001) conducted plant biodiversity assessment in relation to disturbances at mid-elevation forest of central Himalaya and found higher number of trees and shrubs on the western aspect where low erosion and anthropogenic pressure were present. The total tree density was higher at eastern aspect than the western aspect of the hill top. The shrub and herb density was higher on the both the aspect as compared to tree diversity because opening of canopy provided opportunity for the recruitment of shrubs and herbs. Moreover the workers reported significant presence of *Coriaria nepalensis* a non leguminous nitrogen fixing species at all the site of their study area.

Rana and Samant (2009) identified 13 habitats, 23 forest (tress 19 and shrubs 4) communities and 24 alpine (scrubs 10 and herbs 14) communities from Manali wildlife sanctuary in the Indian Himalayan region. Each habitats and community was evaluated for site representation, altitudinal distribution and species richness. Total tree density ranged from 170 to 1190 individual/ha and total basal area ranged from 0.76 to 103.9 m²/ha while total shrub density ranged from 880 to 6800 individual/ha. The workers also reported species richness of 1.55, 1.32, 1.28 and 1.22 in rocky, riverine, dry forest and shady moist forest habitats respectively while remaining habitats showed <1.22 species richness index.

Plant community and diversity pattern within the forested landscape of north-eastern Uttar Pradesh having a mosaic of major and minor plantation forests and interspersed patches of mixed forests were studied by Pande and Shukla (2005). The

authors reported a total of 246 species of angiosperms from their study area with a density of 624 tree individuals/ha. Maximum species of shrubs were found followed by herbs, herbaceous climbers and trees. Moreover, 51 species of trees were recorded whose girth at breast height was more than 30 m. The mixed forests showed greater species richness of 146 as compared to species richness of 92, 80 and 52 in Sal, Eugenia and Teak plantations, respectively. The Shannon's index (α diversity) was maximum for Sal plantation (3.36) followed by Eugenia plantation (3.187), mixed forests (3.167) and lowest for teak plantation (2.766). The species-area curves suggested that the increase in number of species was more regular in mixed forests as compared to plantation. The general form of dominance-diversity curve for the forested landscape was quite normal but that for plantation showed a steep decline. The fairly high species richness and plant diversity suggested that the regional forested landscape is still able to provide the much required gene pool for the conservation of species and ecosystems of the region. The Shannon's index of diversity of forested landscape of north-eastern Uttar Pradesh reported by the authors was however lower than that recorded by Knight (1975) for tropical rain forests of Barro Colorado Island but higher than that recorded by Chandrasekhara and Ramakrishnan (1994) and Ganesh *et al.* (1996) for Western Ghats while density was similar with that reported by Jha and Singh (1990) for dry tropical forest of Vindhyan region. It is argued that each individual species depends on some set of other species for its continued existence and the species have co-evolved in the ecosystem on which they depend (Paine, 1996). The loss of natural associations may be the probable reason for supporting low number of species (Walker, 1992). The status of species richness and plant diversity within the forested landscape of north-eastern Uttar Pradesh suggests that in spite of rare occurrence of many valuable species, the region may still provide the required gene pool of wild indigenous species for the conservation of optimum biodiversity within the regional forest.

Rawat *et al.* (1999) studied plant species diversity and community structure in the outer fringes of Kedarnath Wildlife Sanctuary and reported that the number of woody species was highest in the moderately disturbed site and lowest in the Oak forest. Negi and Nautiyal (2005) recorded 53 species from Thal Ke Dhar Reserve Forest, Pithoragarh;

Central Himalayas. Out of these 13 species are trees, 24 species are shrubs and 16 species are herbs. Woody plant diversity of Doon Valley in outer Himalaya was represented by 674 taxa (591 trees, 35 shrubs, 12 climbers, 15 palms and 21 bamboos) from 92 families and 368 genera (Negi, 2006). Out of these 42 species was Gymnosperms only and 596 were dicots. The dominant families are Caesalpiniaceae, Euphorbiaceae and Papilionaceae (37 species), Myrataceae (32 species) and Mimosaceae (30 species).

Chandra *et al.* (2010) studied vegetational diversity along an altitudinal range in Garhwal Himalaya and reported a total of 209 plant species. Another report of Garhwal Himalaya by Pokhriyal *et al.* (2009) recorded 87 species in *Anogeissus latifolius* at Pathri Rao watersheds, among which 27 were trees, 21 shrubs and 45 herbs and 92 species with 24 trees, 23 shrubs and 45 herbs at Phakot watershed from the same forest. Srivastava *et al.* (2005) reported a total density, basal area cover values in the tree layer, diversity and concentration of dominance ranged from 630 to 1590 stems/ha, 20.04 to 82.51 m²/ha, 1.33 to 2.01 and 0.27 to 0.45, respectively at Garhwal Himalayas. Kumar *et al.* (2004) selected two sites at Puri districts of Garhwal Himalayas on the basis of the disturbance gradient at an elevation from 900 to 1300 m asl and reported that concentration of dominance and index of diversity were higher for the mildly disturbed forest site. Phytosociological and biomass production pattern of undergrowth vegetation in *Eucalyptus tereticornis* plantation in Hardwar forest was studied by Bahar (2003). The workers recorded 56, 39 and 32 plant species during rainy, summer and winter season respectively. *Cannabis sativa* were showed maximum IVI followed by *Ageratum conyzoides*. Kumar and Singh (2001) also recorded 18 species under plantation of *Acacia auriculiformis* at Varanasi Forest Range in Uttar Pradesh.

In tropical dry deciduous forest of Boudh district in Orissa, Sahu *et al.* (2007) recorded 187 species which include 91 trees, 10 shrubs, 12 climbers and 74 herbs. The predominant tree species are *Shorea robusta*, *Bachanania lanzan*, *Cleistanthus collinus* and *Diospyros melanoxylon*. Species rarity, Shannon-Weiner index, Simpson value, stand density and mean basal area recorded were 18 %, 4.51, 0.92, 591 tree/ha and 25.50 m²/ha, respectively. Sahoo *et al.* (2004) reported the plant communities and distribution pattern

during summer, monsoon, post-monsoon and winter seasons in Forest Protection Committee (FPC) managed forest, plantation stand and degraded forest at Abhoya Range Forest of West Bengal. They recorded maximum number of trees, herbs and shrubs species (61) during post-monsoon with FPC-managed forest and lowest number of trees, herbs and shrubs species (12) during pre-monsoon in degraded forest. In Cachar district of Assam among the angiosperms, Asteraceae, Leguminosae and Malvaceae were most dominant (Sharma *et al.*, 2002). Das and Das (2005) recorded a total number of 122 species in the home garden from Barak Valley of Assam. The Shannon-Weiner index of trees in tropical forests of Garo Hills, Meghalaya was recorded as 4.27 which are comparable to the world's richest tropical forests (Kumar *et al.*, 2006). Padalia *et al.* (2004) recorded 369 species belonging to 233 genera and 77 families from Andaman Islands. The workers observed that evergreen forest has 264 tree species belonging to 176 genera and 81 families followed by moist deciduous and semi-evergreen forest with 235 and 231, respectively.

In many part of Asia and Africa care and respect for nature has been influenced for centuries by religious beliefs and traditions (Rao, 1996). All forms of vegetation are conserved including trees, shrubs, herbs and climbers (Gadgil and Vartak, 1976) in specialist area called scared groves. These groves can be considered as a unique example of an ecological understanding and sustainable management of natural resources by our ancestors (Rajendraprasad, 1995; Rajendraprasad *et al.*, 1998 & 2000; Sukumaran and Raj, 1999). The preliminary studies conducted by Sukumaran (1997 & 1998) and Amirthalingam (1998) revealed that the sacred groves of Tamil Nadu constitute a vast array of flora and fauna that many rare, endemic and endangered species. Kanyakumari district is one of the richest phytogeographical regions in Tamil Nadu. This district was the most important region of the erstwhile Travancore state with more than 3, 200 species of flowering plant (Nagamaiya, 1989).

The plant of 201 scared groves of this district was studied by Sukumaran *et al.* (2005). The workers recorded a total number of 329 plant species representing 251 genera and 110 families. Out of these 110 families, 108 are angiosperms and two are

gymnosperms. In angiosperms, among the dicots, polypetalae occupied 40.73 % with representative from 41 families; gamopetalae 33.13 % with 36 families, monoclamydeae 14.28 % with 14 families and monocots comprises 17 families with 11.25 % in distribution. Gymnosperms represent only 0.61 % with two families (Cycas and Gnetum). Among the 134 species of polypetalae recorded, 70 were trees, 38 shrubs, 23 herbs, two climbers and one twiner and among 109 gamopetalae, 29 were trees, 42 shrubs, 28 herbs, five climbers, three twiners and two lianas. Out of 47 species of monochlamydeae, 25 were trees, nine shrubs, 12 herbs and one climber. Thirty nine species (12 were trees, eight shrubs, 16 herbs and one climber) of monocots identified were from 17 families. The predominant life forms of the sacred grove were the trees (42.25 % of the total vegetation) followed by shrubs (28.88 %) and herbs (24.01 %). While the rest 4.86 % were climbers, twiners and lianas. The dominant family was Fabaceae with 16 species followed by Moraceae with 14 plant species and Mimosaceae, Euphorbiaceae, Arecaceae, Rubiaceae, Combretaceae, Acanthaceae, Verbenaceae and Ebenaceae with six species each.

Similarly the sacred groves of Oorani and Olagapuran which are patches of dry evergreen forest around north Pondicherry in southern eastern coastal belt of Tamil Nadu had a total of 169 angiosperms were from both the sites (Ramanujam and Kadamban, 2001). The Oorani grove were less diverse with 74 flowering plant species belonging to 71 genera and 41 families (30 woody species, 8 lianas and 4 parasites) as compared to Olagapuran grove with 136 species belonging to 121 genera and 58 families (woody species were fewer with 9 lianas and 3 parasites). 722 species representing 129 families and 474 genera were recorded by Induchoodan (1996) and 411 species by Krishnan (1998) from the sacred groves of Kerala.

Hajra (1975) reported 392 vascular plants including pteridophytes from Mawphlang sacred groves of Meghalaya. In 56 sacred groves of Meghalaya, Tiwari *et al.* (1998) have reported about 154 woody plants belonging to 340 genera and 131 families. These included 50 rare and endangered species. Khan *et al.* (1997) reported that about eight per cent (90 species) of the endemic species found in Meghalaya are restricted in

the sacred groves of the state. Similarly Jamir and Pandey (2002) recorded a total number of 395 plant species belonging to 108 families including three unidentified tree species from the sacred groves of Jaintia hills in Meghalaya. In these groves angiosperms were dominant with about 94 % of the total flora recorded followed by pteridophytes and gymnosperms. In other parts of India some other sacred groves were also studied by Sethi (1993); Visalakshi (1995) and Amirthalingam (1998).

2.2 PRODUCTION, DECOMPOSITION AND NUTRIENT DYNAMICS

Leith (1964) accounted the primary production in biosphere and Whittaker (1970) compiled the data of net primary production of major ecosystems. He gave the total area of earth as $510 \times 10^6 \text{ km}^2$, out of which land comprises of $149 \times 10^6 \text{ km}^2$ and rest as the total oceans $361 \times 10^6 \text{ km}^2$. The total biomass production for the whole world is 54×10^{10} tonnes. The net primary productions on land is $730 \text{ g /m}^2/\text{yr}$ (on average basis) or say about $10.9 \times 10^{10} \text{ t/yr}$ and this stands for oceans at $155 \text{ g /m}^2/\text{yr}$ ($5.5 \times 10^{10} \text{ t/yr}$). More literature is available due to the findings of Odum and Heald (1975), Goldman (1966) and Eckardt (1968). There is little consensus on the form of the relationship between biodiversity and productivity. Most of such researches were done in temperate grasslands with arid ecosystems receiving comparatively little attention (Cox *et al.*, 2006). The workers suggested that productivity-diversity relationships are best described by a boundary that places an upper limit on species co-existence across the gradient of productivity for site. This upper limit often appears to be maximized at intermediate levels of productivity but it has relatively few points on the downward portion of boundary.

Tropical forests occupy about 13 % of the land surface and their total world biomass is around 90×10^{10} tonnes (on dry weight basis) with an average of $4 \times 10^{10} \text{ t/yr}$. The primary production of tropical rain forest is $2,000 \text{ gm}^{-2} \text{ yr}^{-1}$ (Lieth, 1975). The worker also reported the primary production of tropical rain forest, rain green forest, summer green forest, warm temperate mixed forest, boreal forest, tundra scrub, desert scrub, tropical grassland, temperate grassland, agricultural fields, lake & streams, coral reefs and open oceans are 2000, 1500, 1000, 1000, 500, 140, 70, 700, 500, 650, 500, 2000 and

125g/m²/yr, respectively. Further, Golley and Lieth (1972) estimated the net primary productivity of tropical and temperate grasslands of the world as 1.05x10¹⁰ tonnes and 0.45x10¹⁰ tonnes, respectively.

Similarly the temperate forest has about 12 % land under their cover with biomass production of 2.34x10¹⁰ t/yr while the productivity value of swamp and marshy lands are 0.4x10¹⁰ t/yr (Whittaker, 1970). In temperate deciduous forests, about 41 % of aboveground net primary productivity is allocated to leaf production (Litton *et al.*, 2007). The production of dry desert of the world are insignificant with 3g/m²/yr only and total production of the global cultivated lands is about 1x10¹⁰ tonnes. Variability of tree species in net primary productivity has been attributed to numerous factors related to the physiology of trees, site conditions or structural characteristic of individual tree stands (McMurtrei *et al.*, 1994).

At the stand level in the Caribbean lowlands of Costa Rica, the mixed stands performed well for volume, basal area, above ground biomass and carbon sequestration in comparison to other pure and mixed plantations of tropical timber species (Redondo-Brenes and Montagnini, 2006). Biomass production and partitioning, crown structure and leaf areas of trees can be altered by plant composition (Radosevich and Osteryoung, 1987; Puettmann and Berger, 2006). These changes are important because they affect solar radiation transfer, carbon and nutrient storage, response to disturbance, tree form and commercial value of trees.

Biomass partitioning in red pine (*Pinus resinosa*) in the Upper Peninsula of Michigan were studied by King *et al.* (2007) reported that the carbon(C) concentrations averaged 40.8 – 49.5 % for all plant parts with lowest values in live and dead roots and average nitrogen (N) concentrations ranged from 0.20 – 0.89 % being lowest in the boles and highest in foliage. The author also reported that the strong trend for total shoot and root biomass increased from 0.21 to 118.20 t C/ha and 0.03 to 55.22 t C/ha decreasing to 87.94 t C/ha and 26.35 t C/ha at the 55 year old site, respectively. Petersen *et al.* (2008) estimated the total above ground tree biomass in a five year old Douglas-fir that accumulated per unit ground area was 11.6 Mg/ha with of 4.2 Mg/ha each partitioning to

stem and branches while 3.2 Mg/ha to foliage. Siccama *et al.* (2006) estimated the above ground net primary productivity of trees in a northern hardwood forest at Hubbard Brook in New Hampshire as 6.53 Mg/ha/yr, of which 3.28 and 3.25 Mg/ha/yr was for above ground woody tissues and leaves, respectively. The average net production of Masson pine natural forests in subtropical regions was 5.473 t/hm² where the tree layer contributed 5.163 t/hm² (Feng, 1982).

The total biomass of *Pinus tabulaeformis* stands (at age 29) in the Miyun Reservoir Watershed, Beijing was 92627 kg/hm² (Liu and Yu, 2009). Out of this total biomass the proportion of different tree parts were as 49946 kg/hm² (trunk), 17659 kg/hm² (branch), 12762 kg/hm² (leaf) and 12260 kg/hm² (root) which were in ratios 54:19:14:13. Average net production of the tree layer of Chinese fir plantations was 8.300 t/hm² (Pan, 1981) and that of *Michelia macclurei* plantations 27.590 t/hm² (Feng *et al.*, 1983). The average net production of Camphor tree plantations was 12.100 t/hm², of which the tree layer accounted for 9.550 t/hm² (Yao *et al.*, 2003); for natural spruce forests in southwestern subalpine regions was 6.8385 t/hm² (Ma *et al.*, 2007); for Japanese larch plantations was 3.810 t/hm² (Li, 1984); for locust trees in warm temperate zones was 1.550 t/hm² (Chen, 1986) and the average net production of *Quercus vaiabilis* plantations was 2.060 t/hm² (Bao, 1984). A study conducted to investigate root distribution, biomass and seasonal dynamics in stand of *Caragana korshinskii* Kom. at Tengger desert, China by Zhang *et al.* (2009_a) revealed total root and fine root biomass as 662.4±45.8 and 361.1±10.3 g m⁻² accounting for about two third and one third of the total plant biomass, respectively. Similar results also reported by Liu *et al.* (1991), Jackson *et al.* (1997), Wilcox *et al.* (2004) for desert shrub. Subedi (2004) studied above ground biomass of *Quercus semicarpifolia* Sm. forest at six different localities viz. Suke Pokhari, Deurali, Shivapuri, Phulchoki, Chotra and Chankheli Lekh in eastern, central and western part of Nepal. The author reported above ground tree layer biomass as 479.17, 357.53, 462.60, 358.02, 272.15 and 304.21 t/ha from east to west, respectively.

Growing stock-based forest biomass was estimated for India by Chhabra *et al.* (2002_a). The workers estimated that the total standing biomass (above and below ground)

in the Indian forests as 8683.7 Mt. The above ground and below ground biomass was estimated as 6865.10 and 1818.70 Mt, contributing 79 and 21 % to the total biomass, respectively. The mean biomass density in Indian forests was estimated as 135.6 t/ha and among the states it varied from 27.4 in Punjab to 251.8 t/ha Jammu and Kashmir. The estimates were compared with previous study which had estimated biomass in the range of 4400-8700 Mt for the corresponding period.

Aboveground biomass and net primary production of two stands in a semi-evergreen tropical forest of Manipur, north-eastern India was studied by Devi and Yadava (2009). The workers reported the total biomass as 22.50 and 18.27 t/ha in forest stand I and II, respectively. The annual aboveground net primary production varied from 8.86 to 10.43 t/ha, respectively in two forests stands I and II. The biomass production for evergreen tropical forest of Manipur reported by the workers is lower than that of dry deciduous forest and Sal forest (Mishra *et al.* 1967; Singh *et al.* 1992), coniferous forest (Ovington, 1967) and lowland dipterocarp forest (Kawahara *et al.* 1981).

The estimated standing biomass in mature Sal of dry deciduous forest of Varanasi stands at 233 tonnes ha⁻¹ (Raman, 1975), Sal stand of east Dehra Dun forest division (Negi *et al.*, 1988) is 158.4 tonnes ha⁻¹ and sissoo plantation in Bijnor District of Uttar Pradesh (Sharma *et al.*, 1988) is 186.4 tonnes ha⁻¹. Mishra (1970) reported net primary productivity of forest, grass land and crop land in Varanasi district of Uttar Pradesh as 1296,744 and 780 g m⁻² yr⁻¹, respectively. Primary productions of teak and Sal forests in Dehra Dun were 7.5 and 11.2 tonnes ha⁻¹, respectively (Negi, 1983). Negi (1983) also reported primary production of Teak forest of Dehra Dun, Sal forest of Dehra Dun, mixed grasslands of Rajasthan, rivers of Uttar Pradesh, sewage lagoons, temple tanks, fish ponds and mud water ponds as 7.5, 11.2, 3.9, 3.8, 185.5, 82.2, 63.4 and 72.5 t/ha/yr, respectively. Sharma *et al.* (2008) reported above ground mean tree biomass density as 1158 t/ha in the reserved forest followed by 728, 13, 11, 8, 5, and 3 t/ha from the protected forest, fallow land, cultivated-unirrigated land, grassland, orchards land and cultivated-irrigated land, respectively in a western Himalayan watershed.

A study on productivity was made in the forests of Coimbatore by George, *et al.* (1990_a) which revealed that net primary productivity of these forests is 2.18 tonnes ha⁻¹yr⁻¹ of which 1.57 tonnes ha⁻¹yr⁻¹ was contributed by above ground components and 0.61 tonnes ha⁻¹yr⁻¹ by roots. Similar results were reported for oak, cool temperate deciduous forest and pine forest (Whittaker and Woodwell, 1969; Art and Marks, 1971; Ryunosuke *et al.* 2004), tropical forests (Golley *et al.* 1962). Koul (2004) reported that the total biomass was maximum in natural forest of *Shorea robusta* (1980.04 t/ha) and lowest in case of fallow land (1.31 t/ha). Moreover in natural forest of *S. robusta*, undergrowth was of grass/ herbs/ shrubs contributing biomass of about 1.75 t/ha.

Singh and Gupta, (1993) reported higher biomass in *Eucalyptus* hybrid (26.74 kg/plant) and *Acacia auriculiformis* (6.49 kg/plant) of 7 yrs, *Hardiwickia binata* (36.45 kg/plant) of 19 yrs and *Emblia officinalis* (13.49 kg/plant) of 30 yrs as compared to *Tectona grandis* (11.34 kg/plant) of 30 yrs and *Dalbergia sissoo* (29.64 kg/plant) of 19 yrs. Nutrient content was higher in leaves and lower in roots of all species from Raipur (M. P.). The total above ground biomass (dry matter) was 33.6 Mg/ha for *Eucalyptus camaldulensis* and 53.1 Mg/ha *E. grandis*. The biomass of stem wood, leaves, branches and stem bark for *E. camaldulensis* accounted for 64.4 %, 19.6 %, 15.4 5 and 0.6 5 of the total biomass, respectively. While a similar partition of the total above-ground biomass was also found for *E. grandis* (Pagano *et al.*, 2009) from semiarid Brazil. The author also estimate the dry matter of leaves and branches of *E. camaldulensis* accounted for 35 % total biomass.

Biomass production of *E. tereticornis* in different agroecological regions of India were studied by Rawat and Negi (2004). Generally biomass varied from 11.9 t/ha (in 3 yrs old plantation) to 146 t/ha (in 9 yrs old plantation) in moist region. In dry tropical region it varied from 5.65 t/ha (in 5 yrs old plantation) to 135.5 t/ha (in 9 yrs old plantation). Total aboveground biomass production *Acacia tortilis* was 54.85 kg/tree followed by *A. senegal* 38.35 kg/tree while *Prosopis juliflora* contributed least 36.88 kg/tree reported (Singh, 2005). In semi arid region the total aboveground biomass

production of 48.4 kg/tree for 8 year old *A. tortilis* plantation, of which 28.2, 18.9 and 1.3 kg/tree for main bole, branches and leaves, respectively (Rai, 1999).

In tropical trees bole and branches generally account for 90-95 % of total aerial biomass (Singh *et al.*, 1993). Total mean aerial biomass of *Leucaena leucocephala* from a silvopastoral system in a semi arid region of Jhansi has a range of 12.9-80.3 kg/tree in different diameter classes (Roy *et al.*, 1997). The bole and branches contributed around 95 % of the total aerial biomass. The mean bole biomass increased with tree diameter and height. It ranged between 6.2-52.5 kg/tree. Besides bole, branches contributed much towards biomass and increased mainly with diameter. It ranged between 2.5-59.0 kg/tree. Similarly, leaf and pod yields also increased with diameter. These ranged between 0.3-5.2 and 0.1-2.1 kg/tree, respectively. Similar trend has also been reported by Pathak *et al.* (1992) and Singh *et al.* (1993) in *Albizia lebbeck*.

Litter production can be defined as the shedding of vegetative and reproductive plant parts caused by senescence, stress, mechanical factors (e.g. wind), a combination of these factors or by death and weathering of the whole plant in a given time period (Kozlowski, 1973). Litter production is an indicator of primary productivity and is an important for nutrient cycling and export of nutrients and organic detritus to the ecosystem (Boto and Bunt, 1981; Gong *et al.*, 1984; Gong and Ong, 1990; Lu and Lin, 1990; Steink *et al.*, 1993_a & _b; Lee, 1995; Ashton *et al.*, 1999; Mfiling *et al.*, 2005; Hossain and Fazlul Hoque, 2008). In general the dynamics of litter breakdown vary with species and geographical location (Ashton *et al.*, 1999) and affected by chemical composition of litter such as nutrients and lignin content (Tam *et al.*, 1999).

Litter production and its seasonal distribution had been studied in different forests and plantations (Bray and Gorham, 1964; George, 1977 & 1982; Kunkel-Westphal and Kunkel, 1979; Tanner, 1980; Briggs and Mahar, 1983; Spain, 1984; Pande, 1986; Singh and Arya, 1987; Sharma and Ambasht, 1987; Lowman, 1988; Dunham, 1989; George and Varghese, 1990; Pande and Sharma, 1993; Varshney and Garg, 1996) throughout the world. The litterfall in tropical rain forest, sub-tropical rain forest and temperate forest are about 1,600, 1,200 and 300-500 gm⁻² yr⁻¹, respectively (Rodin and Basilevic, 1968).

The available information related to Indian forests indicate that annual production of dead organic matter in evergreen forests is of the order of 20 tonnes ha⁻¹ and estimated average litter production in tropical forest is 9.3 tonnes ha⁻¹ (Lal, 1992).

Amount of litter production and amount of nutrients and organic matter released during the process of decomposition play an important role in nutrient cycling (Lu and Lin, 1990; Steink *et al.*, 1993_a), tree productivity and related food chain (Ashton *et al.*, 1999). Moreover litter production and the percentage contribution seem to vary with forest type, species, stand structural attributes and seasonal variation in climatic condition. Different tree components contain different amount of nutrients a fraction of which is return through leaf litter, twigs, etc. and is responsible for cycling of nutrients in the forest ecosystem. A number of literature is available on biomass production and nutrient distribution in different components of *Eucalyptus* (George, 1977; Negi and Sharma, 1984; Prasad *et al.*, 1984; Pande *et al.*, 1986 & 1987), but very few studies are there for other species viz. *T. grandis* (Seth *et al.*, 1963; Kaul *et al.*, 1979), *A. auriculiformis* (Pande *et al.*, 1986 & 87), *D. sissoo*, *E. officinalis* and *H. binata* etc. Though nutrient contents of foliage of different tree species have been reported by various authors (Puri and Gupta, 1954; Raman, 1962; Singh, 1969; Lalman and Mishra, 1985) but picture is not vivid yet.

Leaf litter is one of the most important sources of organic matter for soils in the forest ecological systems (Ke *et al.* 1999). Leaves will decompose soon after they drop (Takeda, 1988). Leaf decomposition was always higher than of the twig litter decomposition in all the species Pande and Sharma (1993). The decomposition rates of leaf litter in tropical and subtropical broad-leaved forests and pine trees are ranged from 1.0 to 1.7 (Brown and Lugo, 1982; Cuevas, *et al.*, 1991). Litterfall and throughfall are the major pathways for elements to return from forest canopy to soil. The contribution of each of the two pathways is mainly dependent on the nature of element, foliage properties and rainwater acidity (Rothe *et al.*, 2002; Stachurski and Zimka, 2002; Langusch *et al.*, 2003; Hagen-Thorn *et al.*, 2006 and Lovett *et al.*, 1996).

Decomposition of litter leaf is a fundamental source of energy and nutrients in forested ecosystems (Swift *et al.*, 1979). Ecological impact of C and N dynamics in the litter layer is considerable in forest ecosystem. Fresh litter can uptake or immobilize N because it is relatively rich in C and poor in N. Thus the litter layer can become a significant sink for N. The decomposition of organic residues is an important source of nutrients for primary production, particularly in nutrient-poor soils as those of the humid tropic (Herrera *et al.*, 1978). It is widely believed that plant litter decomposes rapidly and completely in this region because the conditions of humidity and temperature favor the microbial activity (Singh and Gupta, 1977). As decomposition proceeds, mineralization predominates over immobilization, than the litter gradually releases N and becomes a source for N (Xiao-wen *et al.*, 2009).

The amounts of total litterfall under different canopy classes in the dominated by Beach tended to decrease in the order beech > mixed > spruce > gap and in the order spruce > gap > beech > mixed in the spruce dominated plantation but the difference were not significant (Hojjati *et al.*, 2009). Dhaulakhandi and Rajwar (2005) found total litter production of *Quercus leucotricophora* (site-I) forest as $663.9 \pm 56.8 \text{ gm}^{-2} \text{ yr}^{-1}$ and *Q. floribunda* (site-II) forest as $564.1 \pm 27.74 \text{ gm}^{-2} \text{ yr}^{-1}$. Leaf fall contribution to the total litter fall was $530.0 \pm 50.1 \text{ gm}^{-2} \text{ yr}^{-1}$ on site I and $446.0 \pm 25.7 \text{ gm}^{-2} \text{ yr}^{-1}$ on site II. The litter decomposition rate on the both site (0.53 % and 42 %, respectively) was maximum in August. The total litter decomposition after a period of 13 months on site I was 75.1 and on site II was 66.6 %.

Litter production of *Eucalyptus tereticornis* plantation in protected and unprotected upper Gangetic plain was 7287.40 kg/ha (Bahar *et al.*, 2001). Leaf litter contributed 5268.50 kg/ha, twig litter 1396.10 kg/ha and bark litter 622.80 kg/ha in protected plot. However, in unprotected plot around 5478.20 kg/ha litter was produced out of which 4326.00 kg/ha, 740.20 kg/ha and 412.00 kg/ha contributed by leaf litter, twig litter and bark litter, respectively. It was also observed that total litter production was maximum in the month of July and minimum in the month of December in both the conditions.

The litter production in an *Acacia tortilis* (> 12 years) stand at silvopastoral system in the dry tropics was 4.72 t/ha (Roy and Nigam, 2001). Out of these the leaves contributed about 62.4 % followed by reproductive structures (23.02 %) and twigs (14.58 %). However, higher litter production was recorded in the drier months of May (119.92 g/m²) followed by June (88.32 g/m²) and April (72.35 g/m²) but during rainy season (July-October) there was almost no litter production. Dey (2005) reported that the rubber plantation adds leaf litter to the soil up to 7.35 t/ha from the north eastern region of India. Annual litter fall in 14 year old rubber plantation had been reported in the range of 6.8 to 7.7 t/ha in this region by Varghese *et al.* (2001).

Pande (2001) reported that the leaf fall of *Shorea robusta* plantation at Doon valley 83.87 % (8286.87 kg/ha/yr) to the total litter fall (11271 kg/ha/yr). The higher rate of decomposition was recorded during rainy season. Nutrient concentration was generally higher in leaf litter than in twig. Ca and N contributed higher proportion in total nutrient return, release and accumulation. The higher nutrient was associated with the higher litter fall and litter nutrient concentrations. Further, the order of importance in term of magnitude of nutrient return was Ca > N > Mg > K > P. The higher rate of return and release of nutrients were due to higher litter input and its subsequent decomposition. Significant variations in all the nutrients were also noticed.

Litter decomposition and nutrient dynamic were studied by Chacon and Dezzeo (2007) in tall primary forest (TF), slightly fire-affected (MF) and strongly fire-affected (LF) forests of the Gran Sabana, southern Venezuela. The results showed no significant difference in the dry-mass reduction among TF, MF and LF after one year of decomposition. At the end of the decomposition period, the mass loss was 31 % in TF, 24 % in MF and 25 % in LF. The initial litter was poor in nutrients, especially in P, with C/N ratio extremely high, particularly in LF. The general trends in the three studied forests were net N and to less extend P immobilization and release of K, Mg and Ca.

Pande *et al.* (2002) quantified the litter production and analysis the seasonal variation in litter nutrient concentration and nutrient return to the forest floor in some tropical dry deciduous teak forests Satpura Plateau in Chhindwara Forest Division

Madhya Pradesh. The workers recorded the magnitude of annual litter fall in the range of 3,276 to 4,536 kg ha⁻¹ while return of nutrients was in the order of C>N>K>Mg>P. The pattern of litter decomposition in some plantations was in the order Sal (1.668) > Teak (1.651) > Pine (1.350) > Eucalypts (1.350) while in case of twig litter decomposition the order was Teak (0.973) > Sal (0.947) > Pine (0.865) > Eucalypts (0.822). Studies on different pathways of nutrient return through litterfall were carried out by Rajagopal *et al.* (2005) in young teak plantation at Coimbatore. The total litter produced was 4,574 kg ha⁻¹ and the nutrient return in terms of N, P, K, Ca and Mg was 46, 3, 39, 86 and 21 kg ha⁻¹ respectively.

In mangroves, litter production is about 30-60 % of the total primary productivity (Bunt *et al.*, 1979) and has significant effect on detritus based food webs in the coastal environment and coastal fisheries (Odum and Heald, 1975; Ong *et al.* 1984; Lee, 1995). The amount of organic matter exported to the aquatic ecosystem from the mangroves depends on the decomposition rate (Twilley *et al.* 1986; Robertson, 1988; Chale, 1993). The variation of litter production in mangroves may be related to species and geographical locations (Woodroffe *et al.* 1988). Pool *et al.* (1975) reported that riverine forest produced higher amount of litter followed by overwash, fringe, basin and scrub mangrove forests. Day *et al.* (1987 & 1996) documented that *Rhizophora mangle* produced higher amount of litter in riverine mangrove forest followed by fringe and basin mangrove forest. Similarly *R. mucronata* in estuarine mangrove forest produced higher amount of litter than in the fringing mangroves in North West coast of Sri Lanka (Amarasinghe and Balasubramaniam, 1992). Mangroves litter production studies in different geographical locations are shown in table 1.

In general, deciduous forests are believed to have faster nutrient turnover than coniferous forest (Pastor, 1987). A coniferous stand generally accumulate larger quantity of organic matter and has longer mean nutrient resident times than deciduous stands (Vogt *et al.*, 1986), consistent with slower nutrient turnover. The positive effect of deciduous trees on nutrient cycling is usually attributed to their high quality litter causing faster litter decomposition and faster nutrient cycling (Pastor, 1987; Scott and Binkley,

1997). However, the decomposition rate, especially the initial rate, has been shown to be a poor predictor of N availability (Giardina *et al.*, 2001). Prescott, 2002 suggested that the amount of N returned annually in litter may be more influential than the rate litter decay in determine N availability at a site.

Table 1. Rate of litter production by different mangrove species

Location	Species	Dry weight g/m/day	Reference
Middle Horbour, Australia	<i>Avicennia marina</i>	1.59	Goulter and Allaway, 1979
Hinchinbrook Island, Australia	<i>Rhizophora spp.</i>	2.99	Duke <i>et al.</i> , 1981
	<i>C. tagal</i>	1.97	
	<i>Bruguiera gymnorhiza</i>	2.19	
Sungai Merbok, Malaysia	<i>R.apiculata</i>	2.76	Ong <i>et al.</i> , 1980
	<i>R.mucronata</i>		
	<i>B.gymnorhiza</i>		
Western Port Bay, Australia	<i>Avicennia spp.</i>	0.55	Clough and Attiwill, 1982
Kuala Selangor, Malaysia	<i>Avicennia spp.</i>	4.22	Sasekumar and Loi, 1983
	<i>Sonneratia spp.</i>	3.84	
	<i>Rhizophora spp.</i>	4.32	
Matang Mangrove, Malaysia	<i>R.apiculata</i>	1.91-3.12	Gong <i>et al.</i> , 1984
	<i>Bruguiera spp.</i>		
Tuvalu	<i>R. stylosa</i>	5.39	Woodroffe, 1984
Montupore Island, Papua New Guinea	<i>R. stylosa</i>	3.92	Leach and Burgin, 1985
Tabasco, Mexico	<i>A. germinans</i>	1.68	Lopez-portillo and Ezcurr, 1985
Mgeni Estuary, South Africa	<i>A. marina</i>	1.91	Steinke and Charles, 1986
South-West Florida	<i>Avicennia spp.</i>	1.22	Twilley <i>et al.</i> , 1986
	<i>Rhizophora spp.</i>	2.22	
Queensland and Port Clinton, Australia	<i>S. alba</i>	2.48	Duke, 1988
	<i>S. caseolaris</i>	2.56	
St. Lucia and Richards	<i>A. marina</i>	2.78-2.89	Steinke and Ward,

Bay, South Africa	<i>B. gymnorrhiza</i>	2.00	1988
	<i>R. mucronata</i>	2.66	
Darwin Harbour, Australia	<i>C.tagal</i>	1.88-2.04	Woodroffe <i>et al.</i> , 1988
Mai Po Marshes, Hong Kong	<i>Kandelia candel</i>	2.18-3.44	Lee, 1989
Ohura Bay, Okinawa, Japan	<i>Mixed mangrove</i>	2.11-2.94	Hardiwinoto <i>et al.</i> , 1989
Ras Hatiba, Saudi Arabia	<i>Avicennia spp.</i>	2.16	Saifullah <i>et al.</i> , 1989
Hainan Island, China	<i>B. sexangula</i>	3.02-3.44	Lu and Lin, 1990
Transkei estuaries, South Africa	<i>Mixed mangrove</i>	1.24	Steinke and Ward, 1990
Bonny Estuary, Nigeria	<i>Rhizophora spp.</i>	2.32	Abbey Kalio, 1992
	<i>Avicennia spp.</i>	1.76	
	<i>Laguncularia spp.</i>	2.24	
Dutch Bay, Kala Oya and Erumathivu, Sri Lanka	<i>R. murcronata</i>	1.71	Amarasinghe and Balasubramaniam, 1992
	<i>A. marina</i>	1.02-1.51	
Tritih, Java, Indonesia	<i>R. murcronata (Planted)</i>	2.26	Sukardjo and Yamada, 1992
Queensland, Australia	<i>A. marina</i>	2.40	Mackey and Smail, 1996
Onverwagt, Guyana	<i>A. germinans</i>	4.85	Chale, 1996
Gazi Bay, Kenya	<i>R. murcronata</i>	1.15-2.51	Slim <i>et al.</i> , 1996)
Churute Estuary, Ecuador	<i>Rhizophora spp.</i>	1.77-2.92	Twilley <i>et al.</i> , 1997
Mandovi-Zuari Estuaries, India	<i>R. apiculata</i>	3.21	Wafar <i>et al.</i> , 1997
	<i>R. murcronata</i>	3.23	
	<i>S. alba</i>	4.66	
	<i>Avicennia officinalis</i>	2.79	
Al Khor, Qatar	<i>A. marina</i>	4.65	Hegazy, 1998
	<i>Aegiceras corniculatum</i>	3.20	Tam <i>et al.</i> , 1998
Futian, China	<i>K. candel</i>		
Mekong Delta, Vietnam	<i>R. apiculata (Planted)</i>	2.58-4.76	Clough <i>et al.</i> , 2000

Okinawa, Japan	<i>Mixed mangrove</i>	3.55	Mfilinge <i>et al.</i> , 2005
Kuala Selangor, Malaysia)	<i>B. parviflora</i>	2.89 (2.31- 4.46)	Mahmood <i>et al.</i> , 2005

Boreal forest is largely limited by N availability (Mahendrappa and Salonijs, 1982). Comparisons of N availability in boreal coniferous and deciduous have consistently demonstrated the expected greater N availability in deciduous stand. Boreal aspen stands in southern Quebec (Bauhus *et al.*, 1998) and Birch stands in Finland (Priha and Smolander, 1999) had higher microbial N concentration which is an indicator of N availability (Myrold *et al.*, 1989). Trembling aspen stands in Quebec had higher turnover and higher accumulation of nitrate than white spruce stands (Ste-Marie and Pare, 1999). In contrast, higher nitrate concentrations and higher net nitrification were found under pine than under birch in Finnish boreal forests. While 49 year old aspen stands in Quebec had faster potential net N mineralization and nitrification than white spruce stands, no difference was found between older stand of aspen and spruce (Pare and Bergeron, 1991). There was an indication of faster N turnover under birch than under balsam fir in the Canadian eastern boreal forest, but was inconsistent (Evans *et al.*, 1998).

Deciduous stands of boreal mixedwood forests in northwestern Alberta had higher N availability, reflected by higher pools of ammonium and inorganic N in the forest floor and also tended to have higher concentrations of microbial N but did not have higher levels of nitrate or higher rates of net nitrification (Jerabkova *et al.*, 2006). In the same forest, mixed stands showed the highest rates of net N mineralization. The faster decay of spruce needles at these sites with low N availability may be related to their lignin concentration (Carreiro *et al.*, 2000, DeForest *et al.*, 2004). Similar results were also reported for a boreal forest in Quebec (Cote *et al.*, 2000), boreal deciduous stands (Myrold, 1987; Wardle, 1992; Northup *et al.*, 1995), coniferous stands (Hannam *et al.*, 2004) and birch-aspen and black spruce stands in Alaska (Troth *et al.*, 1976).

Gupta *et al.* (2001) reported that organic carbon, N and C: N ratio values were lowest in barren land, intermediate in cultivated well managed soil and highest in forest

and cultivated unmanaged land. The values were higher in cultivated well-managed land in comparison to cultivated unmanaged land. The values of organic carbon, total N and C: N ratio was higher in the surface soils in comparison to sub-surface soils. The findings are supported by positive and significant relationship of total N and organic matter with organic carbon.

The total nutrient store of planted forest of *Pinus tabulaeformis* in the Miyun Reservoir Watershed, Beijing was 695.17 kg/hm² including nitrogen, phosphorus, potassium, calcium (Ca) and magnesium (Liu and Yu, 2009). The sequence of their contents in different organs was given as follow: needle > branch > trunk > root. The annual amount of 85.37 kg/hm² of five nutrient elements were assimilated by *P. tabulaeformis* about 0.34 % of the total store in soil and 3.30 % of available nutrient store in soil depth from 0-30 cm. The nutrient annual retention is 35.92 kg/hm², annual returning 49.46 kg/hm² and rain input 26.04 kg/hm² to the five nutrient element.

Four stands at different altitude with different species composition were studied by Jha and Dimri (1991) in Yamuna Forest Division of Garhwal Himalayas. The stands were dominated by *Pinus roxburghii* at 1,800 m, *Cedrus deodara* and *Pinus wallichiana* at 2,100 m, *Quercus leucotrichophora* and *Q. floribunda* at 2,400m and *Abies pindrow* and *Picea smithiana* at 2,700m. The total nutrient pool of NPK was in the order K>N>P and available nutrient (ANP) pool in order of N>K>P. The ANP for N increased from 200-310 kg⁻¹ ha⁻¹ stand (1) to (4) but for K was greatest in stand (1) and least in stand (4) while for P it was slightly higher in stand (1) than in the others. Soil organic matter increased from 2.94 to 6.26 % in stand (1) to (4).

Ball *et al.* (2009) studied nitrogen and phosphorus release from mixed litter layers and revealed that the *Quercus prinus* content highest concentration both N and P followed by *Liriodendron tulipifera*. *Acer rubrum* content fairly low levels of N but moderately high levels of P and *Rhododendron maximum* was always the lowest for both nutrients. C and nutrient ratio reveals that *Quercus prinus* and *Liriodendron tulipifera* both content similarly high amount of N and P with respect to C followed by *Acer rubrum* and *Rhododendron maximum* had the lowest nutrient content in relation to C.

Decomposition rates and nutrient dynamics of *Populus deltoides* litter was evaluated by Kaushal *et al.* (2006) in three year old coppiced plantation in Himachal Pradesh using the nylon net bags. Complete loss of *Populus* leaf litter was achieved in 20 months. Nitrogen, phosphorus, potassium, calcium and magnesium dynamics in decomposing litter revealed that concentration of N, P and Ca did not follow any specific trend during the decomposition process. K and Mg concentration revealed a decreasing trend throughout the study period. Change in absolute amount, on the other hand followed a release pattern through the study period for N, K and Mg. However, P and Ca showed a three phase pattern i.e. leaching, immobilization and release during the time of investigation.

Srivastava *et al.* (1972) studied the annual release of nutrients in Sal, Chir pine and Teak plantation and found NPK release was 77.6, 14.0 and 42.4, 70.1, 10.7 and 31.7 and 65.5, 11.4 and 44.7 kg ha⁻¹. The study by George, *et al.* (1990_a) in the forests of Coimbatore indicated that the total uptake of various nutrients was only 21 % of N, 11 % of P and 25 % of K which retained in living tissues and the balance returned to forest floor. Jha, *et al.* (1999) studied Soils under 15 yr old plantation of *Pinus roxburghii*, *Tectona grandis*, *Dalbergia sissoo*, *Eucalyptus*, *Acacia catechu* along with natural *Shorea robusta* forest and barren land. Soils under all plantations were well supplied in nitrogen (total N 0.018 to 0.11 %; available N 0.0015 to 0.010 %), Phosphorus (total P 0.0053 to 0.030 %; available P 0.0017 to 0.0045 %) and Potassium (total K 0.29 to 1.04 %; available K 0.0021 to 0.041 %).

Shadangi and Nath (2006) reported that the rate of decomposition was highest in litter of Sal (0.0105g g⁻¹ day⁻¹), *Eucalyptus* (0.0102g g⁻¹ day⁻¹) and pines (0.0090 g g⁻¹ day⁻¹) in Amarkantak, Madhya Pradesh. The authors also reported that the litter decomposition was higher in the rainy season. Similar results were reported by Khan and Kapur (1992) from five predominant tropical forest tree species in Rewa region of Madhya Pradesh. The contents of N, P, K, Ca, Mg and S in leaves and branches of *E. camaldulensis* was 15.5 %, 0.7%, 12.3%, 22.6%, 1.9 % and 1.4 % of those in the total above ground biomass, respectively (Pagano *et al.*, 2009). Koul (2004) reported that the

maximum available nitrogen was maximum in natural forest of *S. robusta* (121.22 kg / ha) and least in fallow land (86.10 kg / ha) that decreased with increase in soil depth.

The aspen and spruce stand of boreal mixed forests in Canada has higher forest-floor pH (Bauhus *et al.*, 1998; Jerabkova *et al.*, 2006) than deciduous and coniferous forests (Raulund-Rasmussen *et al.*, 1995; Priha and Smolander, 1999; Hagen-Thorn *et al.*, 2004). The higher forest-floor pH in aspen stands is often associated with a higher Ca concentration (Brais *et al.*, 1995).

Koul (2004) reported that the pH was highest in fallow land (6.09) and lowest in the natural forest of *Shorea robusta* (5.09) in Terai zone of Cooch Behar, West Bengal. It generally increased with increase in soil depth. Chavan, *et al.* (1995) and Contractor and Badnur (1996) have reported low soil pH under forest plantation. In Assam soils, distribution of pH in profiles ranged from the surface downwards from 6.0 to 8.0 in the soils near the Brahmaputra River, 4.4 to 7.5 in old flood plains and 4.8 to 6.4 in upland soils near the hills (Chakravarty and Barthakur, 1997). This shows that though the surface soil of old flood plain and old uplands are very strongly acidic due to heavy leaching, these are near to the neutral range in lower horizon. The higher pH in the lower horizons of these soils may be owing to impeded drainage for low-lying positions and / or incomplete leaching due to impermeable layer. Sheikh and Kumar (2010) reported that the soil in Oak and Pine forests was acidic with 0.15 and 0.19 % nitrogen; 17.99 and 16.88 kg/ha available phosphorus and 188.92 and 166.43 kg/ha exchangeable potassium, respectively. The worker also reported that the maximum contribution among the nutrient was potassium followed by phosphorus and nitrogen at both the forests in terms of total nutrient generated by soil as an ecosystem service converted to market cost. Thus, the authors preferred Oak forests to protect, enhance their nutrient level for enhancing the forests ecosystem services.

The pH of the temperate forest floors were very low ranged from 2.91 to 3.08 (Bagherzadeh *et al.*, 2008). Raina *et al.* (2001) reported that the soil pH under different forest vegetation ranged from 5.0 to 6.8 and higher in the upper horizons than in the lower ones. Soils under 15 yr old plantation of *Pinus roxburghii*, *Tectona grandis*,

Dalbergia sissoo, *Eucalyptus*, *Acacia catechu* along with natural *Shorea robusta* forest and barren land were acidic in nature up to 150cm depth (Jha, *et al.*, 1999). The soil under *Pinus roxburghii*, *Tectona grandis* and *Eucalyptus* was mildly acidic (5.98 to 6.67) while soil under *Dalbergia sissoo* and *Acacia catechu* along with natural *Shorea robusta* forest and barren land was moderately acidic (4.65 to 5.97).

Chaudhuri *et al.* (2005) reported that soil of mangroves of south Andaman exhibited minimum variation of pH, clay, cation exchange capacity (CEC), Al_2O_3 and Fe_2O_3 levels between the disturbed and undisturbed mangrove forest. The post-tsunami soil samples of mangroves in the Andamans had higher levels of electrical conductivity, Na and Mg while pre-tsunami soil samples had higher levels of organic carbon, P, K and CEC (Chaudhuri *et al.*, 2009). Chandran *et al.* (2009) reported that the soils are neutral to acidic (pH 5.4-7.6) and the pH has a tendency to increase with depth in ferruginous soils of the semi-arid tropics.

2.3 CARBON SEQUESTRATION

The complexes interactions and feedbacks among forest development, demography and health, energy flow and changes in environmental resources and conditions present challenges to our general conceptualization of ecosystem ecology and specifically of predictions of ecosystem C balance. An apparently large C sink in the northern hemisphere has been attributed to storage in northern forest ecosystems (Fan *et al.*, 1998), however the mechanisms controlling this sink are not clear and the future strength of the sink is difficult to predict (Valentini *et al.*, 2000). Global carbon is held in four main reservoirs that include oceans, fossil fuel deposits, the terrestrial system and the atmosphere. In the terrestrial system carbon is sequestered in rocks and sediments, swamps, wetlands, forests & on the soils of forests, grassland and agriculture (Bala *et al.*, 2003). There are approximately 10^{23} g of C on earth. The majority of this C is held within sedimentary rocks. There are about 40×10^{18} grams of C in the active pools near the Earth's surface (Schlesinger, 1977).

The terrestrial carbon flux is an essential function of the earth's system linked to the physical climate system and its response and adaptations to global climate change have become important research topic (Zhang *et al.*, 2009_b). Ability of forest, trees and other vegetation as terrestrial carbon sinks to absorb CO₂ emissions and mitigate the climate change, has attracted wide attention. Currently, total above ground biomass in the world's forests is 421 X10⁶ tonnes distributed over 3869 M ha. Of this, 3682 X 10⁶ ha or 95 per cent is natural forest and 187 X 10⁶ or 5 per cent is plantation area. On an average, forests contain 1.00 m³/ha wood volume and 109 t/ha wood biomass. Forests store 1200 Gt carbon in vegetation and soil globally. Carbon in forests constitutes 54 per cent of the total carbon pool in terrestrial ecosystem (Anon, 2001_b). A slightly smaller amount (560 Gt) is contained in the living biomass of the terrestrial biosphere (Houghton and Skole, 1990_a). Presently the global biomass carbon pool has been estimated at about 385Gt C (Prentice *et al.*, 2000).

There are 750 Gt of C in the atmosphere, the majority of which is in the form of carbon dioxide (CO₂). The concentration of atmospheric CO₂ has increased by 25 per cent since pre industrial era (Anon, 1992). It was observed that level of atmospheric CO₂ has recorded an increase from ~ 280 ppmv in 1800 to ~ 315 ppmv in 1957 to ~ 356 ppmv in 1993 (Schimel, 1994). Three quarters of this added CO₂ has come from burning fossil fuels and roughly a quarter from destruction of tropical rain forests (Panos media briefing, 1996). Carbon is accumulating in the atmosphere at a rate of 03.5 Gt (10¹⁵) per annum as a result of fossil fuel combustion and tropical deforestation (Rosenberg, 1999). The net annual carbon emission estimates for India vary from 0.672 Tg (Pachauri *et al.*, 1992) to 41 Tg (Houghton, 1990_b) where Tg is equal to 10¹² g. On a longer time timescale, the uplift of the Himalaya region was observed with 1.47 x 10⁶ Mg/yr of carbon emitted into atmosphere due to land-use changes (Upadhyay *et al.*, 2005). The estimates of net release of carbon at global level are highly uncertain because of difficulty in obtaining reliable data, ranging from 0.4 – 1.6 G t of C per year (Detwiler and Hall, 1998) to 1.1 – 3.6 G t C per year (Houghton, 1990_b). Manhas *et al.* (2006) reported that in India the conifers of temperate region stocked maximum carbon in their wood (28.88-

65.21 t C/ha) followed by mangrove forest (28.24 t C/ha), Dipterocarp forests (28.00 t C/ha), *Shorea robusta* forest (27.07 t C/ha) and *Boswellia serrata* forests (3.91 t C/ha).

Soil CO₂ efflux is one of the major fluxes in the global carbon cycle; it had been estimated that 76.5 Pg C/ year, which is 30 -60 % greater than terrestrial net primary productivity (Raich and Potter, 1995). Soil efflux had been measured in various forest ecosystems all over the world (Raich and Schlesinger, 1992). However soil efflux show high spatial and temporal variation (Epron *et al.*, 2004; Luo and Zhou, 2006) so there is still a great need for more research. Soil efflux ranged from 14 mg CO₂ M⁻²/ha to 2,329 mg CO₂ M⁻²/ha (SD = 326) and 14 to 2131 mg CO₂ M⁻²/ha and averaged 594 mg CO₂ M⁻²/ha (SD = 335) for the year 2004 and 2005 respectively and averaged value ranged from 594 to 549 respectively for the same year (Hashimoto *et al.*, 2009) from secondary beech forest in Appi highlands, Japan. Similar finding were reported from Fagaceae forests in the temperate zone (Longdoz *et al.*, 2000; Takahashi *et al.*, 2004; Soe and Buchmann, 2005; Jonard *et al.*, 2007).

Soil plays a key role in the global carbon budget and greenhouse effects (Jha *et al.*, 2003). The soils of the earth are estimated to contain between 1,400 and 1,700 Gt of C (Houghten and Skole, 1990). Soil accumulated greater amount of carbon as compared to forest litter as the target quantities of C is stored for longer period of time in the soil then in live component of terrestrial ecosystem (Schlesinger, 1977). It contains 3.5 % of carbon reserves of earth compared with 1.7 % in the atmosphere, 8.9 % in the fossil fuels, 1.0 % in the biota and 84.9 % in the ocean (Lal *et al.*, 1995). The global soil organic carbon (SOC) estimates were varying from 700-3000 PgC (Bouwman, 1990). These estimates was based on a number of approaches such as soil group (Bohn, 1976; Buringh, 1984), vegetation groups (Ajtay *et al.*, 1979; Bolin *et al.*, 1979), FAO/UNESCO soil map (Sombroek *et al.*, 1993), Holdridge life zone classes (Post *et al.*, 1982). Total C pool in top 1m soil is 2011 PgC (Anon., 2000).

The SOC pool is estimated at 21 Pg to 30 cm depth and 63 Pg to 150 cm depth. The soil inorganic carbon (SIC) pool is estimated at 196 Pg to 1m depth. The SOC concentration in most cultivated soils is less than 5 g/kg compared with 15 to 20 g/kg in

uncultivated soils. Low SOC concentration is attributed to plowing, removal of crop residue and other biosolids, and mining of soil fertility. Accelerated soil erosion by water leads to emission of 6 Tg C/y. Potential of soil C sequestration in India is estimated at 7 to 10 Tg C/y for restoration of degraded soils and ecosystems, 5 to 7 Tg C/y for erosion control, 6 to 7 Tg C/y for adoption of RMPs on agricultural soils, and 22 to 26 Tg C/y for secondary carbonates. Thus, total potential of soil C sequestration is 39 to 49 (44±5) Tg C/y (Lal, 2004).

According to the Kyoto Protocol, land use, land use change and forestry (LULUCF) was recognized as serving the role of carbon sources and sink in relation to a change in land cover and carbon stock. It also influence the amount of biomass and carbon stored in vegetation (Anon, 2000). The conservation of natural forests to tree plantations and perennial crops reduce carbon density by at least 50 % when compared to natural forests (Lasco, 2002). Drawing CO₂ out of air and sequestering it into biomass is the only known practical way to remove large volume of greenhouse gases from the atmosphere (Anon, 1998). Every hectare of actively growing forest sequesters between 2 and 5 tonnes of C/year (Brown *et al.*, 1996)

Forest grow and their biomass increase, they absorb carbon from the atmosphere and store it in the plant tissue (Matthews *et al.* 2000). So forest play multiple and significant roles in regulating atmospheric concentrations of carbon dioxide (Rotter and Danish, 2002). Active absorption of CO₂ from the atmosphere through photosynthesis, and its subsequent storage in the biomass of growing trees or plants is the carbon storage (Baes *et al.*, 1977). It was reported that a hectare of actively growing forest can sequesters 2-5 t of carbon/year (Brown, 1996) so forests play an important role in sequestration of carbon globally (Rawat *et al.* 2003).

Temperate and boreal forests demand particular attention in global carbon cycles because they comprise almost 50 % of the world forests and are thought to be a major carbon sink (Tans, *et al.*, 1990; Denning, *et al.*, 1995; Schimel, 1995; Baldocchi and Vogel, 1996; Houghton *et al.*, 1998; Houghton, 2003; Janssens *et al.*, 2003). The boreal forest region accounts for 16 % of the earth's terrestrial land mass but contains

approximately 27 % of the world's vegetation carbon (McGuire, *et al.*, 2002) and 25 -30 % of the world's soil C(300-500 Pg C) Dixon, *et al.* (1994). Secondary forests provide many ecosystem services, including the potential to be sinks for atmospheric carbon in the both biomass and soils (Brown and Lugo; 1990; Silver *et al.*, 2004). Carbon biomass of the tree layer in early succession stages is lower than that in late succession stages (Kimmins, 2004).

It is well known that many factors may affect the carbon budget of an ecosystem: biotic features, including the leaf area, photosynthetic rate, plant architecture and type of forest and abiotic features, such as radiation, temperature, water supply, soil property and length of the growing season. Although the response of carbon fluxes to environmental variables, such as air humidity and temperature has been reported in some studies (Hollinger *et al.*, 1994, 1998; Chen *et al.*, 1999; Clark, *et al.*, 1999; Fan, *et al.*, 1995; Wang, *et al.*, 2004; Li, *et al.*, 2005_b) are rare. Increases in atmospheric concentrations of CO₂ can have large but offsetting effects on ecosystem productivity (King *et al.* 2005). Litterfall amounts can be altered by both elevated CO₂ and O₃ (Liu *et al.*, 2005). Of the total Russian forest area (771 m ha.) with a wood volume of 88.6 x 10⁹ m³, carbon storage in living phytomass was 35.07 Pg total annual carbon deposition was estimated at 213 .2 Tg (Isaev *et al.*, 1995).

Grassland plays an important role in research of global carbon change. The ratio of total biomass of grassland to forest biomass in China is one fourth which is much higher than that of the world suggesting a greater contribution of grasslands to China's carbon pool (Piao *et al.* 2004). On the basis of some studies we can extrapolate that grassland ecosystem had played and or playing important roles in the terrestrial carbon flux and global change (Parton *et al.*, 1993 and Ojima *et al.*, 1993). Zhang *et al.* (2009_b) studied annual carbon flux of grassland ecosystems in extreme arid conditions and reported that 1.91 g C/m²/year net carbon storage. However, author also recorded great variations in net ecosystem productivity over the entire region varying between net carbon storage 52.09 g C/m²/year and net carbon loss 48.28 g C/m²/year.

Forest soil is a huge reserve of carbon in the biosphere as they are the principal part of terrestrial ecosystems that account for 86 % of the vegetation carbon pool and 73 % of the soil carbon pool, thus forest ecosystems are generally thought of as carbon sinks (Fan *et al.*, 1998; Fang *et al.*, 2001; Goodale *et al.*, 2002; Zhang *et al.*, 2007). Eswaran *et al.*, (1993) estimated that the global forest soil organic C stock about 580 Pg. Global warming, atmospheric deposition and increase in atmospheric CO₂ concentration are the primary atmospheric factors which may have impact on forest soils (Josline and Johnson, 1997). Another report estimates that approximately 60-70 % of carbon in forests is stored as organic material in the soil (Janssens *et al.*, 1999). Forest ecosystems fix two-thirds of the carbon in all terrestrial ecosystems annually. Moreover forest ecosystems play an irreplaceable role in regulating the carbon balance, mitigating greenhouse gas concentrations, such as carbon dioxide and maintaining global climates (Zhang *et al.*, 2009_b). In USA on an average, 50 % of the total carbon in the forest was estimated to be stored in soil component (Turner *et al.*, 1995).

Modeling above and below ground carbon dynamics in a mixed beech and spruce stand influenced by climate were studied by Rotzer, *et al.* (2009). The author used BALANCE model and reported initial above ground biomass (agb) of 46.6 t C/ha for the 87 spruce trees in January, 2000 the agb rises up to 65.1 t C/ha in December, 2005. For the below ground biomass (bgb) and increase from 5.6 to 10.3 t C/ha was calculated. The 32 beech trees showed a rise of the agb from 17.9 to 25.5 t C/ha, while bgb was 1.7 t C/ha at 2000 and 2.1 t C/ha at the 2005.

Smith and Johnson (2003) evaluated whether changing the type of plant input to soils alter soil organic carbon (SOC) distribution or soil carbon (C) storage? The answer is critical because woody encroachment may alter C cycling over millions of hectares in the Great Plains and Midwest. In spite of fast dynamics of soil C turnover, there was no net change in SOC amounts over 40-60 years (cumulative mineral and organic SOC in forest, 8782 g C/m² ± 810; in grassland, 7699 ± 1004). Thus as junipers expand into mesic areas of the Great Plains, juniper forests will provide little additional soil C storage.

According to Chauhan *et al.* (2009) the assessment of carbon storage potential has been difficult due to lack of information on biomass compartmentation and carbon allocation in different species. For most of the species use for afforestation/reforestation, only the above ground biomass potential are known but to have a picture of carbon storage potential of species, the below ground biomass pattern are equally important. The biomass accumulation was highest in *Acrocarpus fraxinifolius* which was statistically at par with *Populus deltoides* and *Eucalyptus teriticornis*. There was no statistical difference in below ground biomass of different tree species. The highest tree stem carbon storage at the plantation level was found in *A. fraxinifolius* while the lowest was in *Syzygium cumini*. Stem alone though was the largest store house of carbon but litter and roots in the short rotation tree species play a major role in carbon sequestration in the soil reservoir. Jana *et al.* (2009) estimated annual carbon sequestration rate at 8.97 t C/ha by *Shorea robusta* at Chadra Forest in Paschim Medinipur, 11.97 t C/ha by *Albizia lebbeck* in Indian Botanic Garden, Howrah, 2.07 t c/ha by *Tectona grandis* in Chilapatta Forest Cooch Behar and 3.33 t C/ha by *Artocarpus integrifolia* in Banobitan, Kolkata. The authors also reported that the percentage carbon content (except root) in the above ground biomass of all these four plantation were 47.45, 47.12, 45.45 and 43.33, respectively while the carbon stock per hectare were 5.22, 6.26, 7.97 and 7.28 t C/ha, respectively. Koul and Panwar (2008) found that in Terai zone of West Bengal, fallow land and agricultural field sequester 5.86 % and 4.73 % carbon, respectively compared to the natural forest of *S. robusta*. Similarly carbon stock dynamics was monitored by Bhat *et al.* (2002) in Uttra Kannada district, Karnataka for 10 years. The study indicates that in general the carbon stock has enhanced during the study period with an average growth of 1.008 t/ha/year.

Biomass, carbon content, carbon storage and spatial distribution in the 32-year-old *Phoebe bournei* stand ecosystem in the Lingyan mountain of China were measured by Mingdong *et al.* (2009). Carbon contents of stems, barks, branches, leaves, root, shrub layer, herb layer, lichen layer and litter layer were 0.5769 g C/g, 0.4654 g C/g, 0.5232 g C/g, 0.4958 g C/g, 0.4931 g C/g, 0.4989 g C/g, 0.4733 g C/g, 0.4143 g C/g and 0.3882 g C/g, respectively. The mean carbon content of soil was 0.0139 g C/g, which

reduced gradually along with soil depth. Total carbon storage of the *P. bournei* stand ecosystem was 227.59 t/hm^2 , among which the arbor layer accounted for 40.13 %, the shrub layer accounted for 0.17 %, the herb layer accounted for 0.76 %, the lichen layer accounted for 0.28 % and the litter layer accounted for 0.29 %. Carbon content (0-80 cm) of the forest soil was 58.40 %. Spatial distribution ranking of carbon storage was (0-80 cm) > arbor layer > herb layer > litter layer > lichen layer > shrub layer. Net production of the forest stand was $8.5706 \text{ t/ (hm}^2 \cdot \text{a)}$ in which the arbor layer was $6.6691 \text{ t/ (hm}^2 \cdot \text{a)}$ and it accounted for 77.82 %. Net annual carbon sequestration of the *P. bournei* stand was $4.2536 \text{ t/ (hm}^2 \cdot \text{a)}$ and the arbor layer was $3.5736 \text{ t/ (hm}^2 \cdot \text{a)}$ which accounted for 84.01 %.

Carbon fluxes and their response to environmental variables in a Dahu-rian larch forest ecosystem in northeast China by Wang *et al.* (2008). The author reported that the ecosystem released carbon in the dormant season from mid-October 2004 to April 2005, while it assimilated CO_2 from the atmosphere in the growing season from May to September 2004. The net carbon sequestration reached its peak of $112 \text{ g m}^{-2} \text{ month}^{-1}$ in June 2004 (Simplified expression of $\text{g (carbon) m}^{-2} \text{ month}^{-1}$) and then gradually decreased. Annually, the larch forest was a carbon sink that sequestered carbon of $146 \text{ g m}^{-2} \text{ a}^{-1}$ (simplified expression of $\text{g (carbon) m}^{-2} \text{ a}^{-1}$) during the measurements. The photosynthetic process of the larch forest ecosystem was largely affected by the vapor deficit (VPD) and temperature. Under humid conditions ($\text{VPD} < 1.0 \text{ kPa}$), the gross ecosystem production (GEP) increased with increasing temperature. But the net ecosystem production (NEP) showed almost no change with increasing temperature because the increment of GEP was counterbalanced by that of the ecosystem respiration.

Carbon content in vegetation, liter and soil under 10 different (pine forest, oak forest, pine-oak forest, fir forest, plantation, agricultural fields, grasslands, scrublands, avocado plantation and degraded forests) land use and land-cover classes in central highlands of Michoacan, Mexico was studied by Ordonez *et al.* (2008). The workers reported that 0.2 to 169.7 Mg C/ha in grassland to fir forest, carbon content in litter ranged from 0.6 (agriculture) to 4.1 (fir forest) Mg C/ha and carbon content in soil from

the 0-30 cm depth ranged from 72.8 (degraded forest) to 116.4 (oak forest) Mg C/ha. The authors also described total carbon stock on the basis of forest classes (pine, oak, fir and pine-oak forest) presented 220.7 and 266.9 Mg C/ha, degraded forest contained 169.2 Mg C/ha, plantation 142 Mg C/ha, avocado orchards 156.1 Mg C/ha, scrublands 121 Mg C/ha, grassland 90.8 Mg C/ha and agriculture 82.7 Mg C/ha.

Tropical tree plantations may play important role in mitigating CO₂ emissions through their potential to capture and sequester carbon from the atmosphere (Derwisch *et al.*, 2009). The authors also try to assess the carbon (C) storage potential of 1, 2, and 10 years old *T. grandis* plantations from Western Panama and reported that the average above ground C storage ranged from 2.9 to 40.7 mg C/ha were in the 1 and 10 years old plantations, respectively. Moreover per tree carbon storage ranged from 0.6 kg (1 yr old teak) to 99.2 kg (10 yr old teak) was on the basis of biomass harvest. On a stand level between 0.9 Mg C/ha (1 yr old teak) to 38.0 Mg C (10 yr old teak) were stored in the tree biomass. The average C concentration in the grass/herbaceous vegetation and liter varied little (42-44 %) and did not differ significantly ($P = 0.479$) among land cover type. Similar results were reported by Kraenzel, *et al.* (2003) from Teak plantations in central Panama. Increased mass of dead wood and alterations in vegetation composition of Siberian larch (*Larix sibirica*) and two age-classes of native birch (*Betula pubescens*) in Iceland increased the forest floor C-stock of older forests (Sigurdsson *et al.*, 2005). Carbon density of different *Phyllostachys pubescens* bamboo organ ranged from 0.4683 to 0.5210 g g⁻¹ which was in the order: root > trunk > underground trunk > branch > underground stem > leaf. The organ distribution of carbon storage was 50.97 % for trunk, 19.79 % for root and 4.87 % for leaf (Zhou and Jiang, 2004).

Rhoades *et al.* (2000) estimated the loss of forest-derived soil C (light in ¹³C) and the accumulation of C from replicate sugarcane and pasture vegetation (heavy in ¹³C) using a stable C isotope technique. They also measured differences in the proportion of soil C derived from C₃ and C₄ plants across a land-use progression from agricultural fields through successional communities and undisturbed forest. Total soil C was 23 t/ha lower in the upper 30 cm following 50 year of sugarcane production (24

percent decrease) compared to old-growth forest. The net change ($-0.4 \text{ t ha}^{-1} \text{ year}^{-1}$) in soil C consisted of 1.3 t/ha annual losses of original forest C and 0.9 t/ha annual gains of C from sugarcane. After 15 years beneath pasture, soil C was 11 t/ha less in the upper 30 cm than beneath forest (12 percent decrease).

Carbon storage in two thicket restoration sites was investigated to determine potential rates of carbon sequestration. At the farm Krompoort, near Kirkwood, 11 kg C/m^2 was sequestered over 27 years (average rate of $0.42 \pm 0.08 \text{ kg C m}^{-2} \text{ yr}^{-1}$). In the Andries Vosloo Kudu Nature Reserve, near Grahamstown, approximately 2.5 kg C/m^2 was sequestered over 20 years ($0.12 \pm 0.03 \text{ kg C m}^{-2} \text{ yr}^{-1}$). Slower sequestration in the Kudu Reserve was ascribed to browsing by black rhinoceros and other herbivores, a shallower soil and greater stone volumes (Mills and Cowling, 2006).

A study conducted by Pibumrung *et al.* (2008) to estimate the profile of carbon stocks in forest, reforestation and agricultural land, Northern Thailand. Results revealed that the amount of total carbon stock of forests ($357.62 \pm 28.51 \text{ Mg /ha}$, simplified expression of $\text{Mg (carbon) ha}^{-1}$) was significantly greater ($P < 0.05$) than the reforestation ($195.24 \pm 14.38 \text{ Mg /ha}$) and the agriculture land ($103.10 \pm 18.24 \text{ Mg /ha}$). Soil organic carbon in the forests ($196.24 \pm 22.81 \text{ Mg /ha}$) was also significantly greater ($P < 0.05$) than the reforestation ($146.83 \pm 7.22 \text{ Mg /ha}$) and the agriculture land ($95.09 \pm 14.18 \text{ Mg /ha}$). The author also reported that the above ground: soil organic carbon: fine root carbon ratios (ABGC: SOC: FRC) was 5:8:1, 2:8:1 and 3:50:1 for the forest, reforestation and agriculture land, respectively. Similar results were reported from Thailand by Ogawa *et al.* (1965), Sangtongpraow and Sukwong (1990), Tanee (1997), Terakunpisut (2003).

Afforestation can increase soil organic carbon (SOC) storage, but the selection of tree species may be critical. This study explored soil CO_2 production and effluxes in relation to SOC contents in temperate forests in northern New Zealand. Sites included even-aged (38 years) first generation stands of eight coniferous and two deciduous species planted at three sites along a gradient in soil fertility. SOC stocks (forest floor + mineral soil 0-50 cm) differed significantly between tree species, but soil type influenced SOC stocks the most. SOC stocks were significantly higher for stands on low-fertility

sandy soils than stands on fertile loamy soils. Results suggest that selection of soil type and tree species are important for SOC sequestration in future afforestation projects (Ladegaard *et al.*, 2005).

Alternative land management practices, including agroforestry, help to maintain levels of SOM and can facilitate soil carbon sequestration for mitigating atmospheric CO₂ emissions. This study quantified C inputs and determined the changes of the soil C pool in a 19-year-old *Gliricidia sepium* alley cropping system, studied at two fertilizer levels. The SOC pool in the alley crop was 16-23 per cent higher than the sole crop (Oelbermann *et al.*, 2004). A case study in Pilibhit District (Uttar Pradesh, India) was carried out to judge the potential of farm forestry to sequester CO₂. Medium farmers grow more trees on their lands as compared to other categories (small and large landholders). Usually, *Eucalyptus spp.*, *Populus spp.*, *Tectona grandis* and *Anthocephalus chinensis* are being planted. It was estimated that total biomass production is likely to be 32 800 t/year and the stored carbon 16 400 t/year.

Kumar *et al.* (2009) that the agroforestry plantations (willow and poplar) in cold deserts of Ladakh have received recent attention for its enormous potential carbon pools that reduce carbon emissions to the atmosphere. This agroforestry system of the region had been found to sequester more than 75,000 tonnes of carbon. While these plantations also contributing more than 400 tonnes leaf litter of the ground. Scope of horticulture land-use system in enhancing carbon sequestration ferruginous soils of the semi-arid tropics were analyzed by Chandran *et al.* (2009). The authors reported that the quasi-equilibrium value (QEV) of SOC decreased from 1.78 to 0.68 % in the first 30 cm, when the soils are used for agriculture instead of retaining them as forest while shift from agriculture to horticultural system over 20 years increased the QEV to 0.81 % indicating accumulation of SOC. The highest threshold value of SOC is observed in forest system followed horticultural and the lowest in agricultural system. Thus, farm forestry holds tremendous potential for sequestering and storing carbon (Singh, 2003).

According to Flint and Richards (1994), carbon storage in the vegetation in India from the year 1880 onwards shows a decreasing trend. Carbon storage in vegetation in

India was 8.6 bt in year 1880, 7 bt in year 1920, 6.39 bt in 1950, 5.23 bt in 1970 and 4.39 bt in 1980. The carbon pool for the Indian forests is estimated to be 2026.72 Mt for the year 1995. Estimates of annual carbon uptake increment suggest that Indian forests and plantations have been able to remove at least 0.125 Gt of CO₂ from the atmosphere in the year 1995. Assuming that the present forest cover in the country will sustain itself with a marginal annual increase by 0.5 Mha in area of plantations, it is expected that the Indian forests will continue to act as a net carbon sink in the future (Lal and Singh, 2000). According to the authors, further mitigation of about 3.32 Gt in the next 50 years at an annual reduction of about 0.072 Gt of carbon is possible through plantation. Haripriya (2001) estimated that if the entire area of feasible land of India is used for forestry, the mean estimate of carbon sequestered by natural forests along with newly afforested plantations is around 153 Tg (teragrams) C/year by 2030, equivalent to the 1990 fossil fuel emissions of India.

Based on different approaches, the different estimates of total forest SOC stocks in Indian forest ranged from 23.4-47.5 PgC (or 23.4 – 27.1 Gt) which is 1.6-1.8 per cent of the carbon stored in the world's soils (Dhadwal and Nayak, 1993; Gupta and Rao, 1994; Velayutham *et al.*, 1997; Dhadwal *et al.*, 1998; Rastogi *et al.*, 2002). Chhabra *et al.* (2002_b) estimated the total SOC pool according to soil depth in Indian forests as 4.13 PgC in the top 50 cm and 6.81 PgC in the top 100 cm soil depth. The historic loss in forest soil organic C pool (1880-1981) in the top 100 cm soil depth has been estimated as 4.13 PgC. Das (1975) and Banerjee *et al.* (1986) have reported 40.2 t/ha to 79.2 t/ha soil carbon in the top 30 cm soil of tropical moist deciduous forests of India. Bhadwal and Singh (2002) reported that the carbon sequestered in above ground vegetation of India will be more than double by the year 2050. Cold arid bioclimate constituting 29 % of the total arid ecosystem of the country had a share of 60 % of total soil organic carbon (SOC) stock of the arid bioclimate (Bhattacharyya *et al.*, 2005).

Jha *et al.* (2003) reported that a total of 9815.95 million tonnes of SOC store was estimated in total forest soils (as per 1994 forest stands) under 19 species spread over 27 States and Union territories in India with a national average of 153.63 t/ha. Among the

Indian States, Arunachal Pradesh has maximum SOC store (1702.08 million tonnes) in its forests with the support of five forest covers viz. Chir, mixed conifers, upland hardwood, bamboo and miscellaneous having 6.8602 million ha forest area. The least SOC store 2.42 million tonnes was in Dadra & Nagar Haveli having a forest area of 0.0204 million ha with Teak, Khair and miscellaneous forest cover. West Bengal with forest area of 0.8349 million ha has SOC store of 113.96 million tonnes in its forest. Arunachal Pradesh ranks first amongst states in India with 248.11 t/ha SOC store. Moreover the authors also reported that the national average of SOC/ha in forest soil (based on 19 forest cover) was 182.94 tonnes/ha. When these 19 forest covers were clubbed in five main groups viz. miscellaneous forest, broad leaved, conifers, mangrove and alpine pasture, it was found that their SOC contribution of the total SOC pool of the country were as 65.91, 25.02, 8.65, 0.40 and 0.018 %, respectively. Further the authors also reported that SOC/ha was maximum under Spruce with 386 t/ha and minimum under Khair with 51.93 t/ha.

Jha *et al.* (2003) reported that north eastern states had SOC store of 218 t/ha in the forest lands. A preliminary estimation of carbon stock sequestered through rubber (*Hevea brasiliensis*) plantation in north-eastern (NE) region of India was reported by Dey (2005). A total of 3.734 million tonnes of SOC store was estimated under rubber plantation of NE region. The average carbon store in rubber plantation of NE region was around 136 t C/ha, out of which 92.7 t C/ha was contributed by soil and 2.40 t C/ha through litter fall and undergrowth vegetation. The soils of Tripura showed a maximum SOC store of 1.925 million tonnes with an area of 28,853 ha of rubber plantation followed by Assam 0.919 million tonnes of SOC.

In Rajasthan the proportion of total carbon in the forest stored in the soil component had been worked out to be 67 % (Bala, 2001) and it was 3.60 to 6.38 t ha⁻¹ compared to 1.13 to 5.18 t ha⁻¹, being lowest in the sandy area (Singh *et al.*, 2003). Carbon in the form of vegetation biomass ranged from 1.96-2.83 t/ha in Gujarat and 0.24 to 1.73t/ha in Rajasthan (Singh *et al.*, 2003). Gera *et al.* (2003) estimated that 1.53-3.01 tonnes of carbon were being sequestered ha⁻¹ yr⁻¹ by community-protected forests of Sambalpur Forest Division, Orissa.

The amount of carbon stored in above ground biomass and carbon sequestered in soil under seven different land uses in Terai zone of Cooch Behar, West Bengal were studied by Koul (2004). SOC stock ranged from 6.47 t/ha to 21.21 t/ha and the SOC pool ranged from 59.37 Mg/ha to 212.08 Mg/ha. The maximum SOC stock and pool was present in natural forest of *Shorea robusta* (17.69 t/ha, 176.94 Mg/ha) and least in agriculture field (6.99 t/ha, 66.92 Mg/ha), respectively. In general the organic carbon decreased with increase in soil depth. The C stock was highest in case of natural forest of *Shorea robusta* (891.02 t/ha) and least in fallow land (0.59 t/ha). Total C stock (Plant + Soil) was highest in case of natural forest of *Shorea robusta* (694.79 t/ha) and lowest in agriculture field (32.87 t/ha).

Soil organic matter (SOM) under 15 yr old plantation of *Pinus roxburghii*, *Tectona grandis*, *Dalbergia sissoo*, *Eucalyptus*, *Acacia catechu* along with natural *Shorea robusta* forest and barren land were reported by Jha *et al.* (1999). SOM status before under different plantations showed that the natural *S. robusta* forest had higher values and least in the soils under barren land. While after monsoon higher values with *S. robusta* followed by *Eucalyptus*, *Dalbergia sissoo*, *Pinus roxburghii*, *Acacia catechu*, *Tectona grandis* and least in barren land soil. Hosur and Dasong (1995) also reported similar findings. *Pinus roxburghii* has the highest amount of carbon followed by *Pterospermum acerifolium*, *Syzygium cumini* and *Tectona grandis*. The carbon storing efficiency of some species like *P. roxburghii*, *Shorea robusta* and *Syzygium cumini* decreased with increasing concentration of CO₂ indicating that the biota is currently releasing additional carbon to the atmosphere rather than storing carbon (Dhand *et al.*, 2003).

Negi *et al.* (2003) reported that the more the structural tissue, the higher the ash content and lower will be the carbon content. The ash content showed decreasing trend: bark < leaf < wood, whereas the carbon content showed an increasing trend: bark > leaf > wood. These observations revealed that the wood which constitutes maximum portion of total biomass, stored maximum amount of carbon. While comparing the different life forms, the workers found that the maximum carbon was stored in the order: conifers >

deciduous > evergreen > bamboos. Therefore, it can be said that the conifers are more efficient in carbon sequestration. Stand biomass ranged from 3.94 (1-year old) to 53.67 Mg ha⁻¹ (6-year old) and stand carbon in 6-year old plantations ranged from 24.12 to 31.12 Mg ha⁻¹ at different sites. Swamy *et al.* (2003) reported that among the tree components, the stem wood accounted for maximum C followed by branches, roots and foliage.

The present study entitled “**Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal**” was carried out in Chilapatta Reserved Forest Ecosystem, Cooch Behar, West Bengal, India during April 2007 to March 2009 A. D. The details of experimental site, materials used and methodology adopted in conducting the study are given below:

3.1 SITE DESCRIPTION

Chilapatta Reserve Forest lies within the forests of Cooch Behar Wildlife Division at Terai zone of West Bengal which is located at northern fringe of the state in foothills of the sub-Himalayan mountain belts. This division comprises of the reserved forests of Nilpara, Chilapatta, Jaldapara and Madarihat with nine ranges. The division is bounded on the north by Bhutan, on the east by Buxa Tiger Reserve, on the south by Falakata PWD road and on the west by Lankapara-Dalgaon Falakata PWD road (Anon., 2001_a). Moreover the habitations surrounding the forest are dominated by tribals. The present study was under taken in the Chilapatta Range having three beats viz. Chilapatta, Mendabari and Bania whose total area was about 41 km² but all the quadrats of the study was placed on Chilapatta, Mendabari Beats (Chilapatta Reserve Forest) with four and five blocks, respectively having a total area of 22 km² (Fig. 1). The elevation of the working site as measured by GPS was latitude 26° 32.85' N and longitude 89° 22.99' E. Altitude of the area was 47 m above MSL.

Paul (2004) reported that the soil of Terai zone in West Bengal is high in organic carbon and available nitrogen, medium in phosphorus and potash with acidic reaction having structure at 0-30 cm depth of about 70 % sand, 19 % silt and 11 % clay.

3.2 CLIMATE AND WEATHER

The climate of the Cooch Behar Forest Division is moist tropical (Anon., 2001_a). On an average total annual rainfall received was 2942.40 mm of which 80 % was recorded during June-August and mean monthly relative humidity ranged from 69.0- 91.5 %. The rain fall in Terai zone of West Bengal is due to south-west monsoon. The summer and winter temperature are mild with highest of 32⁰C during May and lowest of 8.9⁰C

Fig. 1 Outline map of Chilapatta Reserve Forest



during January. The temperature was normal during the study period. The meteorological data of the research period (April, 2007-March, 2009) collected from Regional Tobacco Research Station, Dinhata, Cooch Behar, West Bengal are also graphically presented in Fig. 2.

3.3 STUDY DETAILS

Following two studies were conducted:

1. To study the qualitative and quantitative characters of plant communities of the forest.
2. To estimate the biomass along with N, P, K and C stored in the forest.

The material and methods used for both the studies are discussed below:

3.3.1 Sampling

Stratified random nested quadrat sampling method was adopted for analyzing vegetation composition. Quadrat size of $20 \times 20 \text{ m}^2$ for trees within which two $5 \times 5 \text{ m}^2$ quadrats was laid out at the diagonal corners for shrubs and lianas and five $1 \times 1 \text{ m}^2$ quadrats at the four corners and one at the center of the 20×20 meter quadrat for herbs, ferns and climbers (Fig. 3). On the outline map of Chilapatta Reserve Forest, a total of

Fig. 3. Quadrat for vegetation analysis

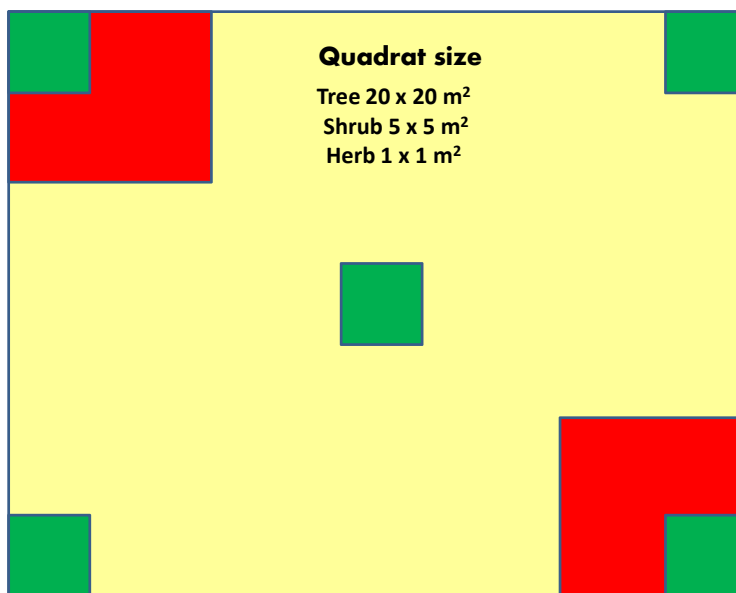
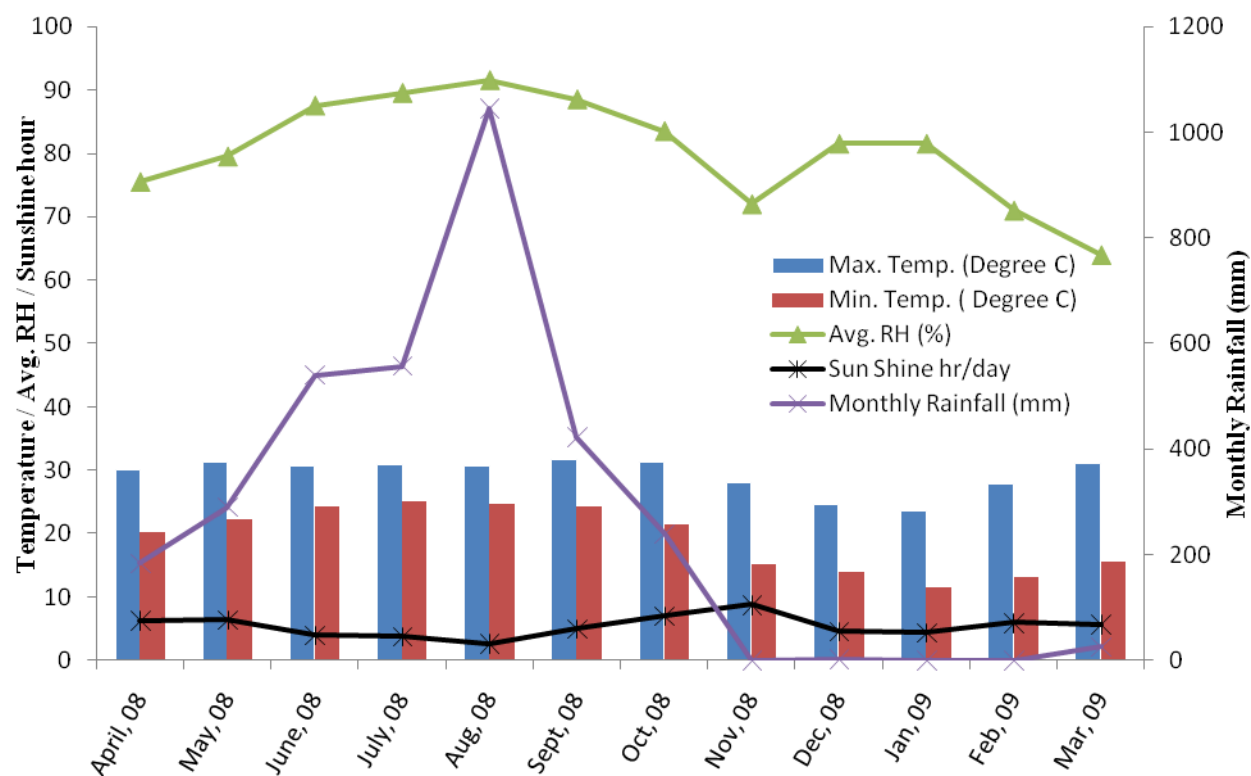
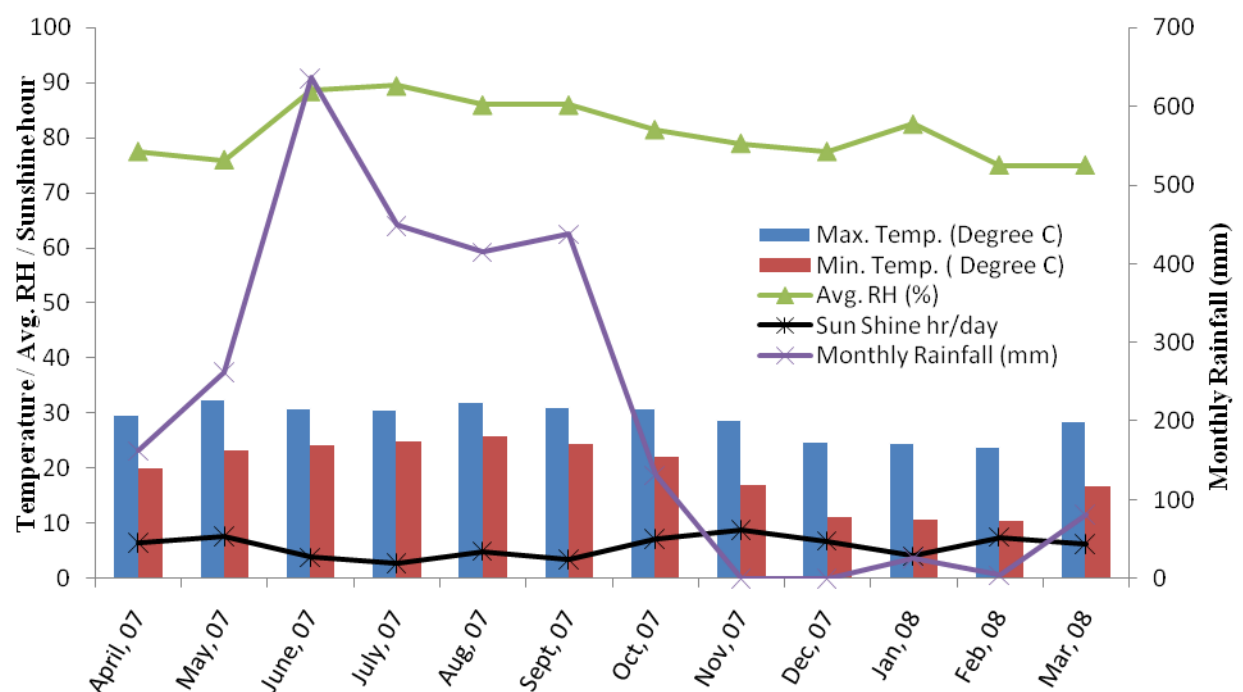


Fig. 2-Metrological Data collected from Regional Tobacco Research Station, Cooch Behar during study period April, 2007-March, 2009



57 quadrats were marked (generally near the forest roads and paths) for trees, 114 for shrubs and lianas while 285 for herbs, ferns and climbers. The laying of quadrats in the forest was avoided in the interior parts either because the forest is classified as wildlife zone or due to the permission obtained from the PCCF, Directorate of Forests, Govt. of West Bengal to work in the forest excluding the core zone (Appendix I). The quadrats were marked in such a way that they were evenly distributed throughout so that they represent the total forest in the study area. After laying the quadrats on the map, they were actually marked in the forest with white paint (generally on a tree or placing a pole where exactly no tree is located) and the quadrats were allotted numerical numbers accordingly for identification.

3.3.2 Identification of Species

Identification of the specimens was done at the field as far as possible with their available local names (Appendix II). All the specimens were collected properly then dried with blotting paper, poisoned with two per cent mercuric chloride in rectified spirit. The dried and poisoned specimens were mounted on standard herbarium sheets and labeled with relevant information. The unidentified voucher specimens were taken for identification to either at Taxonomy and Environment Biology Laboratory, Department of Botany, University of North Bengal, Siliguri or at National Herbarium, Shibpur Howrah.

3.3.3 Vegetation Study/Phyto-sociological Analysis

For each quadrat the plant community will be studied for their qualitative and quantitative character or phytosociology. The trees, shrubs, herbs, epiphytes, lianas, climbers, fern or any other vegetation was noted to keep an account of the floral composition of the site.

3.3.3.1 Qualitative characters: The structure, composition and life form of the plant community in the study area was described just by visual observations. The following characters were recorded:

3.3.3.1.1 Stratification of vegetation: The life forms like trees, shrubs, herbs, ferns and epiphytes (Johnson, 1983) were recorded for each species individually. The symbols used were T, S, H, F and E for trees, shrubs, herbs, ferns and epiphytes, respectively.

3.3.3.1.2 Sociability: This is also called as nature of grouping. The observation was recorded on the basis of whether the species were growing singly, in patches, in colonies, or intermixed (Sagwal, 1995). The symbols assigned were \$, p, c and i, respectively.

3.3.3.1.3 Occurrence/presence: An expression of presence/occurrence of a species in number of quadrats out of the total quadrats studied (Johnson (1983). On the basis of presence/occurrence, if a species was recorded from ≥ 10 , 10-25, 25-75 and ≤ 75 % of the total quadrats marked in the present study, the species were categorized as very less/rare (r), seldom present/less frequent (s), often present/frequent (o) and mostly or generally present/abundant (f), respectively.

3.3.3.1.4 Function: This is expressed as 'd' for deciduous, 's' for semi-deciduous and 'e' for evergreen.

3.3.3.1.5 Size of plants: The size of the trees were categorized on the basis of its height as 't' for tall, 'm' for medium and 'l' for low heights.

3.3.3.1.6 Leaf shape: The shape of the leaf was categorized as 'n' for needle/spine, 'g' for graminoids, 'a' for medium (small), 'h' for broad, 'v' for compound and 'q' for thalloid (Sagwal, 1995).

3.3.3.1.7 Leaf texture: This is expressed as 'f' for filmy, 'z' for membranous, 'x' for sclerophyllous and 'k' for succulents (Sagwal, 1995).

3.3.3.1.8 Canopy cover: the quadrats were categorized as 'b' for barren, 'di' for discontinuous, 'tb' for tufts/bunches and 'co' for continuous canopy covers (Sagwal, 1995).

3.3.3.2 Quantitative Characters: For each quadrat the numbers of individuals for each species were recorded to determine their frequency, density, abundance, basal area etc.

3.3.3.2.1 Frequency (F): Frequency is the degree of dispersion of an individual species in a community. It expresses the percentage and represents the chance of occurrence of species in a given habitat.

$$\text{Frequency (F)} = \frac{\text{No. of quadrats in which a species occurs}}{\text{Total no. of quadrats studied}} \times 100$$

3.3.3.2.2 Relative frequency (RF): RF can be determined by using the following formula by the data obtained by the quadrat methods:

$$\text{Relative frequency (RF)} = \frac{\text{No. of occurrence of a species}}{\text{No. of occurrence of all species}} \times 100$$

3.3.3.2.3 Raunkiaer's law of frequency: the frequency values are grouped in frequency classes to study the homogenous/heterogeneous nature of vegetation (Raunkiaer, 1934). The law of frequency states that the numbers of species of a community in the five twenty per cent classes are A, B, C, D and E distributed as 0-20, 20-40, 40-60, 60-80 and 80-100 %, respectively.

3.3.3.2.4 Density (D): This indicates the abundance of a species in a unit area. Density of a species expresses the numerical strength in a community. This parameter give an idea about the dominance and rarity of a species and is also an indicator of the standing biomass and productivity of the region.

$$\text{Density (D)} = \frac{\text{Total no. of individuals of a species}}{\text{Total no. of quadrats studied}}$$

3.3.3.2.5 Relative density (RD): RD shows the percentage of representation of the species in term of number of individuals in comparison to all other species in a community.

$$\text{Relative density (RD)} = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

3.3.3.2.6 Abundance (A): It is the number of individuals of a species occurring in all the sampled area of a particular vegetation type. This parameter fairly gives an idea about the commonality of a species in a habitat under consideration.

$$\text{Abundance (A)} = \frac{\text{Total no. of individuals of the species}}{\text{No. of quadrats in which a species occurs}}$$

3.3.3.2.7 Relative abundance (RA): RA is the ratio of the species to number of quadrat studied for given vegetation type.

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

3.3.3.2.8 Basal area (BA): BA is the total ground area occupied by a tree and was calculated by taking measurements of tree trunks at breast height (1.37 m). It provides information on the proportion of its dominance in a forest community. It indicates the relative size, volume and weight of a tree. This is also one of the parameter assigned for determining the importance value of a species. Basal area is calculated by the following formula (Chauhan *et al.*, 2009).

$$BA = 0.7854 \times (DBH)^2$$

3.3.3.2.9 Importance value index (IVI): This is a statistical quantity which gives an overall picture of a species and indicates their importance in the plant community. IVI is sum of RF, RD and RA as suggested by Curtis (1959), Phillips (1959), Mishra (1968), Kershaw (1973) and Cintron and Novelli (1984). It helps in understanding the sociological structure of a species in a community.

$$IVI = RF + RD + RA$$

3.3.3.2.10 Height (ht): The height of about 10 randomly selected trees was measured with help of a Ravi's Multimeter in every quadrat.

3.3.3.2.11 Distribution pattern (DP): The abundance to percentage frequency ratio (A/F) provides information about the nature of distribution of species (Cottam and Curtis, 1956). If the value was < 0.025 , $0.025-0.05$ and > 0.05 , the distribution of species were expressed as regular (R), random (R_1), and contagious (C_1), respectively.

3.3.3.2.12 Diversity indices

Various diversity indices were studied to understand the diversity of communities in space and time. These serve as important surrogates for measuring biodiversity. Out of numerous indices formulated by different workers for diversity study, the commonly used diversity indices were adopted.

3.3.3.2.12.1 Species richness (S): Species richness is the expression of diversity and was described by the number of species in a quadrat or habitat.

3.3.3.2.12.2 Species diversity index (D'): The simplest species richness index is based on the total number of species and the total number of individuals of all species (N) in a quadrat or habitat. Menhinick's index (1964) was adopted to understand the species

richness. Menhinick's index unlike Shannon-Wieners index and Simpson's index gives more weightage to the rare species.

$$D_{\square} = S / \sqrt{N}$$

3.3.3.2.12.3 Concentration of dominance (C): This was calculated to evaluate the level of dominance of a species within a community (Simpson, 1949). Simpson's index was used to measure the concentration of dominance. This relates to the number of chance of a particular species that could be encountered during sampling. Its maximum value ranges between 0-1. This value is inversely proportional to Shannon and Wiener index i.e. a higher value is indicative of less diverse community.

$$C = \sum (n_i/N)^2 \text{ (where } n_i = \text{number of individuals of a species)}$$

3.3.3.2.12.4 Shannon-Wiener diversity index ($H_{\square}$): This index (Shannon and Weaver, 1949; Shannon and Wiener, 1963) was used to determine the species diversity. This is the expression of community structure and that indicates the complexity of a habitat. It is also used to describe the landscape diversity by many landscape ecologists. A high index value is suggestive of more diverse community.

$$H_{\square} = -\sum n_i/N \ln n_i/N$$

3.3.3.2.12.5 Species evenness index (EI): This was calculated as Pielou (1975)

$$EI = H_{\square} / \ln N$$

3.3.4 Sample Collection

Soil and litter samples for nutrient analysis and organic carbon estimation were collected quarterly and once, respectively for one year from all the marked quadrats.

3.3.4.1 Soil sampling: Composite soil samples were collected separately from 0-15 and 15-30 cm depth with the help of Dutch augur from all the quadrats. Samples were air dried in shade, grinded with wooden pestle, passed through 2mm sieve and stored in cloth bags for further laboratory analysis.

3.3.4.2 Litter sampling: Initially three 1 x 1 m² sub-quadrats placed diagonally (two at opposite corners and one in the centre) within all the quadrats were cleared and swept of any deposited debris. This debris was brought to the laboratory and oven dried at 80°C till the weight of the dried samples become constant. Samples were air dried in shade, grinded with electric grinder and stored in paper bags for further laboratory analysis.

25 g oven dried litters were put in the 2 mm mesh nylon bags of size 15 x 15 cm². A total of nine bags were placed on forest floor for decomposition, three each in sub-quadrats. One bag from each sub-quadrat was retrieved quarterly, decomposed materials were brought to laboratory in polythene bags, air dried in shade, grinded with electric grinder and then analysed (Pande, 1986).

3.3.5 Soil Physical Characteristics

The following physical characteristics of soil were analyzed following the method given below.

Moisture	Volumetric method
pH (1:2 soil: water suspension)	Beckman's pH meter (Jackson, 1967)
Electrical conductivity (m mhos/ cm) at 25°C (1:2 soil water suspension)	Solubridge conductivity meter

3.3.6 Nutrient Analysis

Soil and litter samples were analyzed for organic carbon and available N, P & K following the method given below.

Organic carbon (%)	Walkley and Black's rapid titration method (Jackson, 1967)
Available N kg ha ⁻¹	Modified Kjeldahl method (Jackson, 1967)
Available P ₂ O ₅ kg ha ⁻¹	Bray's method – Bray and Kurtz, 1945 (Jackson, 1967)
Available K ₂ O kg ha ⁻¹	Flame Photometer method (Jackson, 1967)

3.3.7 Soil Organic Carbon Stock

Soil organic carbon stocks was calculated by multiplying the organic carbon with weight of the soil (bulk density and depth) for a particular depth and expressed as mega grams per ha⁻¹ (Mgha⁻¹) as given by Joao Carlos *et al.* (2001).

3.3.8 Biomass Estimation

Indian laws do not permit to cut or harvest any plants especially the trees from any Reserved Forest so direct or destructive methods of estimation of biomass are not possible. Therefore indirect or nondestructive methods is the only alternative left for biomass estimation by combination of visual or assumption methods. Consulting models developed by Negi *et al.* (1988), Brown *et al.* (1989), Anon. (1997), Luckman *et al.* (1997), the model developed by Brown *et al.* (1989) was used to estimate above ground

biomass because literature showed that this method is one of the most suitable methods for tropical forest (Alves *et al.*, 1997; Brown, 1997; Schroeder *et al.*, 1997; Anon, 1997, Alamgir and Al-Amin, 2008). The model is as follows:

$$Y = \exp. \{-2.4090 + 0.9522 \ln (D^2 \times ht \times S)\}$$

Where, $\exp. = [\dots]$ means “raised to the power of $[\dots]$ ”, Y is the above ground biomass (kg), ht is the height of the tree (m), D is the diameter at breast height (1.3m), S is the density of wood (t/m^2) assumed 0.5 for the tropical woods. Below ground biomass of the species was calculated considering 15 % of the above ground biomass (MacDicken, 1997). Thus the average total biomass was obtained by adding the average above ground biomass and 15 % of the average above ground biomass as below ground biomass. Above ground biomass was separately estimated for stems, branches and leaves.

About 10 trees were selected randomly from each quadrat. The average total biomass, stem biomass and branch biomass of these 10 trees were calculated then multiplied with total number of trees/stem/branch to obtain the total biomass of trees/stems/branches in a quadrat. The height of the stem was measured up to its 1st branch and dbh was measured by a caliper. The number of primary, secondary and tertiary branches was counted from the 10 randomly selected trees in a quadrat. Again five branches in each category were selected from each tree and their length and mid-diameter were measured roughly on a visual estimate by comparing with an exactly measured branch/stick. From five randomly harvested branches of each selected trees all the leaves were plucked to measure their average fresh weight and then multiplied with the total number of branches to estimate the total mass of the leaves in a tree.

Five shrubs were randomly selected from each quadrat, uprooted to measure their average fresh weight separately for stems/branches, leaves and roots and then multiplied with the total number of shrubs in the quadrat. For herbs all the plants from three randomly selected 1 x 1 sub-quadrats within the main quadrats were uprooted to measure their fresh weight separately for roots and above ground parts. The quadrats studied have poor regeneration as was indicated by near absence of seedlings of trees and shrubs. The fresh biomass of seedlings of trees and shrubs found in the quadrats were also directly estimated from a few quadrats only where they were available in numbers to avoid destruction of the seedlings and it was found that their contribution was very negligible as

compared to the total mass of the tree/shrub, so ignored while estimating the total biomass present in an unit area. Proper permission was taken from the authorities of State Forest Department to harvest the branch, shrub and herb samples.

3.3.9 Estimation of Biomass Carbon: The total biomass in a quadrat and the total herb, shrub &, total tree biomass was converted into carbon by multiplying with a factor of 0.45 (Woomer, 1999).

3.3.10 Photosynthetically Active Radiation (PAR)

PAR was recorded with the help of Lp-80 Accu PAR (PAR/LAI Ceptometer Decagon Devices, Inc.) Unintercepted PAR above the forest canopy was impossible to record at the height of tree canopy so this PAR was recorded at clear spots on the road just before entering the quadrat. Beneath the forest canopy PAR was recorded at three heights i.e. above the shrubs, below the shrubs and at ground level. For PAR observation 10 spots were selected randomly and then average PAR was calculated separately for different heights for estimating the interception per cent using the following formula:

$$\text{PARI \%} = \frac{A-B}{A} \times 100$$
, where, A is PAR above tree/shrub/herb canopy and B is PAR below tree/shrub/herb (above ground).

3.3.11 Medicinal Values of Plants

During the course of my study one or other village tribal elder assisted me in documenting about their medicinal, therapeutic, nutritional or other. uses of the plants found in the forest.

The result of the present study entitled, “**Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal**” consisting of two parts is presented below:

4.1 STUDY I: TO STUDY THE QUALITATIVE AND QUANTITATIVE CHARACTERS OF PLANT COMMUNITIES OF THE FOREST

4.1.1 Qualitative Characters

The visual observations for qualitative characters like stratification, occurrence/presence, function, size of plants, sociability, leaf shape and texture are presented in Table 2.

The different life/vegetation forms recorded from the Chilapatta Reserve Forest were trees, shrubs, lianas, climbers, ferns, herbs, and epiphytes. Trees occupied the topmost strata of Forest. After trees the downward strata are occupied by lianas, shrubs, climbers and ferns one below the other while herbs were recorded as the lower most stratum of the forest. Lianas or woody climbers and tree epiphytes occurred in association with the trees and thus can be regarded as same strata as that of the trees. Climbers which occurred mostly in association with shrubs shared same stratum with shrubs. In a few observations, though climbers were found associated with trees but they never crossed the stratum beyond the shrubs.

On the basis of mere presence/occurrence of species in the quadrats at the forest, the species were categorized as very less/rare present, seldom present/less frequent, often present/frequent and mostly or generally present/abundant. A total of 100 species were very less present (i.e. observed in ≥ 10 % of the total quadrats, 165 were less frequent (occurred in 10-25 % of total quadrats) and 46 were often present (occurred in 25-75 % of total quadrats). No species occurred in more than 75 % of the total quadrats (i.e. none were mostly/generally present). 55.9 % of the tree species were less frequent followed by often present with 24.38 % of tree species and 20.63 % were very less present tree species. The very less present trees were like *Albizia procera* *Calamus erectus*,

Table 2. Qualitative characters of Chilapatta Reserve Forest

Sl. no.	1	2	3	4	5	6	7	8	9
1.	<i>Phlogacanthus thysiformis</i> (Hardwicke) Mabber	Acanthaceae	H	c	s	e	-	h	z
2.	<i>Rungia pectinata</i> (L.) Ness	Acanthaceae	H	c	s	e	-	a	z
3.	<i>Drymicarpus racemosus</i> (Roxb) Hk.f.	Anacardiaceae	T	p	s	d	m	h	z
4.	<i>Saurindia madagascarensis</i>	Anacardiaceae	T	i	s	d	m	a	z
5.	<i>Miliusa roxburghiana</i> (wall.)Hook f. Thompson	Annonaceae	S	c	s	e	-	a	z
6.	<i>Uvaria hamiltonii</i> Hook. f. & Thomson	Annonaceae	T	i	o	d	t	h	z
7.	<i>Polyalthia simiarum</i> Benth. & Hk. f.	Annonaceae	T	i	o	d	m	a	z
8.	<i>Alangium chinense</i> (Lour.)	Alangiaceae	C	\$	r	e	-	h	z
9.	<i>Alstonia scholaris</i> (R. BR.)	Apocynaceae	T	i	s	s'	l	a	z
10.	<i>Chonemorpha fragrans</i> (Moon) Alston	Apocynaceae	C	\$	s	e	-	h	z
11.	<i>Ichnocarpus frutescens</i> (L.) Aiton	Apocynaceae	C	\$	s	e	-	a	z
12.	<i>Ichnocarpus volubilis</i> (Lour) Merrill	Apocynaceae	C	\$	s	e	-	a	z
13.	<i>Tabernaemontana</i> spp.	Apocynaceae	S	c	r	e	-	a	z
14.	<i>Tabernaemontana divaricata</i> (L.) Roemer & Schultes	Apocynaceae	S	c	r	e	-	a	z
15.	<i>Vallaris solanacea</i> (Roth)	Apocynaceae	C	\$	s	e	-	a	z

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	Kuntze		T	i	s	d	m	a	z
16.	<i>Wrightia arborea</i> (Dennst.) Mabb	Apocynaceae	T	i	s	d	m	a	z
17.	<i>Wrightia tomentosa</i> (Roxb.) Roem. & Schult.	Apocynaceae	T	i	s	d	m	a	z
18.	<i>Amorphophallus bulbifer</i> (Schott) Blume	Arecaceae	H	c	s	e	-	v	z
19.	<i>Pinangra gracilis</i> (Roxb.) Blume	Arecaceae	T	i	r	d	m	v	z
20.	<i>Calamus erectus</i> Roxb.	Arecaceae	T	i	r	e	m	h	z
21.	<i>Calamus guruba</i> Buch-Ham ex martius	Arecaceae	T	i	r	e	m	h	z
22.	<i>Colocasia esculenta</i> (L.) Schott	Areceae	H	c	s	e	-	h	z
23.	<i>Pothos catheartii</i> Schott	Areceae	C ^e	\$	r	e	-	a	z
24.	<i>Pothos scandens</i> L.	Areceae	C ^e	\$	s	e	-	a	z
25.	<i>Rhaphidophora calophylla</i> Schott	Araceae	H	c	r	e	-	h	z
26.	<i>Rhaphidophora glauca</i> (Wall) Schott.	Areceae	H	c	s	e	-	h	z
27.	<i>Rhaphidophora hookeri</i> (Schott)	Areceae	H	c	r	e	-	h	z
28.	<i>Acmella calva</i> (DC.) Jansen	Asteraceae	H	c	s	e	-	a	z
29.	<i>Ageratum conyzoides</i> L.	Asteraceae	H	c	r	e	-	a	z
30.	<i>Eupatorium odoratum</i> L.	Asteraceae	S	c	o	e	-	a	z
31.	<i>Elepanthropus scaber</i>	Asteraceae	H	c	s	e	-	a	z

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32.	<i>Mikania micrantha</i> Kunth	Asteraceae	C	\$	r	e	-	a	z
33.	<i>Diplazium esculentum</i> (Koenig ex. Retz) SW	Athyriaceae	F	c	s	e	-	q	z
34.	<i>Oroxylum indicum</i> Vent.	Bignoniaceae	T	p	s	d	m	v	z
35.	<i>Bombax ceiba</i> L.	Bombacaceae	T	i	s	d	t	v	z
36.	<i>Cordia obliqua</i> Willd.	Boraginaceae	T	p	s	d	m	a	z
37.	<i>Canarium sikkimense</i> King	Burseraceae	T	i	o	d	t	a	z
38.	<i>Quercus Castanopsis</i>	Capieliferceae	T	i	s	d	t	a	z
39.	<i>Capparis multiflora</i> Hook f. & Thomson	Capparidaceae	T	i	s	d	t	h	z
40.	<i>Capparis sikkimensis</i> Kurz	Capparidaceae	T	i	s	d	m	a	z
41.	<i>Stixis suaveolens</i> (Roxb.) Pierre	Capparidaceae	T	p	s	d	m	h	z
42.	<i>Bauhinia vahlii</i> W. and A.	Caesalpiniaceae	T	i	o	d	m	a	z
43.	<i>Celastrus paniculatus</i> Wild.	Celastraceae	C	\$	r	e	-	a	z
44.	<i>Chloranthus</i> sp	Chloranthaceae	H	c	r	e	-	a	z
45.	<i>Termenalia bellirica</i> (Gaertner) Roxb.	Combretaceae	T	p	s	d	m	a	z
46.	<i>Terminalia chebula</i> Retz.	Combretaceae	T	i	s	d	m	a	z
47.	<i>Terminalia crenulata</i> Roth.	Combretaceae	T	i	r	d	m	a	z
48.	<i>Terminalia myriocarpa</i> Heurck & Muell.	Combretaceae	T	i	o	d	m	a	z
49.	<i>Termenalia tomentosa</i>	Combretaceae	T	i	s	d	m	a	z
50.	<i>Floscopa scandens</i> Loureiro	Commelinaceae	H	c	r	e	-	g	z

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51.	<i>Murdannia nudiflora</i> (L.) Brennan	Commelinaceae	H	c	r	e	-	g	z
52.	<i>Ipomoea hirta</i> L.	Convolvulaceae	C	\$	r	e	-	a	z
53.	<i>Porana paniculata</i> Burm.f.	Convolvulaceae	S	c	r	e	-	a	z
54.	<i>Ophiopogon wallichianus</i> (Kunth) Hook. f.	Convallariaceae	H	c	s	e	-	g	z
55.	<i>Hodgsonia macrocarpa</i> (Blume) Cogniaux	Cucurbitaceae	C	\$	r	e	-	h	z
56.	<i>Momordica charantia</i> L.	Cucurbitaceae	C	\$	r	e	-	v	z
57.	<i>Mucia maderaspatane</i> (L.) M. Roemer	Cucurbitaceae	C	\$	r	e	-	a	z
58.	<i>Cyperus cuspidatus</i> (Kunth)	Cyperaceae	H	c	s	e	-	g	z
59.	<i>Cyperus rotandus</i> L.	Cyperaceae	H	c	s	e	-	g	z
60.	<i>Cyperus</i> sp.	Cyperaceae	H	\$	r	e	-	g	z
61.	<i>Scleria terrestris</i> (L.)	Cyperaceae	C	\$	s	e	-	g	z
62.	<i>Dillenia indica</i> Linn.	Dilleniaceae	T	i	s	s'	m	a	z
63.	<i>Dillenia pentagyna</i> Roxb.	Dilleniaceae	T	i	s	s'	l	h	z
64.	<i>Tetracera sarmentosa</i> (L.) Vahl	Dilleniaceae	T	c	s	s'	m	h	z
65.	<i>Dioscorea belophylla</i> Voigt ex. Haines	Dioscoreaceae	C	\$	r	e	-	h	z
66.	<i>Dioscorea hispida</i> Dennstedt	Dioscoreaceae	C	\$	s	e	-	v	z
67.	<i>Dioscorea pubera</i> Blume	Dioscoreaceae	C	\$	r	e	-	v	z
68.	<i>Shorea robusta</i> Gaerth f.	Diptrocarpaceae	T	c	o	d	t	a	z
69.	<i>Dracaena angustifolia</i> Roxb.	Dracaenaceae	S	c	r	e	-	g	z

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70.	<i>Drynaria propinqua</i> (Wall. Ex Matt.) J. Smith	Drynariaceae	C ^e	\$	s	e	-	q	z
71.	<i>Dryopteris sikkimensis</i> (Bedd.) O. Kuntz	Dryopteridaceae	F	c	s	e	-	q	z
72.	<i>Ehretia acuminata</i> R. Br.	Ehretiaceae	T	i	s	d	m	a	z
73.	<i>Sloania Sterculiaceae</i>	Elaeocarpaceae	T	p	s	d	t	h	z
74.	<i>Elaeocarpus lanceifolius</i> (Roxb.)	Elaeocarpaceae	T	i	s	d	m	a	z
75.	<i>Antidesma acidum</i> (Retzius)	Euphorbiaceae	S	c	r	s'	-	a	z
76.	<i>Baliospermum montanum</i> (Willd.) Mueller	Euphorbiaceae	T	i	s	d	m	h	z
77.	<i>Croton caudatus</i> Geiseler	Euphorbiaceae	T	i	s	d	t	h	z
78.	<i>Macaranga denticulata</i> (Blume) Mueller	Euphorbiaceae	T	p	s	d	m	h	z
79.	<i>Macaranga indica</i> Wight	Euphorbiaceae	T	i	s	d	m	h	z
80.	<i>Mallotus philippensis</i> (Lam.) Mueller	Euphorbiaceae	T	i	s	s'	m	h	z
81.	<i>Phyllanthus reticulatus</i> Poiret	Euphorbiaceae	T	p	s	d	m	v	z
82.	<i>Sapium baccatum</i> Roxb.	Euphorbiaceae	T	p	s	d	-	a	z
83.	<i>Trewia nudiflora</i> L.	Euphorbiaceae	T	i	s	d	t	a	z
84.	<i>Ricinus communis</i> L.	Euphorbiaceae	S	c	s	e	-	h	z
85.	<i>Albizia lucidior</i>	Fabaceae	T	p	s	d	m	a	z
86.	<i>Bauhinia variegata</i> L.	Fabaceae	T	p	o	d	m	v	z
87.	<i>Bauhinia scandens</i> L.	Fabaceae	T	p	s	d	m	h	z
88.	<i>Dalbergia stipulacea</i> Roxb.	Fabaceae	T	p	o	d	t	v	z

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89.	<i>Desmodium gangeticum</i> (L.) DC.	Fabaceae	C	\$	r	e	-	a	z
90.	<i>Desmodium heterocarpon</i> (L.) DC.	Fabaceae	C	\$	r	e	-	a	z
91.	<i>Desmodium styracifolium</i> (Osbeck) Merrill	Fabaceae	C	\$	s	e	-	a	z
92.	<i>Desmodium triquetrum</i> (L.) DC.	Fabaceae	S	c	s	d	-	a	z
93.	<i>Mimosa pudica</i> L.	Fabaceae	H	c	r	e	-	v	z
94.	<i>Pterocarpus marsupium</i> (Roxb.)	Fabaceae	T	i	s	d	m	a	z
95.	<i>Butea parviflora</i> Roxb.	Fabaceae	T	i	s	d	m	a	z
96.	<i>Tephrosia candida</i> D.C.	Fabaceae	T	i	s	d	m	a	z
97.	<i>Acacia lenticularis</i> Ham.	Fabaceae	T	i	s	d	t	a	z
98.	<i>Albizia chinensis</i> (Osbeck) Merr.	Fabaceae	T	p	s	d	t	v	z
99.	<i>Castanopsis indica</i> (Roxb.) A. Dc.	Fagaceae	T	p	s	d	t	h	z
100.	<i>Castanea indica</i>	Fagaceae	T	i	s	d	m	v	z
101.	<i>Gynocardia odorata</i> R. Br.	Flacourtiaceae	T	i	s	d	m	a	z
102.	<i>Aeschynanthus acuminatus</i> A. DC	Gesneriaceae	C	\$	s	e	-	a	z
103.	<i>Helminthostachys zeylanica</i> (L.) Hook	Helminthostachyaceae	F	c	s	e	-	q	z
104.	<i>Curculigo orchiodes</i>	Hypoxidaceae	T	i	s	d	m	a	z
105.	<i>Curculigo</i> sp.	Hypoxidaceae	T	i	s	d	t	a	z

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106.	<i>Gomphostemma ovata</i>	Lamiaceae	C	\$	r	e	-	a	z
107.	<i>Plectranthus barbatus</i> Andrew	Lamiaceae	S	c	r	e	-	a	k
108.	<i>Pogostemon benghalensis</i> (Burman f.) Kuntze	Lamiaceae	H	c	r	e	-	a	z
109.	<i>Actinodaphne obovata</i> (Ness) Blume	Lauraceae	T	i	o	s'	m	h	z
110.	<i>Actinodaphne sikkimensis</i> Meisner	Lauraceae	T	p	s	s'	m	a	z
111.	<i>Beilschmiedia dalzellii</i> (Meisner) Koster.	Lauraceae	T	i	s	d	m	a	z
112.	<i>Cinnadenia paniculata</i> (Hook f.) Koster.	Lauraceae	T	i	s	s'	m	h	z
113.	<i>Cinnamomum bejolghota</i> (Hamilton) Sweet	Lauraceae	T	i	s	s'	m	h	z
114.	<i>Litsea cubeba</i> (Lour.) Persoon	Lauraceae	T	p	s	s'	l	a	z
115.	<i>Litsea glutinosa</i> (Lour.) Robinson	Lauraceae	T	p	s	s'	m	a	z
116.	<i>Litsea hookeri</i> (Meisner) Long	Lauraceae	T	p	s	s'	m	h	z
117.	<i>Litsea lacta</i> (Nees) Hook f.	Lauraceae	T	c	o	s'	m	a	z
118.	<i>Litsea monopetala</i> (Roxb.) Persoon	Lauraceae	T	c	o	s'	m	a	z
119.	<i>Litsea panamanja</i> (Ness) Hook f.	Lauraceae	T	p	o	s'	t	a	z
120.	<i>Litsea salicifolia</i> (Ness) Hook f.	Lauraceae	T	i	o	s'	m	h	z
121.	<i>Machilus villosa</i> Hk. F.	Lauraceae	T	p	o	s'	-	a	z

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122.	<i>Persea glaucescens</i> (Nees) Long	Lauraceae	T	p	o	d	m	a	z
123.	<i>Persea odoratissima</i> (Nees) Kastermans	Lauraceae	T	i	o	d	m	a	z
124.	<i>Phoebe lanceolata</i> (Nees) Nees	Lauraceae	T	i	o	d	l	a	z
125.	<i>Careya arborea</i> Roxb.	Lecythidaceae	T	i	o	d	m	h	z
126.	<i>Leea compactiflora</i> Kurz	Leeaceae	S	c	r	e	-	v	z
127.	<i>Leea guineensis</i>	Leeaceae	S	c	s	e	-	a	z
128.	<i>Leea indica</i> (Burman) Merrill	Leeaceae	S	c	o	d	-	a	z
129.	<i>Albizia lebbeck</i> Linn.	Leguminosae	T	p	o	d	t	a	z
130.	<i>Albizia procera</i> (Roxb.) Benth.	Leguminosae	T	p	r	d	t	a	z
131.	<i>Bridelia sikkimensis</i>	Leguminosae	T	i	s	s'	m	a	z
132.	<i>Dalbergia latifolia</i> Roxb.	Leguminosae	T	p	o	d	t	a	z
133.	<i>Lygodium flexuosum</i> (L.) Sw.	Lygodiaceae	F	c	s	e	t	q	z
134.	<i>Lygodium japonicum</i> (Thunb.) Sw.	Lygodiaceae	F	c	s	e	-	q	z
135.	<i>Lygodium microphyllum</i> (Cav.) R. Br.	Lygodiaceae	F	c	s	e	-	q	z
136.	<i>Lygodium circinatum</i> (Brum.f.) Sw.	Lygodiaceae	F	c	s	e	-	q	z
137.	<i>Lagerstroemia parviflora</i> Roxb.	Lythraceae	T	p	o	d	t	a	z
138.	<i>Lagerstroemia speciosa</i> (Linn.) Pers.	Lythraceae	T	p	o	d	t	a	z

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139.	<i>Duabanga sonneratioides</i> Ham.	Lythraceae	T	i	r	d	t	a	z
140.	<i>Michelia champaca</i> L.	Magnoliaceae	T	c	o	d	t	h	z
141.	<i>Urena lobata</i> L.	Malvaceae	C	\$	r	e	-	a	z
142.	<i>Abelmoschus moschatus</i>	Malvaceae	S	c	s	e	-	a	z
143.	<i>Schumannianthus dichotomus</i> (Roxb.) Gagnepain	Marantaceae	H	p	r	e	-	h	z
144.	<i>Mlastoma malabathricum</i> L.	Melastomataceae	S	c	r	e	-	a	z
145.	<i>Pericampylus glaucus</i> (Lamarck) Merrill	Menispermaceae	C	\$	s	e	-	h	z
146.	<i>Tinospora cordifolia</i> Miers (Willd.)	Menispermaceae	T	p	o	d	m	a	z
147.	<i>Cedrela toona</i> Roxb.	Meliaceae	T	p	s	d	t	a	z
148.	<i>Chukrasia tabularis</i> A. Juss.	Meliaceae	T	p	o	d	t	v	z
149.	<i>Amoora wallichii</i> King.	Meliaceae	T	i	o	d	m	a	z
150.	<i>Swetenia mahogani</i>	Meliaceae	T	i	o	d	t	a	z
151.	<i>Acacia concinna</i> (Willd.) DC.	Mimosaceae	T	i	r	d	m	v	z
152.	<i>Artocarpus chama</i> Hamilton	Moraceae	T	i	o	s'	m	h	z
153.	<i>Artocarpus chaplasha</i> Roxb.	Moraceae	T	i	o	d	m	h	z
154.	<i>Artocarpus lakoocha</i> Wall.	Moraceae	T	i	o	d	m	a	z
155.	<i>Ficus hederacea</i> Roxb.	Moraceae	C ^e	\$	r	e	-	a	z
156.	<i>Ficus neriifolia</i> Smith	Moraceae	T	i	r	d	t	a	z
157.	<i>Ficus religiosa</i> L.	Moraceae	T	i	r	d	t	a	z

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158.	<i>Streblus asper</i> Lour.	Moraceae	T	i	r	d	m	a	z
159.	<i>Morus laevigata</i> Wall	Moraceae	T	i	r	d	m	a	z
160.	<i>Ficus elastica</i> Roxb.	Moraceae	T	i	r	d	t	a	z
161.	<i>Ardisia solanacea</i> Roxb.	Myrsinaceae	S	c	r	e	-	a	z
162.	<i>Ardisia thyrsoiflorus</i>	Myrsinaceae	T	p	s	d	l	a	z
163.	<i>Maesa indica</i> Roxb. A. DC.	Myrsinaceae	H	p	s	e	-	a	z
164.	<i>Myristica eratica</i>	Myrtaceae	T	p	s	e	m	h	z
165.	<i>Myristica longifolia</i> Wall.	Myrtaceae	T	p	s	d	m	h	z
166.	<i>Syzygium operculatum</i> Gamble	Myrtaceae	T	i	o	d	m	h	z
167.	<i>Syzygium balsameum</i> (Wight) Walpers	Myrtaceae	T	i	s	d	m	a	z
168.	<i>Syzygium claviflorum</i> (Roxb.) Cowan & Cowan	Myrtaceae	T	p	s	d	m	a	z
169.	<i>Syzygium cumunii</i> L.	Myrtaceae	T	i	o	d	m	a	z
170.	<i>Syzygium formosum</i> (Wall.) Masamune	Myrtaceae	T	p	s	d	m	h	z
171.	<i>Eugenia cumini</i> L.	Myrtaceae	T	i	s	d	m	a	z
172.	<i>Bulbophyllum bailegi</i>	Orchidaceae	O ^e	c	s	e	-	a	z
173.	<i>Phaus flavus</i> (Bl.) Lindl.	Orchidaceae	O	\$	r	e	-	h	z
174.	<i>Bischofia javanica</i> Bl.	Phyllanthaceae	T	i	s	d	m	a	z
175.	<i>Piper attenuatum</i> Miquel	Piperaceae	C	\$	s	e	-	a	z
176.	<i>Piper peepuloides</i> Roxb.	Piperaceae	C	\$	s	e	-	a	z
177.	<i>Piper sylaticum</i> Roxb.	Piperaceae	C	\$	r	e	-	a	z

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178.	<i>Lindernia crustacean</i> (L.) F. Muell.	Plantaginaceae	H	c	s	e	-	a	z
179.	<i>Acroceras zizanioides</i>	Poaceae	H	p	s	e	-	g	z
180.	<i>Angiopteris evecta</i>	Poaceae	F	p	s	e	-	q	z
181.	<i>Axonopus compressus</i> (Sw.) P.Beauv.	Poaceae	H	c	s	e	-	g	z
182.	<i>Brachiaria milliformis</i>	Poaceae	H	p	s	e	-	g	z
183.	<i>Capillipedium assimile</i> (Steudel) A. camus	Poaceae	H	c	s	e	-	g	z
184.	<i>Saccharum spontaneum</i> Linn.	Poaceae	H	c	r	e	-	g	z
185.	<i>Degitaria ciliaris</i>	Poaceae	H	c	s	e	-	g	z
186.	<i>Neomicrocalamus andropogonifolius</i> (Griff) Stapleton	Poaceae	B	c	r	d	-	g	z
187.	<i>Pennisetum purpureum</i> Schum.	Poaceae	H	p	s	e	-	g	z
188.	<i>Colysis decurrens</i> (Blume) Panigr	Polypodiaceae	F ^c	p	s	e	-	q	z
189.	<i>Polygata glomerata</i> Lour.	Polygonaceae	H	p	s	e	-	a	z
190.	<i>Pteris aspericaulis</i> wall	Pteridaceae	F	c	s	e	-	q	z
191.	<i>Pteris biaurita</i> L.	Pteridaceae	F	c	s	e	-	q	z
192.	<i>Pteris himalayensis</i> Ghosh	Pteridaceae	F	c	s	e	-	q	z
193.	<i>Pteris linearis</i> Poir.	Pteridaceae	F	c	s	e	-	q	z
194.	<i>Pteris semipinnata</i> L.	Pteridaceae	F	c	s	e	-	q	z
195.	<i>Naravelia zeylanica</i> (L.) DC.	Ranunculaceae	C	\$	r	e	-	a	z

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196.	<i>Gouania leptostachya</i> DC.	Rhamnaceae	S	p	s	e	-	a	z
197.	<i>Ziziphus rugosa</i> Lamarck	Rhamnaceae	T	p	s	d	m	a	z
198.	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	T	p	s	d	m	a	z
199.	<i>Coffea bengalensis</i> Roxb.	Rubiaceae	S	p	o	e	-	a	z
200.	<i>Borreria ocimoides</i> f. <i>bisepala</i> (Bremek.) Steyerf.	Rubiaceae	H	c	s	e	-	a	z
201.	<i>Haldina cordifolia</i> (Roxb.) Ridsdale	Rubiaceae	T	p	s	d	t	a	z
202.	<i>Hedyotis scandens</i> Roxb.	Rubiaceae	S	p	o	e	-	a	z
203.	<i>Hyptianthera stricta</i> (Smith) Wight & Arnott	Rubiaceae	T	i	s	d	m	h	z
204.	<i>Ixora javanica</i> (Blume) DC.	Rubiaceae	T	p	s	d	m	h	z
205.	<i>Ixora nigricans</i>	Rubiaceae	T	p	s	d	m	h	z
206.	<i>Meyna spinosa</i> Link	Rubiaceae	S	i	s	d	-	a	z
207.	<i>Morinda angustifolia</i> Roxburgh	Rubiaceae	T	c	o	d	l	h	z
208.	<i>Mussaenda roxburghii</i> Hook. f.	Rubiaceae	T	p	o	d	m	a	z
209.	<i>Neolamarikia kadamba</i> (Roxb.) Bosser	Rubiaceae	T	I	s	d	t	a	z
210.	<i>Oldenlandia stipulacea</i> L.	Rubiaceae	H	p	r	e	-	a	z
211.	<i>Psilanthus bengalensis</i> (Schultes) Leray	Rubiaceae	S	p	s	e	-	a	z
212.	<i>Psychotria calocarpa</i> Kurz.	Rubiaceae	T	i	o	d	m	a	z
213.	<i>Psychotria erratica</i> Hook. F.	Rubiaceae	C	\$	r	e	-	a	z

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214.	<i>Uncaria scandens</i> (Smith) Hutchinson	Rubiaceae	C	\$	r	e	-	a	z
215.	<i>Uncaria rusiacum</i>	Rubiaceae	C	\$	r	e	-	a	z
216.	<i>Glycosmis pentaphylla</i>	Rutaceae	S	p	r	e	-	a	z
217.	<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	Rutaceae	T	i	o	d	m	a	z
218.	<i>Aegle marmelos</i> (L.) Corr.	Rutaceae	T	i	r	d	m	v	z
219.	<i>Carallia brachiata</i> (Loureiro) Merrill	Rhizophoraceae	S	p	o	e	-	a	z
220.	<i>Meliosma pinnata</i> (Roxb.) Maximowicz	Sabiaceae	T	i	o	d	m	v	z
221.	<i>Aesculus assamica</i> Griff.	Sapindaceae	T	i	s	d	m	a	z
222.	<i>Mimusops elengi</i> L.	Sapotaceae	T	i	o	d	m	a	z
223.	<i>Lindernia ciliata</i> (Colsm.) Pennell	Scrophulariaceae	H	p	s	e	-	a	z
224.	<i>Ailanthus integrifolia</i> Lamk.	Simaroubaceae	T	i	s	d	m	a	z
225.	<i>Ailanthus grandis</i> Prain	Simaroubaceae	T	i	s	d	m	a	z
226.	<i>Smilax aspericaulis</i> Wall. Ex A. DC.	Smilacaceae	C	\$	r	e	-	a	z
227.	<i>Smilax ovalifolia</i> Roxb.	Smilacaceae	C	\$	r	e	-	a	z
228.	<i>Smilax perfoliata</i> Laureiro	Smilacaceae	C	\$	r	e	-	a	z
229.	<i>Ardisia solanacea</i>	Solanaceae	T	p	o	d	l	a	z
230.	<i>Solanum khasianum</i> L.	Solanaceae	H	p	s	e	-	h	z
231.	<i>Solanum xanthocarpum</i> L.	Solanaceae	H	p	s	e	-	a	z
232.	<i>Pterygota alata</i> (Roxb.) R. Brown	Sterculiaceae	T	p	o	d	m	h	z

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233.	<i>Sterculia vilosa</i> Roxb.	Sterculiaceae	T	p	s	d	t	h	z
234.	<i>Tetracera sarmentosa</i>	Tetraceraceae	T	i	s	d	m	h	z
235.	<i>Eurya cerasifolia</i>	Theaceae	T	p	s	d	m	a	z
236.	<i>Schima wallichii</i> (DC.) Korth.	Theaceae	T	p	s	d	t	a	z
237.	<i>Eurya japonica</i> Thumb.	Theaceae	T	i	r	d	l	a	z
238.	<i>Cyclosorus holttumii</i>	Thelypteridaceae	F	c	s	e	-	q	z
239.	<i>Cyclosorus mantoniae</i>	Thelypteridaceae	F	c	s	e	-	q	z
240.	<i>Pronephrium nudatum</i> Roxb.	Thelypteridaceae	F	c	s	e	-	q	z
241.	<i>Trema orientalis</i> Blume	Ulmaceae	T	i	r	d	m	a	z
242.	<i>Dendrocnida sinuata</i> (Blume) Chew	Urticaceae	S	p	s	e	-	h	z
243.	<i>Callicarpa longifolia</i> Lam.	Verbenaceae	S	p	s	e	-	h	z
244.	<i>Callicarpa tongifolia</i> Lamarck	Verbenaceae	S	c	s	e	-	a	z
245.	<i>Clerodendrum chinense</i> (Osbeck) Mabberley	Verbenaceae	S	c	s	e	-	a	z
246.	<i>Clerodendrum viscosum</i> Vent.	Verbenaceae	S	p	s	e	-	a	z
247.	<i>Gmelina arborea</i> Roxb.	Verbenaceae	T	i	s	d	t	h	z
248.	<i>Tectona grandis</i> L. f.	Verbenaceae	T	c	o	d	t	h	z
249.	<i>Vitex quinata</i> (Lour.)	Verbenaceae	T	i	r	d	m	a	z
250.	<i>Lantana camara</i> L.	Verbenaceae	S	c	s	e	-	a	z
251.	<i>Ampelocissus</i> sp.	Vitaceae	L	\$	r	s'	-	a	z
252.	<i>Cayratia trifolia</i> (L.) Domin	Vitaceae	C	\$	r	e	-	v	z
253.	<i>Cissus repens</i> Lam.	Vitaceae	H	p	s	e	-	a	z

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254.	<i>Tetrastigma campylocarpum</i> Planch.	Vitaceae	L	\$	s	d	-	h	z
255.	<i>Tetrastigma serrulatum</i> Roxb. Planck	Vitaceae	L	\$	s	e	-	h	z
256.	<i>Alpinia nigra</i> (Gaertn.) B.L.Burt	Zingiberaceae	H	p	s	e	-	h	z
257.	<i>Globba macroclada</i> Gagnepain	Zingiberaceae	H	p	r	e	-	g	z
258.	<i>Globba racemosa</i> Smith	Zingiberaceae	H	p	s	e	-	g	z
259.	<i>Hedychium coccineum</i> Smith	Zingiberaceae	H	p	s	e	-	g	z
260.	Un-1		T	i	s	d	t	a	z
261.	Un -2		T	i	s	d	t	a	z
262.	Un -3		T	i	r	d	t	a	z
263.	Un -4		T	i	r	d	t	h	z
264.	Un -5		T	i	r	d	m	a	z
265.	Un -6		T	i	s	d	m	a	z
267.	Un -7		T	i	s	d	m	h	z
267.	Un -8		T	i	r	d	m	h	z
268.	Un -9		T	p	r	d	m	a	z
269.	Un -10		T	i	r	d	t	a	z
270.	Un -11		T	i	s	d	m	a	z
271.	Un -12		T	i	s	d	m	a	z
272.	Un -13		T	i	s	d	m	a	z
273.	Un -14		T	i	r	d	m	a	z

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274.	Un -15	T	i	s	d	m	h	z
275.	Un -16	T	i	s	d	m	h	z
276.	Un -17	T	i	s	d	m	a	z
277.	Un -18	T	i	r	d	m	a	z
278.	Un -19	T	i	r	d	m	h	z
279.	Un -20	T	i	s	d	m	a	z
280.	Un -21	T	i	s	d	t	a	z
281.	Un -22	T	i	r	d	t	h	z
282.	Un -23	T	i	s	d	t	a	z
283.	Un -24	T	i	s	d	m	a	z
284.	Un -25	T	i	s	d	t	a	z
285.	Un -26	T	i	r	d	m	a	z
286.	Un -27	T	i	r	d	m	a	z
287.	Un -28	T	i	r	d	m	a	z
288.	Un-52	T	p	r	d	m	a	z
289.	Un -29	S	p	s	e	-	a	z
290.	Un -30	S	p	r	e	-	a	z
291.	Un -31	S	p	r	e	-	a	z
292.	Un -32	S	p	r	e	-	a	z
293.	Un -33	S	p	r	e	-	a	z
294.	Un -34	S	p	s	e	-	a	z
295.	Un -35	S	\$	s	e	-	a	z
296.	Un -36	C	\$	r	e	-	a	z

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297.	Un -37	C	\$	r	e	-	h	z
298.	Un -38	C	\$	r	e	-	a	z
299.	Un -39	C	\$	r	e	-	a	z
300.	Un -40	L	\$	r	e	-	a	z
301.	Un -41	C	\$	r	e	-	a	z
302.	Un -42	C	\$	r	e	-	a	z
303.	Un -43	H	p	s	e	-	g	z
304.	Un -44	H	p	s	e	-	g	z
305.	Un -45	H	p	s	e	-	g	z
306.	Un -46	H	p	s	e	-	g	z
307.	Un -47	H	p	r	e	-	g	z
308.	Un -48	H	p	r	e	-	a	z
309.	Un -49	H	p	r	e	-	a	z
310.	Un -50	F	c	r	e	-	q	z
311.	Un -51	F	c	r	e	-	q	z

1. Scientific name; 2. Family; 3. Stratification (**B**- bamboo, **C**- climber, **e**- epiphyte, **F**- fern, **H**- herb, **L**- liana, **O**- orchid, **S**- shrub, **T**- tree); 4. Sociability (**\$**- singly, **c**- colony, **i**-intermixed, **p**-patch); 5. Occurrence/presence (**o**-often present/frequent, **r**-very rare/rare, **s**-seldom present/less frequent); 6. Function (**d**- deciduous, **e**- evergreen, **s**-semi-deciduous); 7. Height of trees (**l**- low, **m**- medium, **t**-tall); 8. Leaf shape (**a**- small/medium, **g**- graminoids, **h**- broad, **q**- thalloid, **v**- compound); 9. Leaf texture (**k**- succulent, **z**- membranous)

C. guruba and *Quercus castanopsis*. Some less frequent tree species were like *Bombax ceiba*, *Oroxylum indicum* and *Terminalia ballerica* while some of the often present tree species were like *Lagerstroemia parviflora*, *Michelia champaca* and *Tectona grandis*. Very less present, less frequent and often present shrubs represented 37.14 % (e.g., *Antidesma acidum*, *Leea compactiflora* and *Tabernaemontana divaricata*); 48.57 % (e.g., *Desmodium triquetrum*, *Leea guineensis* and *Miliusa roxburghiana*) and 14.29 % (e.g., *Eupatorium odoratum*, *Leea indica* and *Coffea bengalensis*) of the total recorded shrub species while for climbers it was 72.09 % (e.g., *Alangium chinense*, *Pothos catheartii* and *Celastrus paniculatus*); 23.26 % (e.g., *Chonemorphia fragrans*, *Pothos scandens* and *Vallaris solanacea*) and 4.65 % (e.g., *Ichnocarpus frutescens* and *I. volubilis*) of total climber species, respectively. Herbs, ferns and lianas occurred either were very less or were less frequent. Species like *Ageratum conyzoides*, *Rhaphidophora calophylla* and *R. hookeri* which were represented by 38.78 % of total recorded herbs were very less present while the remaining like *Amorphophallus bulbifer*, *Phlogacanthus thysiformis* and *Rungia pectinata* were less frequent herbs. Ferns those occurred less frequently were like *Helminthostachys zeylanica*, *Lygodium japonicum* and *L. microphyllum* and they represented 89.47 % of the total recorded ferns while the remaining two ferns could not be identified. Among the four lianas recorded, an unidentified liana and *Ampelocissus sp.* were less present while *Tetrastigma campylocarpum* and *T. serrulatum* were less frequent.

The species in the forest were evergreen, semi-evergreen and deciduous. All the shrubs, herbs, climbers and lianas were observed as evergreen but among the trees, 82.50 % were deciduous, 15.63 % semi-evergreen and only 1.87 % were evergreen. The prominent deciduous species were *Syzygium cumini*, *Shorea robusta*, *Lagerstroemia parviflora*, *Tectona grandis*, *Gmelina arborea*, *Albizia procera* and *A. lebbeck*. Species like *Actinodaphne obovata*, *Dillenia Indica*, *D. pentagyna* and *Mallotus philippensis* were semi-evergreen while *Calamus erectus*, *C. guruba* and *Myristica eratica* were the only evergreen species.

The tree stratum was clearly distinguished in to three layers according to the size of the trees. The size of the trees were recorded by visual observations of their height

they attained which was found as tall, medium and low heights of about 75-90, 50-75 and < 50 feet, respectively. Overall the medium tree species dominated with 67.50 % followed by taller height species with 26.88 % and only 5.62 % tree species were of low height. However two trees belonging to *Ficus religiosa* and an unidentified species with a height of about 120 feet was found as the tallest trees in the forest. The tree species like *Tectona grandis*, *Shorea robusta*, *Albizia lebbbeck*, *A. procera*, *Swetenia mahogany*, *Gmelina arborea*, *Lagerstroemia parviflora*, *Bombax ceiba* and *Terminalia tomentosa* were dominant species in terms of solar radiation interception without any interference because they occupied the top most layer of the tree stratum/canopy. The medium tree stratum/canopy where left over solar radiation could penetrate through the dominant canopy above were occupied by species which are co-dominants like *Dillenia indica*, *Bahunia variegata*, *Cinnamomum bejolghota*, *Terminalia bellirica*, *T. chebula*, *Oroxylum indicum* and *Mallotus philippens*. Species like *Dillenia pentagyna*, *Litsea cubeba*, *Eurya japonica*, *Phoebe lanceolata*, *Alstonia scholaris*, *Ardisia thyrsoflorus* and *Morinda aungustifolia* were the suppressed tree species as they inhabited the lowermost tree stratum/canopy down to which very less solar radiation penetrated.

Visually the sociability or the nature of grouping of species in the forest was categorized as species growing singly, in patches, in colonies and intermixed. The species growing intermixed were only the trees which represented 36.98 % of the total recorded species from the forest while 23.47 % were growing in patches species, 23.15 % were colony growers and 16.40 % of the total species were single growers. Among the tree species, 71.86 % were growing intermixed (e.g., *Uvaria hamiltonii* & *A. procera* intermixed with *A. lebbbeck*; *B. ceiba* with *Michelia champaca*; *Terminalia tomentosa* with *S. robusta*; *D. pentagyna* and *Syzygium cumunii* with *T. grandis*, etc.); 23.14 % in patches (e.g., *T. ballerica*, *Dalbergia stipulacea* and *Actinodaphne obovata*) while only eight species (i.e. 5.00 %) v.i.z. *Litsea hookeri*, *L. lacta*, *L. monopetala*, *Machilus villosa*, *M. champaca*, *T. grandis*, *S. robusta* and *L. parviflora* were found growing in colonies. All the climber and liana species were found growing singly while all the fern species were growing in colonies. Unlike tree species, shrubs were found dominantly growing in colonies (54.29 % of total shrub species) followed by 40.00 % growing in patches and only 5.71 % were found growing singly. Shrub species like *Eupatorium odoratum*,

Porana paniculata and *Dracaena angustifolia* were colony growers; *Antidesma acidum*, *Miliusa roxburghiana* and *Hedyotis scandens* were growing in patches while *Meyna spinosa* and an unidentified species were found growing singly. Among the herbs, *Phaus flavus*, a terrestrial orchid and an unidentified species of genus *Cyprus* were growing singly while 51.02 and 44.89 % of total herb species were observed growing in colonies and patches, respectively. The herbs growing in colonies were like *Mimosa pudica*, all species of *Rhaphidophora*, *Digitaria cillialis*, *Ageratum conyzoides* and *Colocasia esculenta* and those growing in patches were like *Amorphophallus bulbifer*, *Globba racemosa*, *G. macroelada*, *Alpinia nigra*, *Solanum khasianum* and *S. xanthocarpum*.

Species were also classified according to their leaf size. Medium/small leaves (59.52 % of the total species) dominated the forest followed by broad/large leaved species (20.57 % of the total species), species with graminoid leaves having 7.71 % of the total species while species with thalloid and compound leaves each had 6.10 % of the total species were the least. Species having needle/spiny leaves were not found in the forest. Tree species dominated with 63.75 % medium/small leaves followed by 28.75 % broad/large leaves and least 7.50 % with compound leaves. Prominent species having medium/small leaves were *Syzygium cumini*, *Bauhinia vahlii*, *Shorea robusta*, *Lagerstroemia parviflora* and *Terminalia tomentosa*. Some broad/large leafed species were *Tectona grandis*, *Gmelina arborea*, *Dillenia indica*, *D. pentagyna* and *Anthocephalus kadamba*. Trees like *Albizia procera*, *A. lebbeck*, *A. chinensis*, *Oroxylum indicum*, *Acacia lenticularis*, *Bombax ceiba* and *Swetenia mahogany* had compound leaves. Among the shrubs, except *Ricinus communis*, *Leea compactiflora* and *Neomicrocalamus andropogonifolius* had broad/large, compound and graminoid leaves, respectively while all other species (94.44 % of total shrubs) like *Miliusa roxburghiana*, *Eupatorium odoratum*, *Dracaena angustifolia* and *Antidesma acidum* were with medium/small leaves. All the species of climbers and lianas were observed with medium/small leaves. Similarly all the fern species had thalloid leaves. 26.53, 51.02, 18.37 and 4.08 % species of herbs were observed with medium/small, graminoids, broad/large and compound leaves, respectively. Herbs with medium/small leaves were like *Rungia pectinata*, *Acmella calva*, *Ageratum conyzoides* and *Solanum xanthocarpum*. Broad/large leafed herbs found were like *Solanum khasianum*, *Colocasia esculenta* and

all species of *Rhaphidophora*. Herbs with graminoids leaves found in the forest were like all the species of *Cyprus*, *Floscopa scandens* and *Murdannia nudiflora*. *Amorphophallus bulbifer* and *Mimosa pudica* were only two herbs having compound leaves. Except for *Plectranthus barbatus*, a shrub whose leaves are succulent all the species had membranous leaf texture.

The canopy cover of the quadrats were visually categorized as discontinuous, tufts/bunches and continuous (Table 3). The canopy cover of 59.65 % quadrats was continuously covered, 35.09 % were discontinuous and quadrats observed with tuft canopy cover were only 5.26 %. No quadrats were found barren in terms of canopy cover. Based on this observation, Chilapatta Reserve Forest can be classified as dense forest as major proportion of the sampled area had more or less continuous canopy. This was further evidenced from the PAR interception by the forest canopy (Table 4) where the forest canopy intercepted more than 80 % of incident PAR and overall total intercepted PAR by all the strata of forest was more than 98 % of the incident PAR. Of the penetrated PAR, more than 90 % was intercepted by the under storey vegetation.

Table 3. Canopy cover of the quadrats in Chilapatta Reserve Forest

Quadrat No.	Canopy cover	Quadrat No.	Canopy cover	Quadrat No.	Canopy cover
1	di	20	tb	39	co
2	di	21	co	40	di
3	co	22	co	41	di
4	co	23	co	42	di
5	co	24	di	43	co
6	di	25	di	44	di
7	di	26	co	45	di
8	co	27	di	46	co
9	di	28	di	47	co
10	co	29	di	48	co

11	co	30	co	49	co
12	di	31	co	50	co
13	di	32	co	51	co
14	co	33	di	52	co
15	co	34	co	53	co
16	co	35	co	54	co
17	di	36	co	55	co
18	tb	37	co	56	co
19	tb	38	di	57	co

di- Discontinuous, co- Continuous, tb – Tuft/Bunch

Table 4. PAR interception by canopy of Chilapatta Reserve Forest ($\mu\text{molm}^{-2}\text{s}^{-1}$)

Sl No	Life form	PARI (%)	PARI
January, 2008			
1.	Total PAR		1146
2.	Tree	86.07	986
3.	Shrub	78.41	125
4.	Herb/Fern	72.54	25
May, 2008			
1.	Total PAR		1434
2.	Tree	81.85	1173
3.	Shrub	76.62	199
4.	Herb/Fern	70.74	60
September, 2008			
1.	Total PAR		1376
2.	Tree	86.65	1192
3.	Shrub	79.91	147
4.	Herb/Fern	71.33	26
December, 2008			
1.	Total PAR		1132
2.	Tree	86.94	984
3.	Shrub	75.69	105
4.	Herb/Fern	70.19	18

4.1.2 Quantitative Characters

4.1.2.1 Diversity Indices: A total of 311 species of plants were recorded from the Chilapatta Reserve Forest but 52 of these species could not be identified (Table 2). The identified species were represented by 85 families and 167 genera (Table 2). The number of species representing the trees, shrubs, herbs, climbers, lianas, and ferns were 160, 36, 49, 44, 4 and 19, respectively (Table 5). Of these, 132 tree (44 families & 80 genera), 28 shrub (17 families & 20 genera), 42 herb (20 families & 30 genera), 38 climber (31 families & 20 genera), 3 liana (one family & two genera) and 17 fern (eight families & nine genera) species were identified (Table 2). The species richness recorded in the present study is comparable with other studies reporting species richness specifically of the trees for tropical forests in Southeast Asia and other parts of the country like that reported by Chandra *et al.* (2010) from Garhwal Himalayas with a total of 209 plant species out of which 29 were trees, 50 shrubs, 102 herbs, 11 climbers, seven epiphytes, four pteridophytes, three bryophytes and three parasites. The species richness recorded in this study however was lesser as compared to Amazonian rainforests, the most species rich plant communities on earth where tree richness only was as high as 244 tree genera over an area of 300 km² (Laurence *et al.*, 2004). In Southeast Asia, the highest richness recorded for trees was 255 species/ha (Whitmore, 1984). High species richness of various forests at different geographic locations in India like 830 species from Garo, Khasi and Jaintia hills, Meghalaya; 395 species (108 families) from sacred groves of Jaintia hills, Meghalaya; 369 species (233 genera and 77 families) from Andaman Islands; 329 plants (251 genera and 110 families: 139 trees, 95 shrubs, 79 herbs and 16 lianas/climbers/twiners) from Sacred groves in Kanyakumari district, Tamilnadu and 372 species (102 families: 177 herbs, 91 trees, 57 climbers, 44 shrubs and 3 epiphytes) from Bhitarkanika National Park, Orissa (Khan *et al.*, 1997; Jamir and Pandey, 2002; Padalia *et al.*, 2004; Sukumaran *et al.*, 2005; Reddy *et al.*, 2006) was also reported. Similarly high tree species richness of 475 (Hajra *et al.*, 1999) from Meghalaya; 165 (54 families) from tropical forests of Garo Hills, Meghalaya (Kumar *et al.*, 2006) and 147 (109 genera and 46 families) from a tropical moist deciduous forest of Niyamgiri hill ranges, Orissa (Dash *et al.*, 2009) was also reported. Species diversity in tropical areas varies greatly from place to place mainly due to variation in biogeography or local landscape conditions

(e.g., soil type, topography), habitat and disturbance (Whitmore, 1998; Fajardo and Alaback, 2005).

Table 5. Diversity indices of plant communities of Chilapatta Reserve Forest

Life forms	S	D	C	H	EI	D
Tree	160	2.07	0.018	4.70	1.43	2615
Shrub	36	0.73	0.037	2.87	1.49	8512
Herb	49	0.62	0.028	4.46	2.27	7628
Climber	43	0.92	0.038	1.26	1.40	775
Liana	4	0.27	0.075	0.55	3.55	106667
Fern	19	0.34	0.310	1.57	2.49	218982
Forest	311	2.20	0.0072	4.77	1.44	-

S - Species richness, D - Species diversity index, C – Concentration of dominance, H - Shannon and Wiener index, EI-Evenness index, D – individuals ha⁻¹

The dominating families were Rubiaceae, Lauraceae, Fabaceae and Euphorbiaceae with 17, 16, 14 and 10 species, respectively while 35 families each were only represented by single species (Table 2). There were 16 families each of which represented by three species, 15 families each by two species, five families each by four species, three families each by nine species and two families each by eight species. Moreover three families were recorded each with five species while seven species represented single family.

Further, family Rubiaceae dominated with 14 genera followed by Euphorbiaceae, Fabaceae and Poaceae with nine genera each, Lauraceae with seven genera and six genera each in Apocynaceae and Verbenaceae while 47 families each had single genus only. 31 families with 53 genera and 80 species represented only trees; eight families with 12 genera and 13 species represented only herbs; eight families with nine genera and 16 species represented only ferns; seven families with nine genera and 15 species represented only climbers while two families with two genera and four species represented only shrubs (Table 2). Among the genera, Litsea dominated with seven species followed by Pteris, Syzygium and Terminalia with 5 species each and Albizia, Desmodium, Ficus and Lygodium with 4 species each while 147 genera each had only

single species. Moreover there were 28, 7, 4 and 3 genera which were represented by 2, 3, 4 and 5 species, respectively (Table 2).

Trees were dominantly represented by family Lauraceae with eight genera & 16 species followed by Euphorbiaceae, Moraceae, Myrtaceae and Rubiaceae having eight species each. The genera *Litsea* of Lauraceae having seven species was dominant among trees followed by *Syzygium* and *Terminalia* with five species each. The shrubs were dominantly represented by Verbenaceae with three genera and five species followed by Rubiaceae with three genera and four species. The genera *Leea* of Leeaceae with three species dominates the shrubs followed by *Tabernaemontana* of Apocynaceae with two species. Family Poaceae with seven genera having a species each dominated the herbs followed by Cyperaceae with two genera and four species. Among the genera of herbs, *Cyperus* of family Cyperaceae and *Rhaphidophora* of Araceae with three species each dominated followed by *Solanum* of Solanaceae and *Globochaeta* of Zingiberaceae with two species each. In case of climbers, family Apocynaceae having three genera with four species dominated followed by Cucurbitaceae having three genera with three species, Rubiaceae having two genera with three species while Dioscoreaceae, Fabaceae, Piperaceae and Smilacaceae each with one genus *Dioscorea*, *Desmodium*, *Piper* and *Smilax*, respectively was represented by three species. The genera *Dioscorea*, *Desmodium*, *Piper* and *Smilax* were dominating in climbers. Ferns were dominated by family Pteridaceae having one genus *Pteris* with five species followed by Lygodiaceae having one genus *Lygodium* with four species and Thelypteridaceae having two genera with three species.

Ferns were the only non-flowering plants recorded from the forest while all other species recorded were flowering plants (Table 2). One species of bamboo i.e. *Neomicrocalamus andropogonifolius* of family Poaceae, two species of orchids of family Orchidaceae and six species of epiphytes were recorded. Among these epiphytes, *Ficus hederacea* of family Moraceae, *Pothos catheartii* and *P. scandens* of family Araceae were climbers, *Drynaria propinqua* and *Colysis decurrens* of family Drynariaceae and Polypodiaceae, respectively were ferns and *Bulbophyllum bailegi* of family Orchidaceae was an orchid (Table 2). All these epiphytic plants were stem borne tree parasites. The

other orchid recorded was *Phaus flavus* which was a terrestrial orchid. *Calamus guruba* and *C. erectus* were the only two palms recorded from the forest.

The values worked out for species diversity index, concentration of dominance, Shannon and Wiener index, and evenness are given in Table 5. The species diversity index or Menhinick's index of the Chilapatta Reserve Forest was 2.20 which are comparable to that reported for tropical forests of Garo Hills in Meghalaya (Kumar *et al.*, 2006). Among the vegetation/life forms, it was highest for the trees (2.07) followed by climbers (0.92), shrubs (0.73), herbs (0.62), lianas (0.27) and the lowest for ferns (0.34). The index considers the total number of species and total number of individuals of all the species and based on this index it can be stated that though the tree species found in this forest were more diverse but are rarer or less frequently present than other vegetation forms. However the diversity of the forest was neither too high nor too less as the presence of species was more or less frequent. The concentration of dominance for Chilapatta Reserve Forest was 0.0072. This reflects number of chance the species were encountered during sampling and lower value means the chances of encountering being more. Among the vegetation/life forms, the values worked out for trees, shrubs, herbs, climbers, lianas and ferns were 0.018, 0.037, 0.028, 0.038, 0.075 and 0.310, respectively. Shannon and Wiener index that determine diversity was inversely proportional to concentration of dominance and the corresponding values were 4.77, 4.70, 2.87, 4.46, 1.26, 0.55 and 1.57, respectively. This index is also an expression of community structure and complexity of a habitat. A high index value is suggestive of more diverse and stable community. It was also observed that the tree species in the forest were distributed more evenly (1.43) than the different vegetative forms in the forest (1.49 for shrubs, 2.27 for herbs, 2.49 for ferns, 1.40 for climbers and 3.55 for lianas) and was also more evenly distributed than when compared with the overall evenness (0.42) of the Chilapatta Reserve Forest. The evenness or equitability recorded in this study was however higher than reported by Varghese and Menon (1999), Dash *et al.* (2009) and Padalia *et al.* (2004) but lower than that reported by Kumar *et al.* (2004) and Newaz (2006).

Pande *et al.* (2002), Galav *et al.* (2005), Srivastava *et al.* (2005) and Dash *et al.* (2009) also reported inverse relationship between concentration of dominance and Shannon and Wiener index as was also observed in this study. Moreover concentration of

dominance reported by the above workers and Kumar *et al.* (2004) were higher than what was recorded in this study but was similar to those reported for other Indian tropical forests (Pande *et al.*, 2000; Newaz, 2006). Concentration of dominance recorded in this study was low which was accordance with higher diversity and related inversely to the index of dominance (Odum 1971). The lower concentration of dominance recorded in this study can be attributed to the fact that in the Chilapatta Reserve Forest dominance was shared by more than one species which was otherwise higher due to single or few species dominance as was reported by Dash *et al.* (2009) and other workers.

Knight (1975) reported that species diversity index or Shannon and Wiener index of diversity is generally higher for tropical forests. But for Indian tropical forests the value of this index was found between 0.83-4.0 (Singh *et al.*, 1981, 1984_{a & b}). The index recorded in this study was quite high as compared to 2.20-2.65 for the tropical forests of Kodayar in the Western Ghats of Southern India (Sundarapandian and Swamy, 2000); 1.9-2.05 for tropical forests of Andaman Islands (Padalia *et al.*, 2004); 0.001-0.845 for tropical dry deciduous forest of Hastinapur in Uttar Pradesh (Khurana, 2009); 2.07-2.50 for dry *Shorea robusta* forest in Nepal (Sapkota *et al.*, 2009) and 1.48-2.69 for tropical forest patches in northeastern Puerto Rico (Galanes and Thomlinson, 2009) but was comparable to tropical forests of Garo hills with values ranging from 2.47-4.27 (Kumar *et al.*, 2006); Silent Valley, Kerala with values ranging from 3.52-4.15 (Singh *et al.*, 1984_b); tropical forests of Kalakad Reserve Forests in Western Ghats with values ranging from 3.31-3.69 (Parthasarathy *et al.*, 1992); tropical moist deciduous forests of Niyamgiri Hill Ranges in Orissa with values ranging from 3.84 to 4.86 (Dash *et al.*, 2009); rainforests in Nigeria with values ranging from 3.34-3.66 (Adekunle, 2006); degraded tropical rainforests in south-western Nigeria with values ranging from 2.82-3.31 (Onyekwelu *et al.*, 2008) and tropical forests of Barro Colorado Island in Panama with value of 4.8 (Knight, 1975). However it would be inappropriate to draw quantitative comparisons among these studies because of significant differences in sample size, plot size and dimensions along with the differences in the environmental conditions and other site factors.

Chilapatta Reserve Forest is a diverse community in which the species are fairly even distributed with higher chances of encountering a species during sampling which was evidenced from the higher values of species diversity index, concentration of dominance, Shannon and Wiener index, and evenness because of lesser disturbance owing to its status of protection from the law as a Reserve Forest or Protected Forest for wildlife.

4.1.2.2. Vegetation analysis: The parameters for vegetation analysis i.e. frequency, relative frequency, Raunkiaer's law of frequency, density, relative density, abundance, relative abundance, important value index, distribution pattern and basal area are presented in Table 6.

Frequency or the degree of dispersion of the species in the forest ranged from 1.73 -54.39 % i.e. of all the species, chance of occurrence of *Albizia procera*, *Calamus erectus*, *C. guruba* and *Streblus asper* each was lowest while *Lagerstroemia parviflora* occurred most. The chance of occurrence of shrubs, herbs, climbers, lianas and ferns respectively ranged between 2.75-29.82, 2.46-15.79, 2.63-30.70, 6.14-15.79 and 3.16-15.09 %. The species whose chances of finding were minimum and maximum in each of these class were an unidentified shrub & *Eupatorium odoratum*, *Cyprus rotandus* & *Ophiopogon wallichianus*, *Ampelocissus sp.* & *Naravelia zeylanica*, an unidentified liana & *Tetrastigma campylocarpum* and an unidentified fern & *Pteris aspericaulis*, respectively. The species whose chances of occurrence were recorded as more than 40 % can be regarded as the prominent species of Chilapatta Reserve Forest. Only four species of trees v.i.z. *Persea glaucescens* (40.35 %), *Machilus villosa* (42.11 %), *Tectona grandis* (47.37) and *Pterygota alata* (49.12 %) were prominently found. Only seedlings of *M. villosa* were found in the study area. Similarly Negi and Nautiyal (2005) reported frequency of species of the tree layer ranging between 10-100 %, shrub layer between 10-80 % and herbaceous layer between 10-100 % from Central Himalayan forest which is more than the present study. This can be attributed to the lesser diversity/species richness of temperate forest than the tropical or sub-tropical forest (Odum, 1971). Khurana (2009) reported frequency of shrub species ranging between 60-90 % from a tropical dry

Table 6. Quantitative characters of plant communities of Chilapatta Reserve Forest

Sl. no.	1	2	3	4	5	6	7	8	9	10	11
1	<i>Phlogacanthus thysiformis</i>	6.14	0.67	A	2526.32	0.36	2.14	0.16	1.19	R ₁	-
2	<i>Rungia pectinata</i>	5.96	0.59	A	2631.58	0.37	5.71	0.19	1.15	C ₁	-
3	<i>Drymicarpus racemosus</i>	12.28	0.30	A	10.09	0.11	3.29	0.38	0.79	R ₁	4.01
4	<i>Saurindia madagascarensis</i>	17.54	0.35	A	11.84	0.13	2.70	0.26	0.75	R	4.25
5	<i>Miliusa roxburghiana</i>	2.46	0.67	A	178.95	0.25	2.29	0.35	1.27	C ₁	-
6	<i>Uvaria hamiltonii</i>	14.91	0.48	A	16.23	0.18	3.00	0.25	0.92	R	3.26
7	<i>Polyalthia simiarum</i>	29.82	0.58	B	19.30	0.22	2.18	0.28	1.08	R	1.37
8	<i>Alangium chinense</i>	24.56	0.80	B	214.04	0.30	3.14	0.50	1.60	R	-
9	<i>Alstonia scholaris</i>	9.65	0.27	A	9.21	0.10	2.91	0.30	0.68	R ₁	2.54
10	<i>Chonemorpha fragrans</i>	14.04	1.78	A	477.19	0.68	2.63	0.20	2.66	R	-
11	<i>Ichnocarpus frutescens</i>	6.14	1.73	A	463.16	0.66	3.43	0.17	2.55	C ₁	-
12	<i>Ichnocarpus volubilis</i>	27.19	2.69	B	722.81	1.03	2.84	0.24	3.96	R	-
13	<i>Tabernaemontana spp.</i>	8.77	0.42	A	112.28	0.16	2.20	0.34	0.91	R ₁	-
14	<i>Tabernaemontana divaricata</i>	9.65	0.31	A	84.21	0.12	3.27	0.40	0.83	R ₁	-

1. Generic name (**Un**- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (**A**: 0-20, **B**: 20-40, **C**: 40-60 %); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (**R**- regular, **R₁**- random **C₁**- contagious); 11. Basal area (m²ha⁻¹), **S**- seedling

15	<i>Vallisneria spiralis</i>	7.89	0.77	A	207.02	0.29	3.11	0.23	1.29	R ₁	-
16	<i>Wrightia arborea</i>	25.44	0.27	B	9.21	0.10	3.21	0.24	0.62	R	5.08
17	<i>Wrightia tomentosa</i>	15.79	0.46	A	15.35	0.17	2.33	0.31	0.94	R	6.26
18	<i>Amorphophallus bulbifer</i>	17.54	0.61	A	3684.21	0.52	3.50	0.26	1.40	R	-
19	<i>Pinangra gracilis</i>	5.96	0.12	A	3.95	0.04	4.41	0.21	0.37	C ₁	0.39
20	<i>Calamus erectus</i>	1.75	0.05	A	1.75	0.02	1.00	0.23	0.30	R ₁	-
21	<i>Calamus guruba</i>	1.75	0.05	A	1.75	0.02	1.00	0.23	0.30	R ₁	-
22	<i>Colocasia esculenta</i>	3.51	0.69	A	4912.28	0.70	1.00	0.30	1.70	R ₁	-
23	<i>Pothos catheartii</i>	5.61	0.47	A	126.32	0.18	4.56	0.20	18.42	C ₁	-
24	<i>Pothos scandens</i>	10.53	1.16	A	312.28	0.44	4.08	0.26	34.21	R ₁	-
25	<i>Rhaphidophora calophylla</i>	19.30	0.20	A	2175.44	0.31	2.82	0.48	0.98	R	-
26	<i>Rhaphidophora glauca</i>	5.61	0.88	A	4561.40	0.65	4.75	0.22	1.75	C ₁	-
27	<i>Rhaphidophora hookeri</i>	5.26	0.22	A	2561.40	0.36	4.13	0.50	1.08	C ₁	-
28	<i>Acmella calva</i>	3.51	1.32	A	9192.98	1.31	3.01	0.30	2.93	C ₁	-
29	<i>Ageratum conyzoides</i>	5.96	0.20	A	3543.86	0.50	4.29	0.78	1.48	C ₁	-
30	<i>Eupatorium odoratum</i>	29.82	2.00	B	0.84	1.02	2.18	0.57	3.58	R	-
31	<i>Elepanthropus scaber</i>	29.82	1.02	B	6175.44	0.88	6.18	0.26	2.16	R	-

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32	<i>Mikania micrantha</i>	4.21	0.37	A	98.25	0.14	2.83	0.29	0.80	C ₁	-
33	<i>Diplazium esculentum</i>	25.44	0.42	B	92.96	0.25	4.48	10.65	11.32	R	-
34	<i>Oroxylum indicum</i>	12.63	0.34	A	11.40	0.13	9.36	0.25	0.72	C ₁	5.04
35	<i>Bombax ceiba</i>	21.05	0.24	B	7.89	0.09	2.17	0.26	0.58	R	19.43
36	<i>Cordia oblique</i>	8.77	0.12	A	3.95	0.04	1.00	0.17	0.34	R	2.56
37	<i>Canarium sikkimense</i>	14.04	0.35	A	11.84	0.13	1.13	0.31	0.80	R	2.18
38	<i>Quercus Castanopsis</i>	17.54	0.12	A	3.95	0.04	2.70	0.21	0.37	R	17.81
39	<i>Capparis multiflora</i>	5.26	0.35	A	11.84	0.13	4.33	0.39	0.88	C ₁	2.43
40	<i>Capparis sikkimensis</i>	8.77	0.22	A	7.46	0.08	3.40	0.14	0.45	R ₁	3.17
41	<i>Stixis suaveolens</i>	10.53	0.39	A	13.16	0.15	4.50	0.27	0.81	R ₁	1.78
42	<i>Bauhinia vahlii</i>	24.56	0.73	B	24.56	0.28	2.14	0.32	1.33	R	-
43	<i>Celastrus paniculatus</i>	24.56	0.54	B	143.86	0.20	1.79	0.21	0.95	R	-
44	<i>Chloranthus sp</i>	9.65	0.18	A	2807.02	0.40	2.91	0.66	1.24	R ₁	-
45	<i>Termenalia bellirica</i>	11.23	0.80	A	26.75	0.30	5.59	0.39	1.49	C ₁	11.83
46	<i>Terminalia chebula</i>	22.81	0.73	B	24.56	0.28	4.69	0.43	1.44	R	7.92
47	<i>Terminalia crenulata</i>	35.09	0.17	B	5.70	0.06	2.80	0.30	0.53	R	4.88
48	<i>Terminalia myriocarpa</i>	22.81	0.39	B	13.16	0.15	1.77	0.23	0.77	R	6.29

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49	<i>Termenalia tomentosa</i>	26.32	1.02	B	34.21	0.39	4.80	0.69	2.10	R	15.56
50	<i>Floscopa scandens</i>	3.51	0.14	A	1859.65	0.26	1.50	0.56	0.96	R ₁	-
51	<i>Murdannia nudiflora</i>	5.26	0.09	A	1333.33	0.19	4.38	0.63	0.91	C ₁	-
52	<i>Ipomoea hirta</i>	6.67	0.37	A	98.25	0.14	5.01	0.29	0.80	C ₁	-
53	<i>Porana paniculata</i>	6.14	0.29	A	77.19	0.11	3.00	0.25	0.65	R ₁	-
54	<i>Ophiopogon wallichianus</i>	17.54	1.24	A	9929.82	1.41	3.50	0.34	3.00	R	-
55	<i>Hodgsonia macrocarpa</i>	15.79	0.50	A	133.33	0.19	5.06	0.21	0.90	R ₁	-
56	<i>Momordica charantia</i>	17.54	0.44	A	119.30	0.17	1.60	0.22	0.83	R	-
57	<i>Mucia maderaspatane</i>	7.89	0.31	A	84.21	0.12	1.67	0.17	0.61	R	-
58	<i>Cyperus cuspidatus</i>	6.14	0.44	A	11017.54	1.56	3.00	1.06	3.07	R ₁	-
59	<i>Cyperus rotandus</i>	3.86	0.47	A	4035.09	0.57	2.82	0.37	1.41	C ₁	-
60	<i>Cyperus sp.</i>	2.46	0.65	A	3614.04	0.51	1.43	0.24	1.40	C ₁	-
61	<i>Scleria terrestris</i>	4.21	0.77	A	207.02	0.29	2.25	0.32	1.39	C ₁	-
62	<i>Dillenia indica</i>	17.54	0.46	A	15.35	0.17	3.00	0.34	0.97	R	14.67
63	<i>Dillenia pentagyna</i>	8.77	0.65	A	21.93	0.25	2.60	0.44	1.35	R ₁	1.11
64	<i>Tetracera sarmentosa</i>	26.32	0.59	B	19.74	0.22	2.00	0.47	1.28	R	3.24
65	<i>Dioscorea belophylla</i>	22.81	0.47	B	126.32	0.18	3.85	0.42	1.07	R	-

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66	<i>Dioscorea hispida</i>	11.40	1.01	A	270.18	0.38	4.08	0.31	1.70	R ₁	-
67	<i>Dioscorea pubera</i>	21.93	0.42	B	112.28	0.16	5.16	0.34	0.91	R	-
68	<i>Shorea robusta</i>	24.56	2.30	B	77.19	0.88	2.64	0.78	3.96	R	27.56
69	<i>Dracaena angustifolia</i>	21.05	0.37	B	98.25	0.14	4.75	0.29	0.80	R	-
70	<i>Drynaria propinqua</i>	17.54	1.48	A	396.49	0.56	6.05	0.27	2.31	R ₁	-
71	<i>Dryopteris sikkimensis</i>	11.23	0.56	A	3052.63	0.43	8.84	0.23	1.23	C ₁	-
72	<i>Ehretia acuminata</i>	11.93	0.44	A	14.91	0.17	9.24	0.44	1.05	C ₁	1.37
73	<i>Sloania Sterculiaceae</i>	22.81	0.33	B	10.96	0.12	3.85	0.21	0.66	R	2.34
74	<i>Elaeocarpus lanceifolius</i>	12.28	0.47	A	15.79	0.18	1.86	0.35	1.00	R	2.56
75	<i>Antidesma acidum</i>	14.04	0.37	A	98.25	0.14	4.63	0.36	0.86	R ₁	-
76	<i>Baliospermum montanum</i>	8.14	0.24	A	7.89	0.09	7.12	0.17	0.50	C ₁	2.98
77	<i>Croton caudatus</i>	8.77	0.43	A	14.47	0.16	1.80	0.32	0.91	R	1.24
78	<i>Macaranga denticulata</i>	24.56	1.05	B	35.09	0.40	1.79	0.58	2.02	R	4.64
79	<i>Macaranga indica</i>	21.05	0.71	B	23.68	0.27	3.00	0.39	1.36	R	4.02
80	<i>Mallotus philippensis</i>	29.82	0.84	B	28.07	0.32	3.12	0.43	1.59	R	7.93
81	<i>Phyllanthus reticulatus</i>	21.05	0.47	B	15.79	0.18	2.75	0.32	0.97	R	1.25
82	<i>Sapium baccatum</i>	28.07	0.60	B	20.18	0.23	5.00	0.38	1.21	R	S

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83	<i>Trewia nudiflora</i>	8.77	0.51	A	17.11	0.19	3.80	0.41	1.11	R ₁	19.77
84	<i>Ricinus communis</i>	7.72	1.15	A	308.77	0.44	6.91	0.33	1.92	C ₁	-
85	<i>Albizia lucidior</i>	20.18	0.75	B	25.00	0.28	2.09	0.47	1.50	R	11.70
86	<i>Bauhinia variegata</i>	22.81	0.60	B	20.18	0.23	3.23	0.35	1.18	R	11.32
87	<i>Bauhinia scandens</i>	24.56	0.25	B	8.33	0.09	3.29	0.20	0.54	R	5.20
88	<i>Dalbergia stipulacea</i>	11.40	0.37	A	12.28	0.14	2.62	0.20	0.71	R	13.76
89	<i>Desmodium gangeticum</i>	19.30	0.54	A	143.86	0.20	2.36	0.23	0.97	R	-
90	<i>Desmodium heterocarpon</i>	4.39	0.67	A	178.95	0.25	3.4	0.24	1.16	C ₁	-
91	<i>Desmodium styracifolium</i>	18.42	1.19	A	319.30	0.45	3.05	0.24	1.89	R	-
92	<i>Desmodium triquetrum</i>	21.05	1.70	B	456.14	0.65	4.42	0.25	2.60	R	-
93	<i>Mimosa pudica</i>	16.67	1.78	A	2.02	1.76	3.26	1.73	5.27	R	-
94	<i>Pterocarpus marsupium</i>	5.61	0.39	A	13.16	0.15	5.19	0.38	0.93	C ₁	5.88
95	<i>Butea parviflora</i>	14.04	0.13	A	4.39	0.05	5.75	0.19	0.37	R ₁	1.37
96	<i>Tephrosia candida</i>	19.30	0.38	A	12.72	0.14	1.73	0.30	0.83	R	6.24
97	<i>Acacia lenticularis</i>	28.07	0.31	B	10.53	0.12	1.75	0.20	0.63	R	6.56
98	<i>Albizia chinensis</i>	14.04	0.25	A	8.33	0.09	1.63	0.31	0.66	R	10.69
99	<i>Castanopsis indica</i>	10.53	0.56	A	18.86	0.21	1.67	0.50	1.27	R	3.18

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100	<i>Castanea indica</i>	24.56	0.31	B	10.53	0.12	2.86	0.31	0.74	R	4.44
101	<i>Gynocardia odorata</i>	17.54	0.21	A	7.02	0.08	1.80	0.23	0.52	R	1.75
102	<i>Aeschynanthus acuminatus</i>	15.79	0.86	A	231.58	0.33	1.67	0.24	1.43	R	-
103	<i>Helminthostachys zeylanica</i>	10.53	0.42	A	2491.23	0.35	4.92	0.26	1.03	R ₁	-
104	<i>Curculigo orchiodes</i>	7.37	0.39	A	13.16	0.15	4.90	0.38	0.93	C ₁	0.25
105	<i>Curculigo sp.</i>	19.30	0.12	A	3.95	0.04	3.64	0.17	0.34	R	0.40
106	<i>Gomphostemma ovate</i>	15.79	1.13	A	1.21	1.46	1.44	1.45	4.04	R	-
107	<i>Plectranthus barbatus</i>	11.40	0.42	A	112.28	0.16	5.31	0.34	0.91	R ₁	-
108	<i>Pogostemon benghalensis</i>	15.79	0.17	A	807.02	0.11	4.22	0.20	0.49	R	-
109	<i>Actinodaphne obovata</i>	5.96	0.94	A	31.58	0.36	5.24	0.42	1.72	C ₁	6.09
110	<i>Actinodaphne sikkimensis</i>	12.28	0.73	A	24.56	0.28	2.29	0.92	1.93	R	5.47
111	<i>Beilschmiedia dalzellii</i>	10.53	0.25	A	8.33	0.09	1.50	0.27	0.62	R	2.91
112	<i>Cinnadenia paniculata</i>	14.04	0.20	A	6.58	0.07	3.75	0.25	0.52	R ₁	7.88
113	<i>Cinnamomum bejolghota</i>	21.05	0.42	B	14.04	0.16	4.00	0.31	0.89	R	5.72
114	<i>Litsea cubeba</i>	12.28	0.38	A	12.72	0.14	3.43	0.28	0.80	R ₁	4.96
115	<i>Litsea glutinosa</i>	14.04	0.89	A	29.82	0.34	2.38	0.60	1.83	R	4.44
116	<i>Litsea hookeri</i>	12.28	0.92	A	30.70	0.35	2.14	0.73	2.00	R	4.15

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117	<i>Litsea lacta</i>	21.05	0.72	B	24.12	0.27	2.67	0.42	1.42	R	4.69
118	<i>Litsea monopetala</i>	21.05	0.89	B	29.82	0.34	2.42	0.33	1.55	R	4.02
119	<i>Litsea panamanja</i>	22.81	1.01	B	33.77	0.38	5.23	0.52	1.91	R	3.97
120	<i>Litsea salicifolia</i>	19.30	0.68	A	22.81	0.26	6.36	0.30	1.24	R ₁	3.64
121	<i>Machilus villosa</i>	26.32	1.43	B	47.81	0.54	3.67	0.42	2.39	R	S
122	<i>Persea glaucescens</i>	42.11	0.95	C	32.02	0.36	4.21	0.42	1.74	R	0.68
123	<i>Persea odoratissima</i>	40.35	0.73	C	24.56	0.28	3.35	0.36	1.37	R	1.06
124	<i>Phoebe lanceolata</i>	31.58	0.46	B	15.35	0.17	2.89	0.18	0.82	R	3.17
125	<i>Careya arborea</i>	24.56	0.99	B	33.33	0.38	2.86	0.58	1.96	R	7.89
126	<i>Leea compactiflora</i>	26.32	0.27	B	73.68	0.10	4.80	0.35	0.73	R	-
127	<i>Leea guineensis</i>	13.16	0.92	A	245.61	0.35	6.53	0.40	1.67	R ₁	-
128	<i>Leea indica</i>	9.65	1.19	A	319.30	0.45	8.18	0.24	1.89	C ₁	-
129	<i>Albizia lebbeck</i>	15.79	0.44	A	14.91	0.17	3.67	0.18	0.79	R	11.88
130	<i>Albizia procera</i>	1.75	0.05	A	1.75	0.02	1.00	0.23	0.30	R ₁	3.53
131	<i>Bridelia sikkimensis</i>	1.75	0.42	A	14.04	0.16	1.00	0.26	0.84	R ₁	2.63
132	<i>Dalbergia latifolia</i>	29.82	0.51	B	17.11	0.19	2.06	0.28	0.99	R	9.99
133	<i>Lygodium flexuosum</i>	10.53	1.10	A	9263.16	1.32	4.50	0.36	2.78	R ₁	-

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134	<i>Lygodium japonicum</i>	11.58	1.26	A	6175.44	0.88	8.00	0.21	2.34	C ₁	-
135	<i>Lygodium microphyllum</i>	9.47	0.95	A	1719.30	0.24	6.52	0.08	1.28	C ₁	-
136	<i>Lygodium circinatum</i>	7.72	0.63	A	1403.51	0.20	2.23	0.10	0.92	R ₁	-
137	<i>Lagerstroemia parviflora</i>	4.91	4.40	A	147.37	1.67	2.86	1.21	7.28	R ₁	15.46
138	<i>Lagerstroemia speciosa</i>	54.39	0.88	C	29.39	0.33	10.74	0.43	1.64	R	14.22
139	<i>Duabanga sonneratioides</i>	22.81	0.12	B	3.95	0.04	2.08	0.21	0.37	R	7.38
140	<i>Michelia champaca</i>	12.28	1.02	A	34.21	0.39	1.14	0.35	1.75	R	17.80
141	<i>Urena lobata</i>	28.07	0.18	B	49.12	0.07	3.88	0.27	0.52	R	-
142	<i>Abelmoschus Spp.</i>	15.79	0.42	A	112.28	0.16	4.28	0.18	0.76	R ₁	-
143	<i>Schumannianthus dichotomous</i>	14.91	0.18	A	1929.82	0.27	3.24	0.45	0.91	R	-
144	<i>Mlastoma malabathricum</i>	7.89	1.83	A	52.63	0.70	15.56	1.79	4.32	C ₁	-
145	<i>Pericampylus glaucus</i>	11.40	1.15	A	308.77	0.44	2.62	0.32	1.91	R	-
146	<i>Tinospora cordiofolia</i>	7.02	0.46	A	15.35	0.17	6.25	0.24	0.87	C ₁	3.46
147	<i>Cedrela toona</i>	38.60	0.27	B	9.21	0.10	1.45	0.19	0.57	R	12.23
148	<i>Chukrasia tabularis</i>	21.05	0.90	B	30.26	0.34	1.50	0.36	1.61	R	12.46
149	<i>Amoora wallichii</i>	33.33	0.84	B	28.07	0.32	4.32	0.30	1.45	R	10.30
150	<i>Swetenia mahogany</i>	35.09	0.59	B	19.74	0.22	1.85	0.27	1.09	R	13.40

1. Generic name (**Un**- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (**A**: 0-20, **B**: 20-40, **C**: 40-60 %); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (**R**- regular, **R₁**- random **C₁**- contagious); 11. Basal area (m²ha⁻¹), **S**- seedling

151	<i>Acacia concinna</i>	12.28	0.04	A	1.32	0.01	1.43	0.12	0.17	R	2.59
152	<i>Artocarpus chama</i>	21.05	0.44	B	14.91	0.17	1.83	0.20	0.81	R	5.98
153	<i>Artocarpus chaplasha</i>	19.30	0.55	A	18.42	0.21	1.91	0.30	1.06	R	6.55
154	<i>Artocarpus lakoocha</i>	26.32	0.39	B	13.16	0.15	1.67	0.27	0.81	R	5.65
155	<i>Ficus hederacea</i>	21.05	0.64	B	171.93	0.24	2.42	0.43	1.32	R	-
156	<i>Ficus neriifolia</i>	10.53	0.01	A	0.44	0.00	5.33	0.12	0.13	R ₁	36.00
157	<i>Ficus religiosa</i>	21.05	0.04	B	1.32	0.01	2.00	0.17	0.23	R	41.60
158	<i>Streblus asper</i>	1.75	0.05	A	1.75	0.02	1.00	0.23	0.30	R ₁	3.53
159	<i>Morus laevigata</i>	1.75	0.05	A	1.75	0.02	1.00	0.23	0.30	R ₁	3.53
160	<i>Ficus elastica</i>	5.26	0.08	A	2.63	0.03	1.33	0.17	0.28	R ₁	7.38
161	<i>Ardisia solanacea</i>	7.02	0.69	A	185.96	0.26	1.50	0.47	1.43	R	-
162	<i>Ardisia thyrsoiflorus</i>	14.04	0.21	A	7.02	0.08	1.75	0.21	0.49	R	2.93
163	<i>Maesa indica</i>	17.54	0.64	A	5543.86	0.79	0.80	0.37	1.80	R	-
164	<i>Myristica eratica</i>	10.53	0.10	A	3.51	0.04	5.67	0.07	0.22	R ₁	7.37
165	<i>Myristica longifolia</i>	19.30	0.14	A	4.82	0.05	3.36	0.21	0.41	R	8.29
166	<i>Syzygium operculatum</i>	15.79	0.48	A	16.23	0.18	2.11	0.22	0.89	R	7.37
167	<i>Syzygium balsameum</i>	15.79	0.25	A	8.33	0.09	1.78	0.22	0.56	R	5.46

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168	<i>Syzygium claviflorum</i>	22.81	0.27	B	9.21	0.10	4.38	0.40	0.78	R	4.74
169	<i>Syzygium cumunii</i>	10.53	0.75	A	25.00	0.28	1.83	0.27	1.30	R	15.42
170	<i>Syzygium formosum</i>	14.04	0.20	A	6.58	0.07	1.75	0.25	0.52	R	11.52
171	<i>Eugenia cumini</i>	5.26	0.21	A	7.02	0.08	1.00	0.18	0.47	R	2.59
172	<i>Bulbophyllum bailegi</i>	1.75	0.42	A	3052.63	0.43	1.00	0.31	1.17	C ₁	-
173	<i>Phaus flavus</i>	7.02	0.17	A	947.37	0.13	4.55	0.24	0.54	C ₁	-
174	<i>Bischofia javanica</i>	7.37	0.51	A	17.11	0.19	3.62	0.56	1.27	R ₁	12.28
175	<i>Piper attenuatum</i>	7.02	0.97	A	259.65	0.37	2.75	0.30	1.64	R ₁	-
176	<i>Piper peepuloides</i>	12.28	1.22	A	326.32	0.46	4.36	0.37	2.05	R ₁	-
177	<i>Piper sylaticum</i>	17.54	0.44	A	119.30	0.17	6.80	0.30	0.92	R ₁	-
178	<i>Lindernia crustacean</i>	28.95	0.93	B	8771.93	1.25	4.00	0.41	2.58	R	-
179	<i>Acroceras zizanioides</i>	7.72	1.02	A	6175.44	0.88	7.18	0.26	2.16	C ₁	-
180	<i>Angiopteris evecta</i>	7.02	0.54	A	11824.56	1.68	6.50	0.95	3.16	C ₁	-
181	<i>Axonopus compressus</i>	11.23	1.32	A	11192.98	1.59	5.50	0.36	3.27	R ₁	-
182	<i>Brachiaria milliformis</i>	8.77	1.36	A	6280.70	0.89	12.76	0.20	2.45	C ₁	-
183	<i>Capillipedium assimile</i>	11.23	0.48	A	2771.93	0.39	5.59	0.25	1.12	R ₁	-
184	<i>Saccharam spontaneum</i>	8.07	0.14	A	912.28	0.13	3.43	0.27	0.55	R ₁	-

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185	<i>Degitaria ciliaris</i>	3.86	0.90	A	3789.47	0.54	2.36	0.18	1.62	C ₁	-
186	<i>Neomicrocalamus andropogonifolius</i>	5.05	0.13	A	4.39	0.05	3.60	0.58	0.76	C ₁	-
187	<i>Pennisetum purpureum</i>	17.54	0.52	A	2877.19	0.41	3.90	0.24	1.17	R	-
188	<i>Colysis decurrens</i>	5.26	0.88	A	3649.12	0.52	4.47	0.18	1.57	C ₁	-
189	<i>Polygata glomerata</i>	9.47	0.97	A	6666.67	0.95	7.04	0.30	2.21	C ₁	-
190	<i>Pteris aspericaulis</i>	6.67	12.25	A	13403.51	15.59	5.47	10.11	37.94	C ₁	-
191	<i>Pteris biaurita</i>	15.09	1.14	A	13403.51	1.90	8.88	0.51	3.55	C ₁	-
192	<i>Pteris himalayensis</i>	12.28	0.97	A	10736.84	1.52	8.74	0.48	2.97	C ₁	-
193	<i>Pteris linearis</i>	10.18	0.90	A	8701.75	1.24	8.55	0.41	2.55	C ₁	-
194	<i>Pteris semipinnata</i>	10.53	1.19	A	5438.60	0.77	5.17	0.20	2.16	R ₁	-
195	<i>Naravelia zeylanica</i>	9.12	0.20	A	52.63	0.07	8.58	0.25	0.52	C ₁	-
196	<i>Gouania leptostachya</i>	30.70	1.56	B	210.53	1.25	5.89	0.90	3.71	R	-
197	<i>Ziziphus rugosa</i>	15.79	0.30	A	10.09	0.11	3.28	0.19	0.60	R	0.89
198	<i>Ziziphus mauritiana</i>	10.53	0.18	A	6.14	0.07	1.83	0.10	0.35	R	1.28
199	<i>Coffea bengalensis</i>	3.51	1.69	A	452.63	0.64	2.50	0.22	2.55	C ₁	-
200	<i>Borreria ocimoides</i>	4.56	1.43	A	5719.30	0.81	12.54	0.17	2.41	C ₁	-

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201	<i>Haldina cordifolia</i>	7.02	0.60	A	20.18	0.23	2.25	0.38	1.21	R ₁	12.23
202	<i>Hedyotis scandens</i>	10.53	1.58	A	424.56	0.60	3.00	0.17	2.36	R ₁	-
203	<i>Hyptianthera stricta</i>	17.54	0.29	A	9.65	0.11	1.60	0.23	0.63	R	7.38
204	<i>Ixora javanica</i>	8.77	0.44	A	14.91	0.17	2.00	0.30	0.92	R	6.31
205	<i>Ixora nigricans</i>	15.79	0.30	A	10.09	0.11	2.44	0.29	0.71	R	5.68
206	<i>Meyna spinosa</i>	24.56	0.50	B	16.67	0.19	2.64	0.23	0.92	R	-
207	<i>Morinda angustifolia</i>	28.07	0.44	B	14.91	0.17	3.25	0.21	0.82	R	5.70
208	<i>Mussaenda roxburghii</i>	24.56	0.77	B	25.88	0.29	3.29	0.62	1.68	R	16.89
209	<i>Neolamarikia kadamba</i>	17.54	0.29	A	9.65	0.11	1.60	0.23	0.63	R	7.38
210	<i>Oldenlandia stipulacea L.</i>	6.32	0.10	A	666.67	0.09	3.56	0.27	0.47	C ₁	-
211	<i>Psilanthus bengalensis</i>	9.65	0.63	A	168.42	0.24	2.55	0.24	1.11	R ₁	-
212	<i>Psychotria calocarpa</i>	19.30	0.61	A	20.61	0.23	2.00	0.19	1.04	R	1.39
213	<i>Psychotria erratica</i>	7.02	0.64	A	171.93	0.24	5.13	0.47	1.36	C ₁	-
214	<i>Uncaria scandens</i>	9.65	0.81	A	217.54	0.31	2.55	0.32	1.44	R ₁	-
215	<i>Uncaria rusiacum</i>	10.53	0.18	A	49.12	0.07	3.17	0.23	0.48	R ₁	-
216	<i>Glycosmis pentaphylla</i>	4.38	0.22	A	59.65	0.08	4.01	0.16	0.47	C ₁	-
217	<i>Zanthoxylum rhetsa</i>	22.81	0.71	B	23.68	0.27	2.62	0.31	1.29	R	5.11

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218	<i>Aegle marmelos</i>	5.26	0.07	A	2.19	0.02	4.00	0.29	0.38	C ₁	6.10
219	<i>Carallia brachiata</i>	15.79	0.84	A	224.56	0.32	2.56	0.22	1.37	R	-
220	<i>Meliosma pinnata</i>	33.33	0.61	B	20.61	0.23	2.00	0.27	1.12	R	3.63
221	<i>Aesculus assamica</i>	33.33	0.55	B	18.42	0.21	1.79	0.37	1.13	R	5.46
222	<i>Mimusops elengi</i>	5.96	0.64	A	21.49	0.24	5.12	0.28	1.17	C ₁	4.67
223	<i>Lindernia ciliata</i>	3.51	1.87	A	7859.65	1.12	1.00	0.18	3.17	R ₁	-
224	<i>Ailanthus integrifolia</i>	19.30	0.25	A	8.33	0.09	2.64	0.27	0.62	R	8.87
225	<i>Ailanthus grandis</i>	8.77	0.22	A	7.46	0.08	5.90	0.22	0.52	C ₁	10.00
226	<i>Smilax aspericaulis</i>	8.77	0.29	A	77.19	0.11	3.60	0.32	0.71	R ₁	-
227	<i>Smilax ovalifolia</i>	17.54	0.16	A	42.11	0.06	3.85	0.35	0.56	R	-
228	<i>Smilax perfoliata</i>	15.79	0.27	A	73.68	0.10	5.06	0.22	0.60	R ₁	-
229	<i>Ardisia solanacea</i>	3.16	0.52	A	17.54	0.20	3.00	0.17	0.89	C ₁	2.91
230	<i>Solanum khasianum</i>	4.75	0.73	A	7929.82	1.13	3.80	0.47	2.32	C ₁	-
231	<i>Solanum xanthocarpum</i>	49.12	1.03	C	8280.70	1.18	3.36	0.34	2.55	R	-
232	<i>Pterygota alata</i>	35.09	4.68	B	157.02	1.78	3.30	1.53	8.00	R	5.93
233	<i>Sterculia villosa</i>	6.32	1.16	A	39.04	0.44	4.64	0.93	2.54	C ₁	S
234	<i>Tetracera sarmentosa</i>	26.32	0.65	B	21.93	0.25	2.67	0.38	1.29	R	12.15

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235	<i>Eurya cerasifolia</i>	35.09	0.14	B	4.82	0.05	3.95	0.21	0.41	R	2.63
236	<i>Schima wallichii</i>	22.81	0.85	B	28.51	0.32	3.23	0.83	2.01	R	11.89
237	<i>Eurya japonica</i>	35.09	0.04	B	1.32	0.01	4.00	0.12	0.17	R	2.63
238	<i>Cyclosorus holtumii</i>	7.72	1.22	A	4701.75	0.67	5.27	0.17	2.05	C ₁	-
239	<i>Cyclosorus mantoniae</i>	8.77	0.90	A	4210.53	0.60	5.44	0.20	1.70	C ₁	-
240	<i>Pronephrium nudatum</i>	6.56	0.95	A	6350.88	0.90	5.62	0.29	2.14	C ₁	-
241	<i>Trema orientalis</i>	14.04	0.08	A	2.63	0.03	2.38	0.69	0.80	R	7.38
242	<i>Dendrocnida sinuata</i>	7.89	1.39	A	371.93	0.53	3.56	0.17	2.08	R ₁	-
243	<i>Callicarpa longifolia</i>	17.54	0.81	A	217.54	0.31	5.65	0.14	1.26	R ₁	-
244	<i>Callicarpa tongifolia</i>	14.04	0.77	A	207.02	0.29	2.56	0.17	1.24	R	-
245	<i>Clerodendrum chinense</i>	14.91	0.90	A	242.11	0.34	3.00	0.27	1.52	R	-
246	<i>Clerodendrum viscosum</i>	8.77	0.99	A	266.67	0.38	7.10	0.16	1.54	C ₁	-
247	<i>Gmelina arborea</i>	15.79	1.07	A	35.96	0.41	1.89	1.89	3.37	R	15.57
248	<i>Tectona grandis</i>	47.37	5.15	C	172.81	1.96	1.48	1.62	8.74	R	24.39
249	<i>Vitex quinata</i>	21.05	0.07	B	2.19	0.02	17.83	0.29	0.38	C ₁	4.67
250	<i>Lantana camara</i>	11.40	1.28	A	343.86	0.49	5.08	0.26	2.03	R ₁	-
251	<i>Ampelocissus sp.</i>	7.02	0.60	A	161.40	0.23	2.38	0.25	1.08	R ₁	-

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252	<i>Cayratia trifolia</i>	2.63	0.26	A	70.18	0.10	1.67	0.33	0.69	R ₁	-
253	<i>Cissus repens</i>	3.16	1.27	A	6666.67	0.95	2.78	0.23	2.44	C ₁	-
254	<i>Tetrastigma campylocarpum</i>	15.79	1.14	A	252.63	0.43	4.89	0.67	2.24	R ₁	-
255	<i>Tetrastigma serrulatum</i>	11.40	0.94	A	305.26	0.36	3.77	0.24	1.54	R ₁	-
256	<i>Alpinia nigra</i>	6.67	0.48	A	1824.56	0.26	3.74	0.16	0.91	C ₁	-
257	<i>Globba macroclada</i>	7.37	0.25	A	2491.23	0.35	6.00	0.43	1.03	C ₁	-
258	<i>Globba racemosa</i>	10.18	0.71	A	4421.05	0.63	5.45	0.27	1.60	C ₁	-
259	<i>Hedychium coccineum</i>	5.61	0.95	A	5543.86	0.79	4.81	0.25	1.99	C ₁	-
260	Un-1	14.04	0.13	A	4.39	0.05	1.63	0.16	0.35	R	4.69
261	Un -2	7.02	0.17	A	5.70	0.06	1.50	0.19	0.42	R	5.16
262	Un -3	3.51	0.08	A	2.63	0.03	1.50	0.17	0.28	R ₁	2.23
263	Un -4	8.77	0.04	A	1.32	0.01	1.40	0.17	0.23	R	7.96
264	Un -5	10.53	0.09	A	3.07	0.03	1.67	0.16	0.29	R	5.23
265	Un -6	10.53	0.13	A	4.39	0.05	1.83	0.19	0.37	R	10.57
266	Un -7	5.26	0.14	A	4.82	0.05	2.00	0.21	0.41	R ₁	11.37
267	Un -8	8.77	0.08	A	2.63	0.03	2.00	0.23	0.34	R	3.79
268	Un -9	8.77	0.13	A	4.39	0.05	2.00	0.23	0.41	R	5.01

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269	Un -10	10.53	0.13	A	4.39	0.05	1.33	0.23	0.41	R	10.57
270	Un -11	10.53	0.10	A	3.51	0.04	1.67	0.15	0.30	R	8.05
271	Un -12	14.04	0.13	A	4.39	0.05	1.50	0.19	0.37	R	5.73
272	Un -13	7.02	0.16	A	5.26	0.06	1.50	0.17	0.39	R	7.38
273	Un -14	8.77	0.08	A	2.63	0.03	2.60	0.17	0.28	R ₁	7.96
274	Un -15	14.04	0.17	A	5.70	0.06	1.38	0.21	0.45	R	7.38
275	Un -16	14.04	0.14	A	4.82	0.05	1.25	0.16	0.36	R	8.21
276	Un -17	3.51	0.13	A	4.39	0.05	2.00	0.14	0.32	C ₁	7.65
277	Un -18	8.77	0.05	A	1.75	0.02	1.60	0.15	0.23	R	9.31
278	Un -19	12.28	0.10	A	3.51	0.04	1.57	0.18	0.33	R	9.03
279	Un -20	12.28	0.14	A	4.82	0.05	1.71	0.18	0.38	R	8.55
280	Un -21	5.26	0.16	A	5.26	0.06	2.00	0.20	0.41	C ₁	8.69
281	Un -22	12.28	0.08	A	2.63	0.03	2.14	0.23	0.34	R	8.36
282	Un -23	8.77	0.20	A	6.58	0.07	1.40	0.19	0.46	R	7.65

1. Generic name (**Un**- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (**A**: 0-20, **B**: 20-40, **C**: 40-60 %); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (**R**- regular, **R₁**- random **C₁**- contagious); 11. Basal area (m²ha⁻¹), **S**- seedling

283	Un -24	8.77	0.22	A	7.46	0.08	5.60	0.33	0.63	C ₁	6.17
284	Un -25	5.26	0.37	A	12.28	0.14	1.33	0.40	0.91	R ₁	8.80
285	Un -26	8.77	0.05	A	1.75	0.02	1.40	0.15	0.23	R	11.23
286	Un -27	8.77	0.17	A	5.70	0.06	1.80	0.50	0.73	R	8.05
287	Un -28	5.26	0.09	A	3.07	0.03	2.67	0.16	0.29	C ₁	7.41
288	Un -29	0.19	0.12	A	3.95	0.04	0.60	0.21	0.37	C ₁	8.15
289	Un -30	6.14	1.18	A	315.79	0.45	2.00	0.27	1.89	R ₁	-
290	Un -31	7.02	0.86	A	231.58	0.33	2.75	0.28	1.47	R ₁	-
291	Un -32	2.75	1.01	A	270.18	0.38	1.25	0.34	1.73	R ₁	-
292	Un -33	9.65	0.72	A	192.98	0.27	1.91	0.30	1.30	R	-
293	Un -34	4.39	0.44	A	119.30	0.17	4.00	0.22	0.83	C ₁	-
294	Un -35	5.26	1.28	A	343.86	0.49	2.67	0.30	2.07	C ₁	-
295	Un -36	7.02	0.84	A	224.56	0.32	3.75	0.22	1.38	C ₁	-
296	Un -37	4.51	0.21	A	56.14	0.08	3.75	0.31	0.60	C ₁	-
297	Un -38	3.63	0.39	A	105.26	0.15	3.33	0.38	0.93	C ₁	-
298	Un -39	4.39	0.20	A	52.63	0.07	2.60	0.25	0.52	C ₁	-

1. Generic name (**Un**- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (**A**: 0-20, **B**: 20-40, **C**: 40-60 %); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (**R**- regular, **R₁**- random **C₁**- contagious); 11. Basal area (m²ha⁻¹), **S**- seedling

299	Un -40	6.14	0.13	A	35.09	0.05	3.71	0.29	0.47	C ₁	-
300	Un -41	7.89	0.21	A	56.14	0.08	1.89	0.46	0.75	R	-
301	Un -42	3.63	0.17	A	45.61	0.06	3.07	0.30	0.53	C ₁	-
302	Un -43	2.63	0.34	A	91.23	0.13	2.17	0.25	0.72	C ₁	-
303	Un -44	3.51	0.51	A	3263.16	0.46	2.90	0.27	1.25	C ₁	-
304	Un -45	3.81	0.38	A	3403.51	0.48	2.88	0.39	1.25	C ₁	-
305	Un -46	3.51	1.41	A	7087.72	1.01	2.86	0.22	2.63	C ₁	-
306	Un -47	2.46	0.90	A	4315.79	0.61	1.29	0.21	1.72	R ₁	-
307	Un -48	3.86	0.27	A	2666.67	0.38	2.59	0.42	1.07	C ₁	-
308	Un -49	7.02	0.24	A	2245.61	0.32	4.55	0.41	0.96	C ₁	-
309	Un -50	3.16	0.26	A	3192.98	0.45	3.00	0.52	1.24	C ₁	-
310	Un -51	3.51	0.33	A	2070.18	0.29	2.90	0.27	0.89	C ₁	-
311.	Un-52	0.19	0.27	A	3649.12	0.52	0.30	0.57	1.36	R ₁	-

1. Generic name (**Un**- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (**A**: 0-20, **B**: 20-40, **C**: 40-60 %); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (**R**- regular, **R₁**- random **C₁**- contagious); 11. Basal area (m²ha⁻¹), **S**- seedling

deciduous forest of Hastinapur which was again much higher than the frequency per cent of shrubs in the present study. This can be attributed due to disturbance in the forest as reported by the workers which had mainly affected the tree layer giving more chance of shrubs species to get introduced coupled with good growth. Moreover Rikhari *et al.* (1997) reported that as tree density decreases the infiltration of light increases that affect the lower strata. The higher shrub density on highly disturbed site may attribute to the availability of greater light on the ground which also explains the lower frequency per cent of shrubs, herbs, climbers, lianas and ferns. Contrary to these reports, due to undisturbed tree layer in the present study owing to its protection from law as Reserved Forest, lower frequency per cent was found for the species occupying under storey strata. In the present study the frequency values indicates that it ranges from low to medium as compared to the above reports. This may be because of high species richness/diversity of the forest leading to nearly equally fairer chance of all the species to occur with less deviation from each other due to favorable/optimum climatic and edaphic conditions for all the species or not a single species highly dominating over the other.

Similarly the chance of occurrence of *Pteris aspericaulis* relative to all other species in the forest was highest with 12.25 % while *Albizia procera*, *Calamus erectus*, *C. guruba* and *Streblus asper* each recorded lowest with 0.01 %. The relative chance of occurrence of trees, shrubs, herbs, climbers, lianas and ferns ranged between 0.01-5.15 % (*Calamus erectus*, *C. guruba* and *Streblus asper* - *Tectona grandis*), 0.20-2.00 % (*Mlastoma malabathricum* - *E. odoratum*), 0.10-1.43 % (*Oldenlandia stipulacea* – *Borreria ocimoides*), 0.13-2.69 % (an unidentified climber – *Ichnocarpus volubilis*), 0.21-1.14 % (an unidentified liana - *Tetrastigma campylocarpum*) and 0.42-12.25 % (*Diplazium esculentum* - *P. aspericaulis*). The relative frequency of tree, shrub and herbaceous layer from Central Himalayan forest reported by Negi and Nautiyal (2005) was higher than that was estimated in the present study which may be attributed to lower species richness in the temperate forests than the tropical or sub-tropical forests as discussed earlier for frequency. Comparative values of relative frequency with present study in the range between 0.48-13.46 were however reported by Newaz (2006) for secondary forests of Chittagong, Bangladesh.

The forest was grouped into three frequency classes as A, B and C following Raunkiaer's law of frequency (Raunkiaer, 1934) in which 77.49, 20.90 and 1.61 % respectively of species were distributed. The law of frequency states that the number of species in a community in the five per cent classes is A, B, C, D and E distributed as 0-20, 20-40, 40-60, 60-80 and 80-100 %, respectively. This clearly indicate that the law holds good for Chilapatta Reserve Forest also because the distribution of frequency classes was exactly similar to what was described in the law as $A > B > C$. But unlikely the law where five classes was described; this forest had only three classes which may be due to its higher heterogeneous nature and also due to the deviation from the normal frequency distribution as described by Raunkiaer (1934). Raunkiaer's normal frequency distribution was 53, 14, 9, 8 and 18 % of species in frequency classes A, B, C, D and E where as in Chilapatta Reserve Forest it is 77.49, 20.90 and 1.61 %, respectively. This means that the species with poor dispersion of frequencies were higher in number than the number of species with higher frequency values. Trees represented all the three classes (99 species in A, 54 in B and seven in C). No species of shrubs and climbers represented the frequency class C. Shrubs had 32 and three species while climbers had 35 and nine species in class A and B, respectively. Herbs, lianas and ferns were only represented by frequency class A. The trend of species falling in the frequency classes reflects the higher heterogeneous nature of herbs, lianas and ferns as compared to shrubs, climbers and trees. A plant species is considered homogenously distributed if the number of individuals are same in all parts of an area. A decreasing number of species in successive 20 % frequency class intervals but an increase in the 80-100 % class intervals has been widely interpreted as being a fundamental community characteristics indicating homogeneity (McIntosh, 1975) but contrary to this in the present study the forest exhibited reverse trend showing heterogeneity. The tree species falling in class A were like *Bombax ceiba*, *Terminalia tomentosa*, *Dillenia indica*, *Albizia lebbeck* and *A. procera*; in class B were like *Oroxylum indicum*, *Bauhinia vahlii*, *Shorea robusta* and *Mallotus philippensis* and *Persea glaucescens*, *Machilus villosa*, *Tectona grandis*, *Pterygota alata* and *Lagerstroemia parviflora* represented class C. Shrub species like *Tabernaemontana divaricata*, *Porana paniculata* and *Dracaena angustifolia* represented class A while in class B the shrubs were like *Ricinus communis*, *Eupatorium odoratum*

and *Meyna spinosa*. Class A in climbers was represented by species like *Ichnocarpus volubilis*, *Vallaris solanacea* and *Pothos scandens* while species like *I. frutescens*, *Mikania micrantha* and *Dioscorea hispida* were climbers those represented class B. Analysis of Raunkiaer's frequency classes revealed that most of the species had low frequency as would be expected in typical species-abundance distributions in tropical forests. Similar observations were also reported by Varghese and Menon (1999) and Kumar *et al.* (2006).

Density or numerical strength of species per unit area ranged from 0.44 to 13,403.51 individuals ha⁻¹. This means *Albizia procera*, *Calamus erectus*, *C. guruba* and *Streblus asper* each were sparse while *Pteris aspericaulis* was densest. The density of trees, shrubs, herbs, climbers, lianas and ferns respectively, ranged between 0.44-172.81 individuals ha⁻¹ (*Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* - *Tectona grandis*), 59-424.56 individuals ha⁻¹ (*Glycosmis pentaphylla*- *Hedyotis scandens*), 2.02-11192.98 individuals ha⁻¹, (*Mimosa pudica* - *Axonopus compressus*), 1.21-396.49 individuals ha⁻¹ (*Gomphostemma ovate* - *Drynaria propinqua*), 56.14-305.26 individuals ha⁻¹ (an unidentified liana - *Tetrastigma campylocarpum*) and 92.96-13,403.51 individuals ha⁻¹ (*Diplazius esculentum* - *Pteris aspericaulis*). The tree, shrub, liana, climber, fern and herb density in the forest was 2,615; 8,512; 775; 7,628; 1, 06,667 and 2, 18,982 plants ha⁻¹, respectively. The tree density recorded in the present study is much higher than the estimates from other studies of tropical forest within and outside India (280-1720 trees ha⁻¹; Table 7) which may be because of high tree species richness. Density of trees in tropical forests ranges from a low value of 245 individuals/ha (Ashton, 1964; Richards, 1996), to intermediate values of 420-617 in Brazilian Amazon (Campbell *et al.*, 1992) and to a high value of 639-713 or even higher in Central Amazonian upland forest (Ferreira and Prance, 1998; Campbell *et al.*, 1992). Plant density varies with forest community type, forest age class, tree species and size class, site history, site condition and other factors (Kumar *et al.*, 2006). Evaluation of density-dependent status of a

Table 7. Vegetation characteristic of forest communities in the tropics of India and other countries

Forest type	Location	Sample size (ha)	Tree girth (cm)	Density (no./ha)	Basal area (m²/ha)	Source
Tropical wet evergreen to moist deciduous forest	Chilapatta (W. B.)	0.04	50	2515	522.91	Present study
Evergreen forest	Silent Valley	-	≥31.5	620-709	29-103	Singh <i>et al.</i> , 1984 _b
Tropical forest	Western Ghats	0.2	>20	320-1260	18-107	Parthasarthy, 1986
Tropical wet evergreen forest	Western Ghats	1.0	>30	574-915	55-94	Parthasarthy <i>et al.</i> , 1992
Evergreen forest	Karnataka	0.44	-	466-1386	33-48	Rai and Procter, 1986
Dry tropical forest	Vindhyan region	-	>30	294	559	Jha and Singh, 1990
Dry evergreen forest	Coromandel coast	0.3	≥20	280	11	Visalakshi, 1995
		0.2		1130	36	
Tropical wet evergreen forest	Kalakad Western Ghats	0.50	>30	315-418	54-84	Ganesh <i>et al.</i> , 1996
Tropical wet evergreen forest	Kodayar Western Ghats	0.50	>30	352-1173	28-81	Sundarapandian and Swamy, 2000
South Garo Hills	Meghalaya	1.0	>30	417-1111	12-162	Kumar <i>et al.</i> 2006
Semi Evergreen, Evergreen forest & Moist	Andaman	4- 4.52	-	946-1137	28.60-44.28	Padalia <i>et al.</i> , 2004

deciduous

Evergreen forest	Kolli Hills	8		3825	43.6	Chittibabu and Parthasarathy, 2000
Deciduous forest	Mudumalai	50	-	25929	-	Sukumar <i>et al.</i> , 1992
Semi evergreen	Eastern Ghats	4	-	367-667	25.8	Kadavul and Parthasarathy, 1999
Tropical rain forest	Barro Colorado Island, Panama	5	60.0	171	-	Thorington <i>et al.</i> , 1982
-do-	-do-	50	>62.8	152	-	Hubbell and Foster, 1983
-do-	Amazonia	3	31.4	1420	28-68	Campbell <i>et al.</i> , 1986
Equatorial insular forest	Eastern Caroline Island, Panama	50	>31.4	98-114	17	Itow, 1986
Tropical rain forest	Jengka reserve, Malaysia	11	91	104	23	Ho <i>et al.</i> , 1987
-do-	Gunung Silam, Malaysia	0.04	31.4	513-1596	23-46	Proctor <i>et al.</i> , 1988
-do-	Singapore	0.4	>6.3	604	-	Swan Jr., 1988
-do-	Valcan Barva, Costa Rica	6	>31.4	391-617	-	Heaney and Proctor, 1990
Slope forest & Alluvium forest	New Caledonia	2.6-2.8	>31.4	1183-1533	47-49	Jaffre and Veillon 1990

Equatorial forest	Kongo Island, Zaire	-	-	440-553	10-45	Mosango and Contribution, 1991
Tropical rain forest	Amazonia	3	>31.4	1720	78	Campbell <i>et al.</i> , 1992
Paleotropical rain forest	Brunei	40	-	30000	-	Ashton, 1964
Paleotropical rain forest	Malaysia	4	-	3374	-	Campbell <i>et al.</i> , 1986
Semi deciduous forest	North western Argentina	5	-	247-337	21-31	Piers <i>et al.</i> , 1953

species in a study site is important for conservation and management of forests. Overall the density of the forest is high because of lesser disturbance owing to its protection from the law as a Reserve Forest or Protected Forest for wildlife.

Relative density ranged from 0.005 to 15.59 % i.e. *Pteris aspericaulis* had the highest representation while *Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* each had the lowest relative to all other species. Relative density of trees ranged between 0.005-1.96 %. Similarly for shrubs it was between 0.07-1.25 %, 0.09-2.57 % for herbs, 0.05-1.46 % for climbers, 0.08-0.43 % for lianas and 0.25-15.59 % for ferns. Except for *Gomphostemma ovate* which recorded highest relative density in climbers, the species falling in highest and lowest relative density in trees, shrubs, herbs, lianas, ferns and lowest relative density in climbers are same as recorded for density. Newaz (2006) also reported relative density from secondary forests of Chittagong, Bangladesh in the range 0.34 to 15.52 which is comparative to the present study.

Species abundance is numerical strength of species in sampled area and in the present study it ranged from 0.80 to 17.83 i.e. *Ardisia thyrsoflorus* had least while *Tectona grandis* had highest number of individuals in the forest. Among trees, *Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* each had minimum individuals each with value 1.00 while *Lagesstromia parviflora* had maximum individuals with 10.74. The

minimum individual among shrubs was 0.60 for an unidentified species and maximum of 8.18 for *Leea guineensis*. The minimum and maximum number of individuals for herbs was recorded with *Cyprus rotandus* (1.43) and *Axonopus compressus* (12.76), respectively; for climbers it was *Hodgsonia macrocarpa* (1.60) and *Drynaria propinqua* (8.84), respectively; for lianas it was *Ampelocissus sp.* (2.38) and *Tetrastigma campylocarpum* (4.89), respectively while with ferns it was an unidentified species (0.60) and *P. aspericaulis* (8.88), respectively. The abundance for shrubs reported by Khurana (2009) in disturbed dry deciduous tropical forest of Hastinapur and Central Himalayan forest (Negi and Nautiyal, 2005) was comparatively lower than what was estimated in the present study because of lesser disturbance owing to its protection from law as Reserve Forest and also due to higher species richness and higher number of individuals of each species than the temperate forests.

Abundance, however did not give a total picture of the numerical strength of a species because it considers only the quadrats of occurrence of a species. Therefore the abundance of a species relative to total abundance of all the species in all sampled quadrats is indicative of actual numerical strength of a species and in the present study, it was found that *Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* each had the lowest with 0.12 % while *P. aspericaulis* had highest numerical strength of 10.11 % relative to all other species found in the forest. Relatively in numerical strength the trees ranged from 0.12-1.89 % (*Calamus erectus*, *C. guruba* and *Streblus asper* - *Gmelina arborea*), shrubs ranged from 0.18-0.90 % (an unidentified shrub - *Gouania leptostachya*), herbs ranged from 0.16-1.73 % (*Phlogacanthus thysiformis* - *Mimosa pudica*), climbers ranged from 0.17-1.45 % (*Ichnocarpus frutescens* - *Gomphostemma ovate*), lianas ranged from 0.25-0.67 % (*Ampelocissus sp.* - *T. campylocarpum*) and ferns ranged from 0.10-10.11 % (*Lygodium circinatum* - *P. aspericaulis*). Relative abundance reported by Newaz (2006) for secondary forests of Chittagong does not widely vary between the species (2.44-5.29) where as in present study it varied comparatively wider which may be attributed to the wide range of occurrence of individuals between the species.

Moreover *Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* each recorded lowest IVI of 0.13 while *P. aspericaulis* highest with 37.94. This clearly indicates the ecological importance of *P. aspericaulis* in Chilapatta Reserve Forest as the species was relatively most abundant and had the maximum occurrence in the forest. The tree IVI ranged between 0.13-8.74; meaning lowest for *Albizia procera*, *C. erectus*, *C. guruba* and *Streblus asper* and highest for *Tectona grandis*. Similarly shrub IVI ranged between 0.46-3.71 (*Mlastoma malabathricum* - *Gouania leptostachya*), herb between 0.47-5.27 (*Oldenlandia stipulacea* - *Mimosa pudica*), climber between 0.48-4.04 (an unidentified climber - *Gomphostemma ovate*), liana between 0.72-2.44 (an identified liana to *Tetrastigma campylocarpum*) and fern it ranged between 0.89-37.94 (an unidentified fern to *Pteris aspericaulis*). The tree layer in the forest was dominated by *Tectona grandis* with highest IVI of 8.74. The second most dominant species was *Pterygota alata* (IVI=8.00). Other associate trees species were *Lagerstroemia parviflora* (IVI=7.28), *Actinodaphne obovata* (IVI= 6.09), *A. sikkimensis* (IVI=5.47), *Shorea robusta* (IVI= 3.46) and *Gmelina arborea* (IVI=3.37) which were far lower than those reported from Andaman Islands (Padalia *et al.*, 2004) i.e. the dominant species in the Islands on the basis of IVI were *Myristica andamanica* (16.42), *Dipterocarpus turbinatus* (13.54), *Knema glaucasens* (11.00), *D. gracilis* (9.81) and *Artocarpus chama* (9.78). Similarly higher IVI values ranging between 10.03 and 366.48 were also reported by Khurana (2009). Comparative IVI values to the present study ranging from 3.27 to 32.90 and 0.29 to 14.32 was reported by Newaz (2006) and Onyekwelu *et al.* (2008), respectively. The large deviation of IVI values between this study and others was because of different estimation methods used, for instance in this study relative frequency, relative density and relative abundance was used while others workers used either relative dominance or relative basal area instead of relative abundance and even some used only relative density and relative dominance. Whatever the method of estimation, calculation of IVI help in understanding the ecological significance of the species irrespective of vegetation types and more the IVI value the more ecological significance of the species is in that particular ecosystem.

The distribution pattern of species in the forest was largely regular i.e. 49.20 % of the species were regularly distributed. Among the remaining species, 28.29 % were

contagious and 22.55 % were randomly distributed. 129 tree species were regularly distributed (e.g., *Bombax ceiba*, *Terminalia tomentosa*, *Shorea robusta*, *Albizia lebbeck*, *Tectona grandis* and *L. parviflora*), 23 were randomly distributed (e.g., *Terminalia Myriocarpa*, *Dillenia indica*, *Albizia procera* and *Streblus asper*) and eight were contagious (e.g., *Pinangra gracilis*, *Eugenia cumini* and *Haldina cordifolia*). 15, 8 and 12 shrub species were regularly (e.g., *Miliusa roxburghiana*, *Eupatorium odoratum*, *Porana paniculata* and *Ricinus communis*); randomly (e.g., *Tabernaemontana divaricata*, *Leea compactiflora*, *Hedyotis scandens* and all the species of *Callicarpa*) and contagiously (e.g., *Clerodendrum viscosum*, *Coffea bengalensis*, *Leea guineensis* and *Carallia brachiata*) distributed, respectively. Only one herb i.e. *Scleria terrestris* was distributed regularly while eight were random (e.g., *P. thysiformis*, *Ophiopogon wallichianus*, *Maesa indica* and *Capillipedium assimile*) and 40 (e.g., *Rungia pectinata*, *Amorphophallus bulbifer*, *Colocasia esculenta* and all the species of *Rhaphidophora*) were contagious. No species of fern and liana were found regularly distributed. Four ferns (*Lygodium microphyllum*, *L. circinatum*, *Pteris linearis* and *Angiopteris evecta*) and three lianas (*Ampelocissus* sp., *Tetrastigma campylocarpum* and *T. serrulatum*) were random while 14 ferns (e.g., *Lygodium japonicum*, *L. flexuosum*, *Pteris himalayensis* and *P. semipinnata*) and one unidentified liana were contagious. The climbers were mostly contagious with 20 species (e.g., *Desmodium gangeticum*, *Pericampylus glaucus*, *Psychotria erratica* and *Smilax ovalifolia*) while remaining random (e.g., *Ficus hederacea*, *Piper attenuatum*, *P. peepuloides* and *Urena lobata*) and regular (e.g., *Desmodium heterocarpon*, *Piper sylaticum*, *Naravelia zeylanica* and *Smilax perfoliata*) constitute 12 species each. Odum (1971) had stressed that contiguous distribution is the commonest pattern in nature; random distribution is found in very uniform environment and regular distribution occurs when severe competition exists between individuals. Singh and Yadava (1974) and Dash *et al.* (2009) also reported contiguous distribution in natural vegetation. Contrary to these reports, in the present study almost half of the species were found regularly distributed which can be attributed to high species richness as well as higher density of species in the forest leading to severe inter and intra specific competition. Regular distribution however was reported from sub-montane forests of

evergreen, semi-evergreen and moist-deciduous forests of Andaman Islands (Padalia *et al.*, 2004) and dry deciduous forests of Hastinapur in Uttar Pradesh (Khurana, 2009).

The total ground area occupied by a tree or its basal area in the forest ranged from 0.25-41.60 m² ha⁻¹, the highest being *Ficus religiosa* and lowest *Curculigo orchiodes*. Basal area of some important timber species found in the forest was recorded as 27.56, 24.39, 17.80, 15.57 and 15.46 for *Shorea robusta*, *Tectona grandis*, *Michelia champa*, *Gmelina arborea* and *Lagerstroemia parviflora*, respectively. The basal area for *Calamus erectus*, *C. guruba*, *Machilus Villosa*, *Sapium baccatum* and *Sterculia vilosa* could not be worked out as only seedlings of these species were found from the sampled area. The basal area of 522.91 m² ha⁻¹ estimated in this study was far greater than the highest value of 162 m² ha⁻¹ reported for any of the tropical forests of the world (Table 7). High species richness coupled with high tree growth rates due to high annual precipitation rate and optimum climatic conditions of Terai zone might have contributed to high basal area as was also reported by Kumar *et al.* (2006). Moreover, because of lesser disturbance owing to its protection from the law as a Reserve Forest or Protected Forest for wildlife the basal area of the trees increased without being removed.

Ficus religiosa is a tree which is intricately associated with religious culture in India and thus generally found within the limits of human habitation specifically near the sites having religious and sacred sentiments of the people. Three trees of the species were found deep inside the forest where ancient ruins of fortress of the Raja Nala believed to be of the Mahabharata times by the local inhabitants was located. These *Ficus religiosa* trees were actually not wild but may had been planted when the site was inhabited by humans and is there standing till now experiencing the change of site gradually to wilderness and so may be believed that the age of these trees is much more than the age of the forest as was also evidenced from the largest girth and tallest height the trees had attained. The site is locally known as “*Rajmahal*”. Whatever the belief is, the presence of ruins in the forest indicates human habitation once upon a time and may be due to reasons unknown (even by the local people) the habitation was abandoned and gradually replaced by vegetation which is the deepest, densest and most diverse part of the whole Chilapatta Reserve Forest. The locals strongly regard that the area is

religiously sacred as it is believed to be haunted by the spirit of the Raja Nala for which this part of the forest is revered and thus no one dares to venture this part of the forest freely either to collect fire wood/NTFP or to cut any vegetation of the forest or otherwise they believe the offender will be harmed. This highlights the importance of socio-religious belief in conservation and the site to be preserved as a cultural and historical heritage. Moreover the site has become popular tourist spot firstly due to presence of ruins and secondly due to presence of a tree species *Myristica longifolia* that exudes a blood like sap when injured. During the course of this study, from the whole forest I could locate only eight individuals of the species in the near vicinity of the ruins but unfortunately during the end of the study I found two individuals completely dried away due to repeated injuries caused to the plants by the curious tourists. This clearly advocates the cautions to be adopted by the forest managers before opening any such wilderness area for ecotourism or otherwise the concept of ecotourism will badly affect the efforts of conservation.

Moreover some of the species recorded from the forest are used by the local tribal inhabitants for their everyday medicinal, therapeutic, nutritional and decorative needs (Table 8). This again strongly advocates conservation of such a natural wealth. Similar reports of plants of Jaldapara Wildlife Sanctuary being listed as NTFPs were also reported by Pandit *et al.* (2004) and Anon. (2009).

Table 8. List of important medicinal plants used by tribes of Chilapatta Reserved Forest

Botanical Name	Vernacular Name	Parts used	Ailments
<i>Aegle marmelos</i>	<i>Bael</i>	Leaf, fruit, bark	Indigestion and dysentery
<i>Albizia procera</i>	<i>Sada sirish</i>	Leaf	Ulcers
<i>Albizia lebbeck</i>	<i>Sirish</i>	Seed	Piles, body pain
<i>Alstonia scholaris</i>	<i>Chhatian</i>	Bark	Skin disease
<i>Amoora wallichii</i>	<i>Lali</i>	Fruit	Body pain and weakness
<i>Artocarpus chama</i>	<i>Latore</i>	Fruit, leaf	Food

<i>Artocarpus lakucha</i>	<i>Dahua</i>	Fruit, leaf, bark	Skin disease, purgative
<i>Bauhinia veriegata</i>	<i>Raktokanchan</i>	Root, bark, fruit, shoot	Mouth ulcer, smallpox
<i>Bauhinia vahlii</i>	<i>Kanchan</i>	Fruit, bark, flower	Mouth ulcer, smallpox
<i>Bombax ceiba</i>	<i>Simul</i>	Fruit, root	Headache
<i>Cinnamomum bejolghota</i>	<i>Tejpata</i>	Leaf, bark	Hypertension, diarrhea
<i>Clerodendron indicum</i>	<i>Bamunhati</i>	Root	Asthmatic problems, cold and cough
<i>Cyperus rotandus</i>	<i>Mutha</i>	Rhizome	Dysentery, fever, ulcers
<i>Dillenia indica</i>	<i>Chalta</i>	Fruit, leaf, bark	Indigestion and dysentery
<i>Dillenia pentagyna</i>	<i>Tantari</i>	Leaf	Decorative, food
<i>Gmelina arborea</i>	<i>Gamari</i>	Leaf, root, fruit	Small pox
<i>Lantana camara</i>	<i>Ban-tulshi</i>	Leaf	Ringworm
<i>Mallotus repandus</i>	<i>Sindure</i>	Shoot, flower, fruit	Gall bladder
<i>Michelia champaca</i>	<i>Champ</i>	Leaf, seed	Fever, eye disease
<i>Mimosa pudica</i>	<i>Lajjabati</i>	Leaf, root	Orchitis, depurative
<i>Oroxylum indicum</i>	<i>Totala</i>	Bark	Jaundice
<i>Ricinus communis</i>	<i>Arenda</i>	Root, Leaf, seed	Wounds, piles
<i>Solanum xanthocarpum</i>	<i>Kantakari</i>	Root	Asthmatic problems, cold and cough
<i>Syzygium cumini</i>	<i>Jam</i>	Fruit, Seed, leaf, bark	Indigestion and dysentery

<i>Termenalia bellirica</i>	<i>Bahera</i>	Fruit	Rheumatism
<i>Termenalia chebula</i>	<i>Haritaki</i>	Fruit	Rheumatism
<i>Terminalia crenulata</i>	<i>Pakasaj</i>	Fruit	Rheumatism
<i>Tinospora cordifolia</i>	<i>Gulancha</i>	Stem	Rheumatism and jaundice
<i>Toona ciliate</i>	<i>Toon</i>	Leaf, fruit	Medicine & decorative
<i>Vitex negundo</i>	<i>Nisinda</i>	Whole plant	Rheumatism
<i>Ziziphus mauritiana</i>	<i>Kul</i>	Fruit, leaf, seed	Vomiting
<i>Abelmoschus moschatus</i>	<i>Latakasturi</i>	Seed	Medicine
<i>Ageratum conyzoides</i>	<i>Dochunti</i>	Leaf	Medicine
<i>Amoora wallichii</i>	<i>Lasue</i>	Leaf, fruit	Medicine
<i>Anthocephalus kadamba</i>	<i>Kadam</i>	Leaf, fruit	Medicine & decorative
<i>Calamus guruba</i>	<i>Murgi Bet</i>	Root	Medicine
<i>Careya arborea</i>	<i>Kumbhi</i>	Fruit, flower, leaf, Bark	Medicine
<i>Chukrasia tabularis</i>	<i>Chikrasi</i>	Fruit	Decorative & medicine
<i>Colocasia esculenta</i>	<i>Ban-kachu</i>	Rhizome	Edible
<i>Diplazium esculentum</i>	<i>Dhekia sag</i>	Young foliage	Food
<i>Ficus religiosa</i>	<i>Peepal</i>	Fruit, leaf	Decorative & food
<i>Lagerstroemia parviflora</i>	<i>Jarul</i>	Fruit, flower, shoot	Decorative & medicine
<i>Mallotus philippensis</i>	<i>Sindure</i>	Fruit, leaf, bark	Medicine

<i>Mlastoma malabathricum</i>	<i>Datrangi</i>	Flower	Medicine
<i>Phlogacanthus thysiformis</i>	<i>Rambasak</i>	Root, stem	Medicine
<i>Pterocarpus marsupium</i>	<i>Piasal</i>	Leaf	Medicine
<i>Saccharum spontaneum</i>	<i>Kush Mat</i>	Root, Leaf	Decorative
<i>Schima wallichii</i>	<i>Chilauni</i>	Stem, bark	Medicine
<i>Shorea robusta</i>	<i>Sal</i>	Leaf, resin	Edible & leaf plate
<i>Solanum khasianum</i>	<i>Kantikari</i>	Fruit, Leaf	Medicine
<i>Solanum xanthocarpum</i>	<i>Jangli baungan</i>	Fruit, Leaf	Medicine, food
<i>Tectona grandis</i>	<i>Segun/Teak</i>	Seed	Medicine
<i>Vitex quinata</i>	<i>Nichinda</i>	Fruit, leaf	Medicine
<i>Alpinia nigra</i>	<i>Purundigazi</i>	Fruit, shoot	Medicine
<i>Bauhinia scandens</i>	<i>Naglata</i>	Old stem	Food, medicine
<i>Clerodendrum viscosum</i>	<i>Bhat</i>	Leaf, fruit, root	Medicine
<i>Cyperus rotandus</i>	<i>Mutha</i>	Rhizome	Medicine
<i>Desmodium gangeticum</i>	<i>Salpani</i>	Whole plant	Medicine
<i>Dioscorea belophylla</i>	<i>Bhegur & Ghita torul</i>	Rhizome	Edible & medicine
<i>Litsea monopetala</i>	<i>Kutmero</i>	Twing, bark, root	Edible & medicine
<i>Pterygota alata</i>	<i>Nerkeli</i>	Fruit, leaf	Decorative

It is useful to rank/order tropical/sub-tropical forests by species richness, diversity, density and basal area. In so doing, Chilapatta Reserve Forest rank as one of the most diverse and dense in the world. The rarer tree species with poor representation in quadrats need proper attention from plant biologist to determine their conservation status and key functions. Mapping concentration areas of these species and further study on their key ecological and cultural functions would help identify locations for conservation actions and determine which wildlife species may depend on them in the Chilapatta Reserve Forest. Forest manager can use such information on rare and common species like to help manage wildlife habitat as well as provide cultural resources values of these species. The quantitative characters related with density, dominance and diversity of these species could well act as indicators of changes and susceptibility to anthropogenic stressors among various vegetation categories and their formation which could to further interpreted as distinct wildlife habitat (Kumar *et al.*, 2006). The frequency distribution suggested that most of the species had low frequency as would be expected in typical species-abundance distribution. The knowledge on distribution patterns of several species would of prime importance in deciding the management options for specific host population of native wildlife which otherwise may face the danger of local extinction due to heavy human pressure surrounding the Chilapatta Reserve Forest which may lead to removal of original forest condition.

4.2. STUDY II: TO ESTIMATE THE BIOMASS ALONG WITH N, P, K AND C STORED IN THE FOREST

4.2.1 Biomass Accumulation and Partitioning

Estimates of rate of biomass accumulation and partitioning at the time of observation of the forest are given in Table 9. The total biomass accumulated per hectare of Chilapatta Reserve Forest was in the tune of 1995.98 mega grams. Almost all the biomass of the forest was contributed by the trees (99.69 %) while a negligible amount was contributed by shrubs (0.25 %) and herbs (0.06 %) together. The biomass partitioned in to stem, branch, leaves and roots in perennial component while it partitioned as foliage and root in herbs. In trees, stem biomass contributed the most (58.74 %) followed by branches (28.04 %), roots (12.90 %) and least by the leaves (0.32 %). The trends was

similar in shrubs except where the contribution of root (19.80 %) is next to the stem (48.16 %) followed by branches (19.39 %) and the least contributed by the leaves (12.65 %). Similarly the contribution of foliage or above ground biomass in herbs was 68.91 % and rest by the roots. The contribution of above ground biomass in both the trees and shrubs accounted to more than 80 % i.e. (87.10 and 81.20 %, respectively) while the rest was contributed by the below ground biomass i.e. roots. A recent report from the same study area by (Koul and Panwar, 2008) also support the rate of biomass accumulation and trend of partitioning estimated in the present study. In a similar study from a reserve and protected temperate forest in Western Himalaya comparatively lesser total aboveground biomass accumulation of 1149.78 and 674.61 Mgha⁻¹, respectively was reported (Sharma *et al.*, 2008).

Table 9. Total biomass accumulation and partitioning (Mgha⁻¹) in Chilapatta Reserve Forest

Life form	Stem	Branch	Leaves/ Foliage	Above ground biomass	Root	Total
Trees	1168.78	558.01	6.34	1733.13	256.76	1989.89
Shrub	2.36	0.95	0.62	3.93	0.97	4.90
Herb	-	-	0.82	0.82	0.37	1.19
Total	1171.14	558.96	7.78	1737.88	258.10	1995.98

The total biomass stored at the time of observation in Chilapatta Reserve Forest was enormous in tune of 4391191 mega grams and the contribution by trees, shrubs and herbs along with its storage in stems, branches, leaf/foliage and roots are given in Table 10.

Table 10. Total biomass reserves (Mega gram) in Chilapatta Reserve Forest

Life form	Stem	Branch	Leaf/Foliage	Above ground	Root	Total
Trees	2571316	1227657	13948	3812921	564872	4377793
Shrubs	5192	2090	1364	8646	2134	10780
Herbs	-	-	1804	1804	814	2618
Total	2576508	1229747	17116	3823371	567820	4391191

Biomass partitioning is an important driver of whole-plant net carbon gain and has a direct influence on future plant growth and reproduction (Evans, 1972; Silverton and Doust, 1993; Bazzaz and Grace, 1997). Biomass allocation between vegetative and reproductive compartments will greatly improve our understanding of plant life history strategies (Westoby *et al.*, 2002; Wright *et al.*, 2004; Pickup *et al.*, 2005; Niinemets *et al.*, 2007) thereby will improve the silvicultural techniques efficiently to manage a forest sustainably. This will in turn help us to identify the productivity of dominant tree species in different forests as the dominant tree species greatly influence the magnitude and pattern of energy flow that is stored in trunks, branches, leaves and roots in the form of various organic substances and material remained in continuous circulation between biotic and abiotic components of the ecosystem (Devi and Yadava, 2009). Moreover biomass of forest vegetation can be used for storage of carbon and carbon cycling at a regional as well as global level can be estimated for planning viable options to mitigate CO₂ increased climate change.

4.2.2 Litter Production and Decomposition

The rate of litter production and its subsequent decomposition (%) with its periodic change is given in Table 11. The litter production of Chilapatta Reserve Forest was 5.37 Mgha⁻¹. The return to soil through decomposition from total litter was highest during first quarter of the year and then subsequently decreased in next two quarters. The decomposition gradually increased with time and after 12 month more than 90 % of the total litter got decomposed i.e. 5.10 Mgha⁻¹ litters decomposed. The rate of litter decomposition (Mgha⁻¹ month⁻¹) in terms of quarterly intervals was highest (0.59) during first quarter followed by second quarter (0.44) and lowest (0.24) in the last quarter. This may be due to favourable temperature, optimum rainfall (Fig.2) and soil moisture (Table 12) regime prevailed in the forest. The lowest rate of decomposition during last quarter even after favourable conditions may be attributed to less amount of litter left for decomposition (22.90 % of the initial litter) after the first two quarters.

Table 11. Litter production and decomposition in Chilapatta Forest Reserve

Initial litter mass (Mgha ⁻¹)	Decomposition of initial litter (%)			Litter decomposed (Mgha ⁻¹ /4 months)			Total decomposition (Mgha ⁻¹)
	May	Sept	Dec	May	Sept	Dec	
5.37	43.76	77.09	95.03	2.35	1.79	0.96	5.10

The annual litter fall for tropical dry deciduous, tropical dry evergreen, temperate evergreen and temperate moist deciduous forests of India were 4.33, 7.52, 6.44 and 8.39 Mgha^{-1} , respectively (Dadhwal *et al.*, 1997) while at deciduous and semi-deciduous forests of Brazil (Hasse, 1999) was 4.86-7.71 Mgha^{-1} which were comparable to the present study. Similar trend of decomposition of liter was reported by Pande and Sharma (1993), Pande (1999), Rajagopal *et al.* (2005) and Shadangi and Nath (2006). The material turnover through litter decomposition was 5.10 Mgha^{-1} within 12 months in this study i.e. more than 90 % of the total litter produced was decomposed because Chilapatta Reserve Forest was categorized as moist deciduous forest (Champion and Seth, 1968) which support the report by Pastor (1987) that deciduous forests are believed to have faster nutrient turnover than any other forests. Positive effects of deciduous trees on nutrient cycling are usually attributed to their high quality litter causing faster decomposition and faster nutrient cycling (Scott and Binkly, 1997). Generally, the decomposition rates of leaf litter in tropical and subtropical broad-leaved forests and pine trees are from 1.0 to 1.75; for example, the turnover rate (time required to decompose 95 % of litter) of leaf litter decomposition is 1.7 to 3 years (Brown and Lugo, 1982; Cuevas *et al.*, 1991; Zhang *et al.*, 2009_a). It requires just 1.5 years in tropical rain forests of China (Ren *et al.*, 1999) and 3-5 years (Zhang *et al.*, 1999) or 8-14 years in temperate deciduous broad leaved forests (Wang and Huang, 2001) as compared to turnover rate of only 12 months for the forest in this study which may be due to optimum temperature, rainfall and relative humidity (Fig.2) in the area with abundant moisture in the soil (Table 12). The differences in turnover rates may be affected by the environment (soil and climate) and are mainly due to biological actions (Zhang *et al.*, 2009_a). It is widely believed that plant litter decomposes rapidly and completely in humid tropics because the condition of humidity and temperature favour the microbial activity (Singh and Gupta, 1977).

Table 12. Soil available N, P & K (Kg ha^{-1}) and pH, EC (m mhos cm^{-1}) & moisture (%) of Chilapatta Reserve Forest

Month	15 cm					
	N ₂	P ₂ O ₅	K ₂ O	pH	EC	Moisture
Jan, 08	260.96	107.94	154.88	5.47	0.050	32.44
May	271.61	115.51	161.14	5.54	0.074	30.72

Sept	279.24	128.41	173.12	5.72	0.074	36.64
Dec	261.70	109.21	156.60	5.50	0.054	32.93
30 cm						
Jan, 08	249.97	93.76	135.96	5.68	0.060	35.39
May	257.43	98.60	147.94	5.72	0.088	34.39
Sept	263.47	115.93	150.17	5.85	0.086	38.82
Dec	250.78	94.88	137.87	5.71	0.064	35.51

It seems that the higher rate of litter production and its subsequent decomposition under tropical climate contributed rapid turnover of nutrients and affect the nutrient cycling, in cases where growth period and uptake are not synchronized with leaf fall and its subsequent decomposition (Pande *et al.*, 2002) as in the case of present study area where the most of the trees were either semi-deciduous or deciduous.

4.2.3 Litter NPK Release

The NPK content (%) of fresh and decomposing litter with their total NPK (Mgha^{-1}), its release in the soil (Mgha^{-1}) and their periodic change is given in Table 13. The NPK content in fresh litter of forest was recorded as 1.58, 0.42 and 1.12 %. The annual return of nutrient was in the order $\text{N} > \text{K} > \text{P}$ as was also observed by Pandey (2001). The NPK content decreased periodically as the decomposition progressed. The total NPK and its periodic change also showed similar behaviour as exhibited by its content. The return of NPK by litter decomposition cumulated over the period of 12 months coincided with what was recorded as total NPK from the fresh litter. The return of available NPK from litter through decomposition to the soil in the forest after one year was 0.084, 0.023 and 0.060 Mgha^{-1} , respectively which is nearly equal to the amount of available NPK in the fresh litter. This means there was no net increase or decrease of NPK in the system and which indicate it's cycling in a sustainable manner. This is also evident from the fact that there is nearly no net increase or decrease in soil total available NPK over the yearly cycle (Table 12).

Table 13. Available nutrient released from litter (Mgha⁻¹) in Chilapatta Reserve Forest

	Jan, 08		May		Sept		Dec		*Return to Soil
	%	A	%	B	%	C	%	D	
N₂	1.58	0.085	1.26	0.038	0.55	0.0068	0.210	0.0006	0.084
P₂O₅	0.42	0.023	0.20	0.0025	0.018	0.0005	0.004	0.00001	0.023
K₂O	1.12	0.060	0.91	0.027	0.31	0.0040	0.140	0.00038	0.060

***Return to soil: [(A-B) + (B-C) + (C-D)]**

A gradual decomposition of litter and its incorporation into the soil amounts a step further in the process of mineralization and subsequently its availability. It is largely governed by chemical composition of litter, environmental conditions, soil flora and fauna (Singh and Gupta, 1977). Environmental conditions (temperature and moisture) play important role in governing the rate of litter decomposition (Upadhyay and Singh, 1981). It is evident from the trend of periodic change of NPK content in litter that initially there was slow rate of N and K release which increased as decomposition progressed gradually but no such trend was observed for P release from the litter. This pattern of NPK release from the decomposing litter has been also recorded from other tropical forests (Chacon and Dezzio, 2007). In general the magnitude of total nutrient return was in order to the total litter fall. The higher nutrient was associated with higher litter fall and litter nutrient concentrations (Pande, 2001).

4.2.4 Physico-chemical Properties of Forest Soil

The physical and chemical parameters of forest soil taken at two depths with its periodic change are given in Table 12.

The pH of the forest at both the depth was moderately acidic as was also reported by Koul (2004) from the same study area. At both the depths acidity decreased gradually but very nominally from first three months to ninth month and then decreased again at last three months of the year to the same level as in the first three months. Chavan *et al.* (1995) and Contractor and Badnur (1996) have also reported low soil pH under forest plantations. Soil pH under different forest vegetation ranged from 5.0 to 6.8 and higher in the upper horizons than in the lower ones (Raina *et al.*, 2001). Jha *et al.*, (1999) reported

that soil under *Pinus roxburghii*, *Tectona grandis* and *Eucalyptus* was mildly acidic (5.98 to 6.67) while soil under *Dalbergia sissoo* and *Acacia catechu* along with natural *Shorea robusta* forest and barren land was moderately acidic (4.65 to 5.97). This may be attributed to similar trend of periodic change in soil moisture, EC and subsequent increase of materials through litter decomposition (Table 13). Presence of high organic matter along with leaching of bases and enhancement of weathering process due to decomposition of litter increases the soil EC and moisture which in turn lowers the pH in forest soil (Chakravarty and Barthakur, 1997; Paudel and Sah, 2003). Due to subsequent release of nutrients in to the soil by mineralization after decomposition along with release of water as byproduct of decomposition also explains the increase of EC and moisture in the soil and then decreased after nine months because by this time almost all the litter in soil had decomposed thereby decreasing mineralization which decreased EC, moisture and ultimately increasing acidity again (Johnston, 1986; Sheikh and Kumar, 2010). Further moisture regime in a forest depends upon many biotic and abiotic factors v.i.z. rainfall, amount of radiation received on the forest floor, its aridity, humidity, temperature are abiotic factors while structure and function of forest covers are biotic factors (Pande, 2001). The study area has humid climatic conditions due to high rainfall and humidity (Fig. 2.) Moreover due to higher proportion of continuous canopy cover by virtue of higher density of plants in the forest less than two per cent of incident radiation reached the forest floor causing less evaporation thereby conserving high soil moisture.

The average total available NPK reserve at the time of observation in the Chilapatta Reserve Forest at 15 cm soil depth was 590.43, 253.59 and 355.16 mega grams while at 30 cm depth it was 561.77, 221.74 and 314.57 mega grams, respectively and the periodic change of available NPK is given in Table 14.

Table 14. Total available soil NPK reserve (mega grams) in Chilapatta Reserve Forest

Periods	15 cm			30 cm		
	N ₂	P ₂ O ₅	K ₂ O	N ₂	P ₂ O ₅	K ₂ O
Jan, 08	574.11	237.47	340.74	549.93	206.27	299.11
May	597.54	254.12	354.51	566.35	216.92	325.47
Sept	614.33	282.50	380.86	579.63	255.05	330.37
Dec	575.74	240.26	344.52	551.17	208.74	303.31

The availability of nutrient in soil was in the order $N > K > P$ as was also reported by Pande (2001). The available NPK of Chilapatta Reserve Forest also increased from first three months to ninth month and again decreased during last three months of the year to the same level as was in the first three months of the year at both the depths. This can be attributed to addition of nutrients by decomposition of litter in similar trend as nutrients in the soil increased and then decreased over the quarterly periods (Table 13) and subsequently being drawn up by the plants for their nutrition. This was indicated from the fact that though decomposing litter released NPK over time which simultaneously increased the soil NPK but due to consumption by plants the initial and final available NPK in the soil over the yearly cycle is nearly equal. The average available NPK over the period of 12 months in the forest soil at 15 cm depth was 268.37, 115.27 and 161.44 Kg ha⁻¹ while at 30 cm depth it was 255.40, 100.79 and 142.99 Kg ha⁻¹, respectively.

Prescott (2002) and Jerabkova *et al.* (2006) also reported that soil NPK availability is more closely related to litter NPK content than to litter decomposition rate. Plant tissues (above and below ground litter) are the source of soil organic matter which influence the physico-chemical characteristics of soil such as texture, water holding capacity, pH and nutrients availability (Johnston, 1986). Physico-chemical characteristics of forests vary in space and time because of variation in topography, climate, weathering process, vegetation cover and microbial activities (Paudel and Sah, 2003). The nutrients thus, returned in the soil, exerts a strong feedback on the ecosystem processes (Pastor *et al.*, 1984). Nutrients supply varies widely among ecosystems (Binkly and Vitousek, 1989) resulting in differences in plant community structure and its production (Ruess and Innis, 1977). It is therefore forest soils strongly determine the composition of forest stand and ground cover, rate of plant growth, vigour of natural reproduction and other silviculturally important factors (Bhatnagar, 1965).

4.2.5 Soil Organic Carbon (SOC)

The carbon content, total carbon and the periodic change in carbon recorded at soils of Chilapatta Reserve Forest are given in Table 15. For both the depths, carbon

content also increased gradually up to nine month and then decreased up to the level similar to that recorded for the first three month which was due to its synchronization with decomposition of litter (Table 13) as discussed earlier subsequently releasing carbon into the soil up to nine months and then decreased. Similarly the total carbon also changed periodically. The increase in SOC to their initial value is believed to be due to the effect of litter addition (Singh *et al.*, 2004). Accumulation of SOC through litter fall might have regulated organic matter decomposition and the formation of stable and labile soil organic matter pool (Vitousek and Sanford, 1986). The average total carbon recorded over the periods of 12 months at 0-15 cm depth was 40.27 Mgha⁻¹ and at 15-30 cm depth it was 35.56 Mgha⁻¹ which is similar to that reported by Koul (2004) from the same study area.

Table 15. Carbon content (%) and total carbon (Mgha⁻¹) in soils of Chilapatta Reserve Forest

Month	15 cm		30 cm	
	Content	Total	Content	Total
Jan, 08	1.74	38.98	1.52	34.05
May	1.82	40.77	1.62	36.29
Sept	1.88	42.11	1.62	36.29
Dec	1.75	39.20	1.59	35.62

The average total SOC estimate of 75.83 Mgha⁻¹ up to 30 cm soil depth coincides with that reported for other tropical moist deciduous forests in India i.e. 8.9-176.1 Mgha⁻¹ of top 50 cm depth (Chhabra and Dadhwal, 2005). However it was far lesser than the national average of SOC i.e. 182.94 Mgha⁻¹ (Jha *et al.*, 2003) which can be attributed to higher rates of decomposition due to high temperature. SOC store has great importance to conserve carbon and restrict the carbon emission. Temperate forests have unique feature to accumulate high quantity of soil organic matter and litter because of slow decomposition rate due to low temperature (Jha *et al.*, 2003) and the reverse was true for the condition of the study area of the present study which explains the lesser total SOC.

4.2.6 Carbon Pool Estimates

Carbon pool estimates and partitioning at the time of observation of the forest are given in Table 16. The total carbon pool of Chilapatta Reserve Forest in its soil, live and organic biomass was 973.65 Mgha⁻¹. Almost all the carbon of the forest was contributed by the trees (91.97 %) while a negligible amount was contributed by shrubs (0.23 %), herbs (0.05 %), litter (0.25 %) and soil up to 30 cm depth (7.50 %) together. In trees, stem contributed the most carbon (58.74 %) followed by branches (28.04 %), roots (12.90 %) and least by the leaves (0.32 %). The trends was similar in shrubs except where the contribution of root (19.91 %) is next to the stem (47.96 %) followed by branches (19.46 %) and the least contributed by the leaves (12.67 %). Similarly the contribution of foliage or above ground biomass in herbs was 68.52 % and rest by the roots. The contribution of above ground biomass in both the trees and shrubs accounted to more than 80 % i.e. (87.10 and 80.10 %, respectively) while the rest was contributed by the below ground biomass i.e. roots. Similar report regarding carbon stock in biomass of 891.02 Mgha⁻¹ and its similar trends of partitioning was also reported by Koul and Panwar (2008) and Jana *et al.* (2009) from the same study site.

Table16. Estimates of carbon storage (Mgha⁻¹) at Chilapatta Reserve Forest

Life form	Stem	Branch	L/F	Ag	Root	Tb	Litter	Soil (0-30 cm)	Pool
Trees	525.95	251.11	2.85	779.91	115.54	895.46	-	-	-
Shrubs	1.06	0.43	0.28	1.77	0.44	2.21	-	-	-
Herbs	-	-	0.37	0.37	0.17	0.54	-	-	-
Total	527.01	251.54	3.50	782.06	116.15	898.21	2.41	75.83	976.45

L/F: Leaves/Foliage; Ag: Above ground; Tb: Total biomass

Carbon stock is intricately linked with site quality, nature of land use, choice of species and other silvicultural practices adopted (Swamy *et al.*, 2003) which explains higher biomass in the present study and hence more carbon stock in the forest. Higher biomass in the forest can also be explained because of efficient utilization of space due to presence of grasses/ferns, shrubs and trees on the same unit area of land. Further higher

SOC in forest soil also leads to increase rate of plant growth increasing the biomass again.

A C:N ratio of about 30:1 (C- 2.41 Mgha⁻¹, Table 16; N- 0.085 Mgha⁻¹ Table 13) was observed in the present study which is comparable to that reported for boreal mixed wood forests (Jerabkova *et al.*, 2006). The ecological impact of carbon and nitrogen dynamics in the litter layer is considerable in forest ecosystems (Xiao-wen *et al.*, 2009). Fresh litters can uptake or immobilize N because it is relatively rich in C and poor in N. Thus the litter layer can become a significant sink for N. As decomposition proceeds mineralization predominates over immobilization, then the litter gradually releases N and become a source for N. In addition, the dissolved organic C and dissolved organic N originated from litter decomposition is the most important source of dissolved organic matter in forest soils (Qualls and Haines, 1991; Park *et al.*, 2002) which is considered to be an energy and nutrient source of microbial metabolism (Magill and Aber, 2000). The total carbon stored at the time of observation in Chilapatta Reserve Forest was also enormous in tune of 2148168 mega grams and the contribution by trees, shrubs and herbs along with its storage in stems, branches, leaf/foliage, roots, litter and soil up to 30 cm depth are given in Table 17.

Table 17. Carbon storage (Mgha⁻¹) in Chilapatta Reserve Forest Ecosystem

Life form	Stem	Branch	L/F	Ag	Root	Tb	Litter	Soil (0- 30 cm)	Total pool
Trees	1157090	552442	6270	1715802	254188	1970012	-	-	-
Shrubs	2332	946	616	3894	968	4862	-	-	-
Herbs	-	-	814	814	374	1188	-	-	-
Total	1159422	553388	7700	1720532	255530	1976062	5302	166804	2148168

L/F: Leaves/Foliage; Ag: Above ground; Tb: Total biomass

Forests are the most important carbon pool on land (Pibumrung *et al.*, 2008) which is clearly indicated from the enormous value of total carbon storage in the 2200 ha area of Chilapatta Reserve Forest ecosystem. It is well known that many factors may

affect the carbon budget of an ecosystem: biotic features including the leaf size, photosynthetic rate, plant architecture and type of forests (evergreen or deciduous) and abiotic features such as radiations, temperature, water supply, soil property and the length of growing season (Hui-min *et al.*, 2008). Although the response of carbon fluxes to environmental variables such as air, humidity (or dryness) and temperature has been reported (Hollinger *et al.*, 1994 & 1998; Fan *et al.*, 1995; Chen *et al.*, 1999; Clark *et al.*, 1999; Wang *et al.*, 2004). Furthermore litter CO₂ respiration can account for 10-30 % of total soil CO₂ flux and it is important for the balance of forest carbon budgets (Buchmann, 2000; Lin *et al.*, 2004). In general, evergreen broad-leaved forest ecosystems have a high capacity for carbon sequestration (Waring and Running, 1998). At Chilapatta Reserve Forest, carbon dioxide measured in ambient air was 380.43 ppm while the rate of daily CO₂ sequestration with annual CO₂ sequestration ranged from 2.42 to 5.02 g/hr and 2.07 to 3.33 MgCha⁻¹, respectively (Jana *et al.*, 2009). This means that the net carbon storage of the forest was between 973.12 to 974.38 MgCha⁻¹. Tropical deforestation has been responsible in part for the increasing concentration of CO₂ in the atmosphere (Houghton, 1990). Currently world's forests are estimated to be a net source of atmospheric CO₂, primarily because of deforestation and forest degradation in the tropics (Brown *et al.*, 1996) which clearly advocates the sustained continuous conservation of tropical forest ecosystems like the Chilapatta Reserve forests or any other such forests so that atmospheric CO₂ increased climate change can be mitigated effectively and viably at regional and global level.

The present study entitled “**Biomass Production and Vegetation Analysis of Chilapatta Reserve Forest Ecosystem of West Bengal**” was carried out during April 2007 to March 2009. The present study was under taken in the Chilapatta Range having three Beats viz. Chilapatta, Mendabari and Bania whose total area was about 41 km² but all the quadrats of the study was placed on Chilapatta, Mendabari Beats with four and five blocks, respectively having a total area of 22 km². Stratified random nested quadrat sampling method was adopted for analyzing vegetation composition. 57 quadrats of size 20 x 20 m² for trees within which two 5 x 5 m² quadrats was laid out at the diagonal corners for shrubs and lianas (total 114) and five 1 x 1 m² quadrats at the four corners and one at the center of the each 20 x 20 meter quadrat for herbs, ferns and climbers (total 285). The trees, shrubs, herbs, epiphytes, lianas climbers along with their host, fern or any other vegetation was noted to keep an account of the floral composition of the site. Plant community was studied for their qualitative and quantitative character or phytosociology for each quadrat. The structure, composition and life form of the plant community in the study area was described just by visual observations. The numbers of individuals for each species were recorded to determine their frequency, density, abundance, basal area to estimate IVI, distribution pattern and various diversity indices like Menhinick’s index, Simpson’s index, Shannon and Wiener index and species evenness index. Soil and litter samples were collected to analyze EC, pH, moisture, available N, P & K, organic carbon and its stock. Nondestructive method was adopted to estimate biomass to analyze its carbon stock. PAR interception by the forest canopy was also recorded.

5.1 TO STUDY THE QUALITATIVE AND QUANTITATIVE CHARACTERS OF PLANT COMMUNITIES OF THE FOREST

The different life/vegetation forms in the Chilapatta Reserve Forest were trees, shrubs, lianas, climbers, ferns, herbs, and epiphytes. Trees occupied the top most strata of the forest. After trees the downward strata are occupied by lianas, shrubs, climbers and ferns one below the other while herbs were recorded as the lower most strata of the

forest. A total of 100 species were very less present (i.e. observed in ≥ 10 % of the total quadrats, 165 were less frequent (occurred in 10-25 % of total quadrats) and 46 were often present (occurred in 25-75 % of total quadrats). All the shrubs, herbs, climbers and lianas were evergreen but among the trees, 82.50 % were deciduous, 15.63 % semi-evergreen and only 1.87 % were evergreen. The tree stratum was clearly distinguished in to three layers according to the height of the trees. Overall the medium tree species dominated with 67.50 % followed by taller height species with 26.88 % and only 5.62 % tree species are of low height. The species growing intermixed were only the trees which represented 36.98 % of the total species while 23.47 % of the total species were growing in patches, 23.15 % were colony growers and 16.40 % of the total species were single growers. Medium/small leaves (59.52 % of the total species) dominated the forest followed by broad/large leaved species (20.57 % of the total species), species with graminoid leaves having 7.71 % of the total species while species with thalloid and compound leaves each had 6.10 % of the total species were the least. The canopies of 59.65 % quadrats were continuously covered, 35.09 % were discontinuous and quadrats observed with tuft canopy cover were 5.26 % only. Overall intercepted PAR by all the strata of forest was more than 98 % of the incident PAR.

A total of 311 species of plants were recorded but 52 of these species could not be identified. The identified species were represented by 85 families and 167 genera. The number of species representing the trees, shrubs, herbs, climbers, lianas, and ferns were 160, 36, 49, 44, 4 and 19, respectively. The dominating families are Rubiaceae, Lauraceae, Fabaceae and Euphorbiaceae with 17, 16, 14 and 10 species, respectively. The species diversity index/Menhinick's index and concentration of dominance were 2.20 and 0.0072, respectively. This reflects number of chance the species were encountered during sampling and lower value means the chances of encountering being more. Shannon and Wiener index that determine diversity was inversely proportional to concentration of dominance and the corresponding value was 4.70. High index values suggest the community to be more diverse and stable. It was also observed that the tree species in the forest were distributed more evenly than the different vegetative forms in the forest and was also more evenly distributed than when compared with the overall evenness of the Chilapatta Reserve Forest.

Frequency of species in the forest ranged from 1.73 -54.39 % i.e. of all the species chance of occurrence of *Albizia procera*, *Calamus erectus*, *C. guruba* and *Streblus asper* each was lowest while *Lagerstroemia parviflora* occurred most. Similarly the chance of occurrence of *Pteris aspericaulis* relative to all other species in the forest was highest with 12.25 % while the lowest with 0.01 % were the same species having lowest frequency. Density, relative density, relative abundance and IVI ranged from 0.44 to 13,403.51 individuals ha⁻¹; 0.005-15.59 %, 0.12-10.11 % and 0.13-37.94, respectively. The species corresponding to lowest and highest record for density, relative density, relative abundance and IVI are same as was recorded for relative frequency. The tree, shrub, liana, climber, fern and herb density in the forest was 2,615; 8,512; 775; 7,628; 1,06,667 and 2, 18,982 plants ha⁻¹, respectively. The species were grouped into three frequency classes of A, B and C having 77.49, 20.90 and 1.61 % of the total species, respectively. Species abundance ranged from 0.80 to 17.83 i.e. *Ardisia thyrsoiflorus* had least while *Tectona grandis* had highest number of individuals in the forest.

The distribution pattern of species in the forest was largely regular i.e. 49.20 % of the species were regularly distributed. Among the remaining species, 28.29 % were contagious and 22.55 % were randomly distributed. The basal area of trees species in the forest ranged from 0.25-41.60 m² ha⁻¹, the highest being *Ficus religiosa* and lowest was *Curculigo orchiodes*. Basal area of some important timber species found in the forest was recorded as 27.56, 24.39, 17.80, 15.57 and 15.46 m² ha⁻¹ for *Shorea robusta*, *Tectona grandis*, *Michelia champa*, *Gmelina arborea* and *Lagerstroemia parviflora*, respectively. The total basal area of trees estimated was 522.91 m² ha⁻¹ which is far greater than the highest value of 162 m² ha⁻¹ in any of the tropical forests of the world.

5.2 TO ESTIMATE BIOMASS OF THE FOREST ALONG WITH ITS NUTRIENT DYNAMICS

The total biomass accumulated per hectare in the forest was in the tune of 1995.98 mega gram. Almost all this biomass was contributed by the trees (99.69 %) while a negligible amount was contributed by shrubs (0.25 %) and herbs (0.06 %) together. In trees, stem biomass contributed the most (58.74 %) followed by branches (28.04 %), roots (12.90 %) and least by the leaves (0.32 %). The trends was similar in shrubs except

where the contribution of root (19.80 %) was next to the stem (48.16 %) followed by branches (19.39 %) and the least contributed by the leaves (12.65 %). Similarly the contribution of foliage or above ground biomass in herbs was 68.91 % and rest by the roots. The contribution of above ground biomass in both the trees and shrubs accounted to more than 80 % i.e. (87.10 and 81.20 %, respectively) while the rest was contributed by below ground biomass i.e. roots. The total biomass stored at the time of observation in the forest was enormous in tune of 4391191 mega grams. The litter production was 5.37 Mgha^{-1} . The decomposition gradually increased with time and after 12 month more than 90 % of the total litter got decomposed i.e. 5.10 Mgha^{-1} litters decomposed. The rate of litter decomposition ($\text{Mgha}^{-1} \text{ month}^{-1}$) in terms of quarterly intervals was highest (0.59) during first quarter followed by second quarter (0.44) and lowest (0.24) in the last quarter.

The soils of the forest were acidic with electrical conductivity of 0.063-0.075 mhos cm^{-1} and had 33.15-36.06 % moisture, respectively at 0-15 and 15-30 cm depth. The available NPK over the period of 12 months in the forest soil at 0-15 cm depth was 268.37, 115.27 and $161.44 \text{ Kg ha}^{-1}$ while at 15-30 cm depth was 255.40, 100.79 and $142.99 \text{ Kg ha}^{-1}$, respectively. The total available NPK reserve at the time of observation in the forest at 0-15 cm depth was 590.43, 253.59 and 355.16 mega grams while at 30 cm depth it was 561.77, 221.74 and 314.57 mega grams, respectively and the periodic change of available NPK. The NPK content in fresh litter of forest was recorded as 1.58, 0.42 and 1.12 %. The return of available NPK from litter through decomposition to the soil in the forest after one year was 0.084, 0.023 and 0.060 Mgha^{-1} , respectively which was nearly equal to the amount of available NPK in the fresh litter.

The total carbon recorded over the periods of 12 months at 15 cm depth was 40.27 Mgha^{-1} and at 30 cm depth it was 35.56 Mgha^{-1} . The total carbon pool of the forest in its soil, live and organic biomass was 973.65 Mgha^{-1} . Almost all of this carbon was contributed by the trees (91.97 %) while a negligible amount was contributed by shrubs (0.23 %), herbs (0.05 %), litter (0.25 %) and soil up to 30 cm depth (7.50 %) together. In trees, stem contributed the most carbon (58.74 %) followed by branches (28.04 %), roots (12.90 %) and least by the leaves (0.32 %). The trend was similar in shrubs except where the contribution of root (19.91 %) was next to the stem (47.96 %) followed by branches

(19.46 %) and the least contributed by the leaves (12.67 %). Similarly the contribution of foliage or above ground biomass in herbs was 68.52 % and rest by the roots. The contribution of above ground biomass in both the trees and shrubs accounted to more than 80 % i.e. (87.10 and 80.10 %, respectively) while the rest was contributed by the below ground biomass i.e. roots. The total carbon stored at the time of observation in the forest was also enormous in tune of 2142030 mega grams.

5.3 CONCLUSION

In ranking tropical/sub-tropical forests by species richness, diversity, density and basal area, the Chilapatta Reserve Forest may rank as one of the most diverse and dense in the world. The forest is a diverse community in which the species are fairly even distributed with higher chances of encountering a species during sampling where dominance was shared by more than one species because of lesser disturbance owing to its status of protection from the law as a Reserve Forest or Protected Forest for wildlife. Analysis of Raunkiaer's frequency classes revealed that most of the species had low frequency as would be expected in typical species-abundance distributions in tropical forests that reflects the higher heterogeneous nature of the forest. The tree density recorded in the present study is much higher than the estimates from other studies of tropical forest within and outside India advocating the site is important for management and conservation. Important timber species found in the forest are *Shorea robusta*, *Tectona grandis*, *Michelia champa*, *Gmelina arborea* and *Lagerstroemia parviflora*. The rarer tree species with poor representation in quadrats need proper attention from plant biologist to determine their conservation status and key functions. Mapping concentration areas of these species and further study on their key ecological and cultural functions would help identify locations for conservation actions and determine which wildlife species may depend on them in the Chilapatta Reserve Forest. Presence of ancient ruins of fortress of the Raja Nala attracts tourists to the forest which signifies its preservation as site of cultural and historical heritage on one side but also warrants being cautious while promoting ecotourism.

Moreover biomass of forest vegetation can be used for storage of carbon and carbon cycling at a regional as well as global level can be estimated for planning viable options to mitigate CO₂ increased climate change. In general the magnitude of total nutrient return was in order to the total litter fall. The higher nutrient was associated with higher litter fall and litter nutrient concentrations and soil NPK availability is more closely related to litter NPK content. SOC store has great importance to conserve carbon and restrict the carbon emission. Carbon stock is intricately linked with site quality, nature of land use, choice of species and other silvicultural practices adopted. Forests are the most important carbon pool on land which is clearly indicated from the enormous value of total carbon storage in the forest ecosystem. Tropical deforestation has been responsible for increasing CO₂ in the atmosphere which clearly advocates the sustained continuous conservation of this forest also.

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Plate.1. *Phlogacanthus thysiformis*



Plate.2. *Rungia pectinata*



Plate.3. *Drymicarpus racemosus*



Plate.4. *Saurindia madagascarensis*



Plate.5. *Milusa roxburghiana*



Plate.6. *Uvaria hamiltonii*



Plate.7. *Alangium chinense*



Plate.8. *Alstonia scholaris*



Plate.9. *Chonemorpha fragrans*

Plate.10. *Ichnocarpus frutescens*

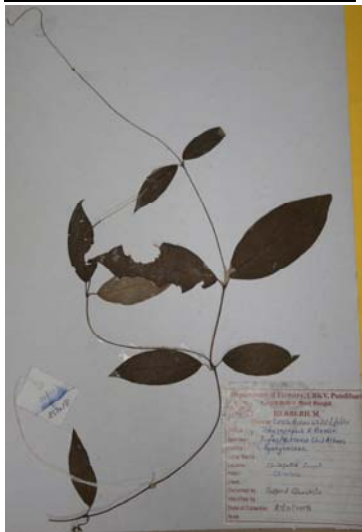


Plate.11. *Ichnocarpus volubilis*



Plate.12. *Tabernaemontana* spp.

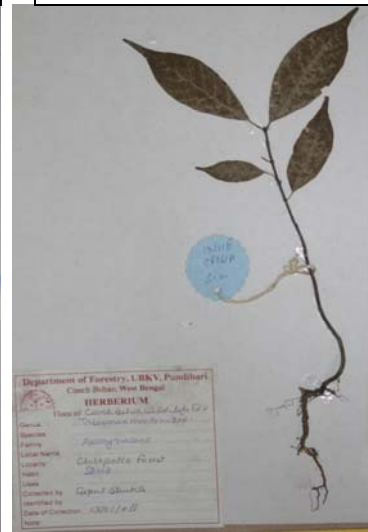


Plate.13. *T. divaricata*



Plate.14. *Vallisneria spiralis*



Plate.15. *Wrightia arborea*



Plate.16. *Amorphophallus bulbifer*



Plate.17. *Pinangra gracilis*



Plate.18. *Calamus erectus*

Plate.19. *Colocasia esculenta*



Plate.20. *Pothos cathartii*



Plate.21. *Pothos scandens*

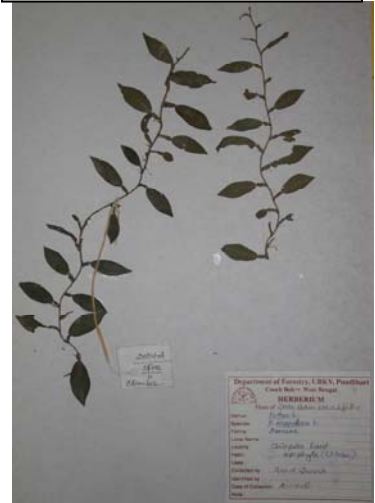


Plate.22. *Rhaphidophora calophylla*

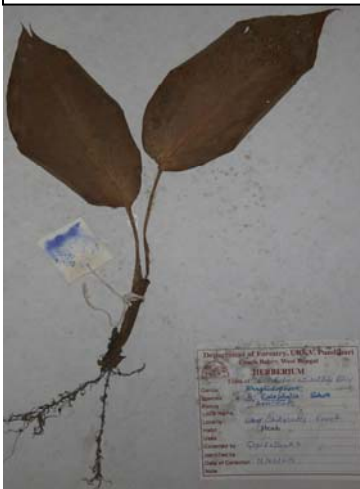


Plate.23. *Rhaphidophora glauca*



Plate.24. *Rhaphidophora hookeri*



Plate.25. *Acmeila calva*



Plate.26. *Ageratum conyzoides*



Plate.27. *Eupatorium odoratum*

Plate.28. *Elephantropus scaber*



Plate.29. *Mikania micrantha*



Plate.30. *Diplazium esculentum*



Plate.31. *Bombax ceiba*

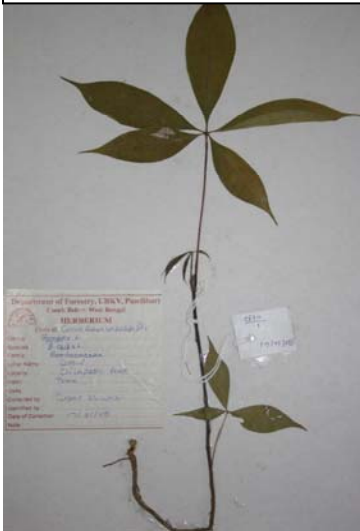


Plate.32. *Cordia obliqua*



Plate.33. *Quercus Castanopsis*



Plate.34. *Capparis multiflora*



Plate.35. *Capparis sikkimensis*

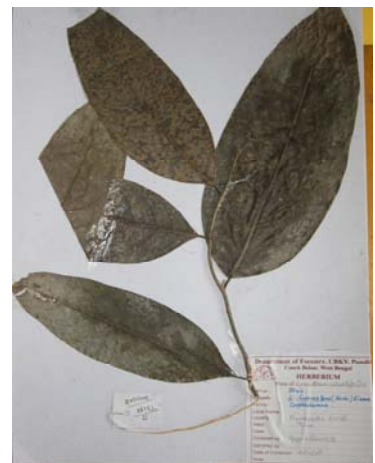


Plate.36. *Stixis suaveolens*

Plate.37. *Celastrus paniculatus*



Plate.38. *Chloranthus* spp.



Plate.39. *Termenalia bellirica*



Plate.40. *Floscopa scandens*



Plate.41. *Murdannia nudiflora*



Plate.424. *Ipomoea hirta*



Plate.43. *Porana paniculata*



Plate.44. *Ophiopogon wallichianus*



Plate.45. *Hodgsonia macrocarpa*

Plate.46. *Momordica charantia*



Plate.47. *Mucia maderaspatane*



Plate.48. *Cyperus cuspidatus*



Plate.49. *Cyperus rotandus*



Plate.50. *Cyperus spp.*



Plate.51. *Scleria terrestris*

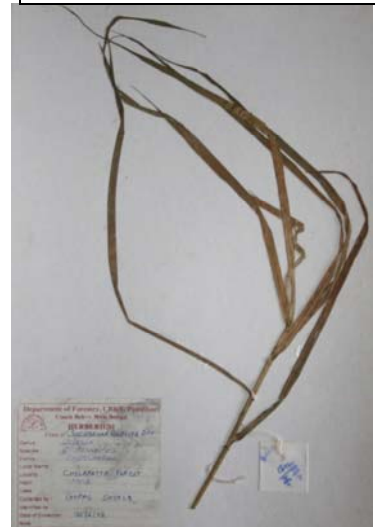


Plate.52. *Dillenia pentagyna*



Plate.53. *Tetracera sarmentosa*



Plate.54. *Dioscorea belophylla*

Plate.55. *Dioscorea hispida*



Plate.56. *Dioscorea pubera*



Plate.57. *Shorea robusta*



Plate.58. *Dracaena angustifolia*

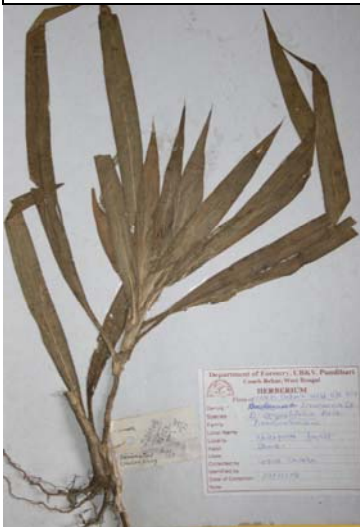


Plate.59. *Drynaria propinqua*

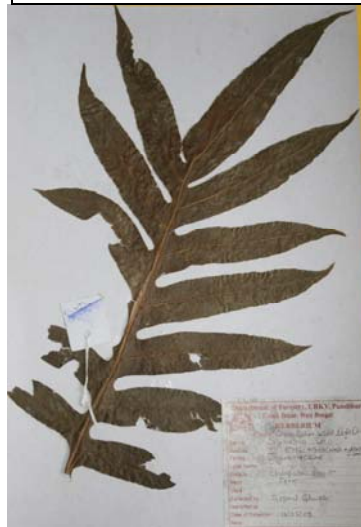


Plate.60. *Dryopteris sikkimensis*



Plate.61. *Ehretia acuminata*

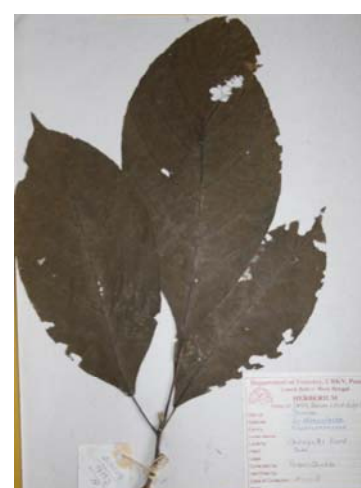


Plate.62 Sloania Sterculiaceae



Plate.63. *Elaeocarpus lanceifolius*

Plate.64. *Antidesma acidum*



Plate.65. *Baliospermum montanum*



Plate.66. *Croton caudatus*



Plate.67. *Macaranga denticulata*



Plate.68. *Macaranga indica*

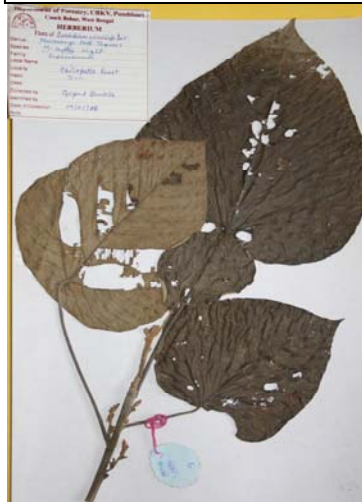


Plate.69. *Mallotus philippensis*



Plate.70. *Phyllanthus reticulatus*



Plate.71. *Sapium baccatum*



Plate.72. *Ricinus communis*

Plate.73. *Albizia lucidior*



Plate.74. *Bauhinia variegata*



Plate.75. *Bauhinia scandens*



Plate.76. *Dalbergia stipulacea*

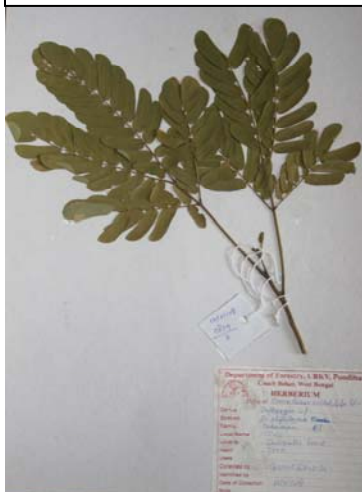


Plate.77. *Desmodium gangeticum*



Plate.78. *Desmodium heterocarpon*

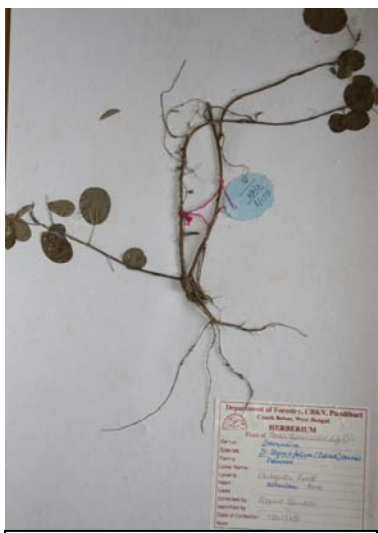


Plate.79. *Desmodium styracifolium*



Plate.80. *Desmodium triquetrum*



Plate.81. *Mimosa pudica*

Plate.82. *Albizia chinensis*



Plate.83. *Castanopsis indica*



Plate.84. *Castanopsis indica*



Plate.85. *Aeschynanthus acuminatus*



Plate.86. *Helminthostachys zeylanica*



Plate.87. *Curculigo orchides*



Plate.87. *Curculigo* sp.



Plate.88. *Gomphostemma ovata*



Plate.89. *Plectranthus barbatus*

Plate.90. *Pogostemon benghalensis*



Plate.91. *Actinodaphne obovata*



Plate.92. *Actinodaphne sikkimensis*



Plate.93. *Beilschmiedia dalzellii*

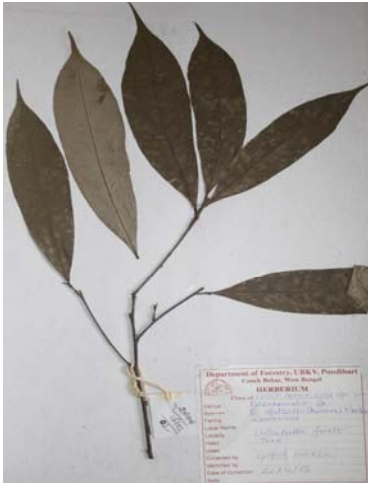


Plate.94. *Cinnadenia paniculata*



Plate.95. *Cinnamomum bejolghota*



Plate.96. *Litsea cubeba*



Plate.97. *Litsea glutinosa*

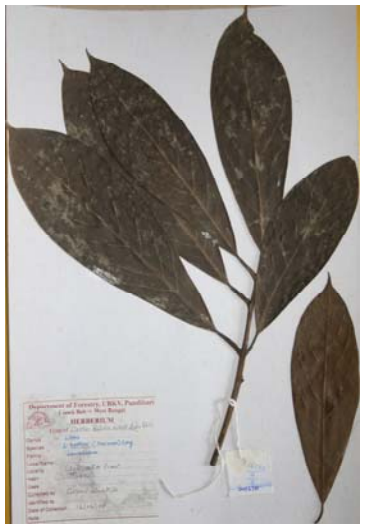


Plate.98. *Litsea hookeri*

Plate.99. *Litsea lacta*



Plate.100. *Litsea monopetala*



Plate.101. *Litsea panamanja*



Plate.102. *Litsea salicifolia*



Plate.103. *Persea glaucescens*



Plate.104. *Persea odoratissima*

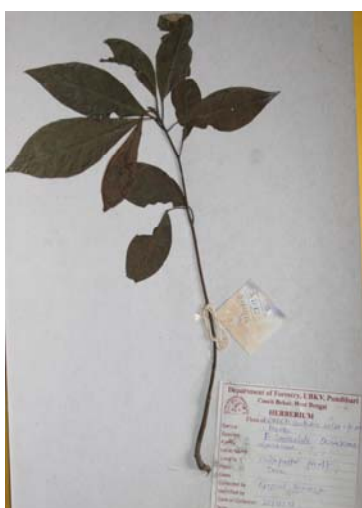


Plate 105 *Phoebe lanceolata*



Plate.106. *Careya arborea*



Plate.107. *Leea compactiflora*

Plate.108. *Leea guineensis*



Plate.109. *Leea indica*



Plate.110. *Bridelia sikkimensis*

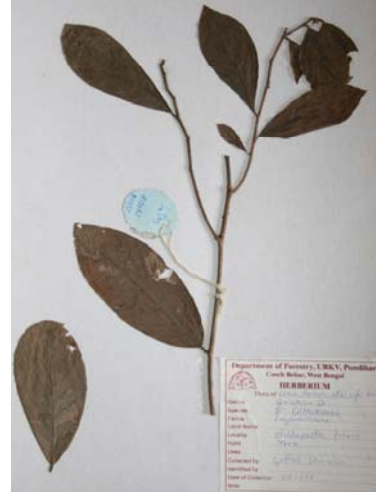


Plate.111. *Lygodium flexuosum*



Plate.112. *Lygodium japonicum*



Plate.113. *Lygodium microphyllum*



Plate.113. *Lygodium circinatum*



Plate.114. *Lagerstroemia parviflora*



Plate.115. *Michelia champaca*

Plate.116. *Urena lobata*



Plate.117. *Abelmoschus moschatus*



Plate.118. *Mlasmoma malabathricum*



Plate.119. *Pericampylus glaucus*



Plate.120. *Cedrela toona*



Plate.121. *Chukrasia tabularis*



Plate.122. *Acacia concinna*



Plate.122. *Acacia concinna*



Plate.123. *Ficus hederacea*

Plate.124. *Ficus neriifolia*



Plate.125. *Ficus religiosa*



Plate.126. *Streblus asper*



Plate.127. *Morus laevigata*



Plate.128. *Ardisia solanacea*



Plate.129. *Ardisia thyrsoiflorus*



Plate.130. *Myristica eratica*



Plate.131. *Myristica longifolia*



Plate.132. *Syzygium operculatum*

Plate.133. *Syzygium claviflorum*



Plate.134. *Syzygium cumunii*



Plate.135. *Syzygium formosum*



Plate.136. *Eugenia cumini*



Plate.137. *Bulbophyllum bailegi*



Plate.138. *Phaus flavus*



Plate.139. *Piper attenuatum*



Plate.140. *Piper peepuloides*



Plate.141. *Piper sylaticum*



Plate.142. *Lindernia crustacea*



Plate.143. *Acroceras zizanioides*



Plate.144. *Angiopteris evecta*



Plate.145. *Axonopus compressus*



Plate.146. *Brachiaria milliformis*



Plate.146. *Capillipedium assimile*



Plate.147. *Degitaria ciliaris*



Plate.148. *N andropogonifolius*



Plate.149. *Colysis decurrens*

Plate.150. *Polygata glomerata*



Plate.151. *Pteris aspericaulis*



Plate.151. *Pteris biaurita*



Plate.152. *Pteris himalayensis*



Plate.153. *Pteris linearis*



Plate.154. *Pteris semipinnata*



Plate.155. *Naravelia zeylanica*



Plate.156. *Gouania leptostachya*

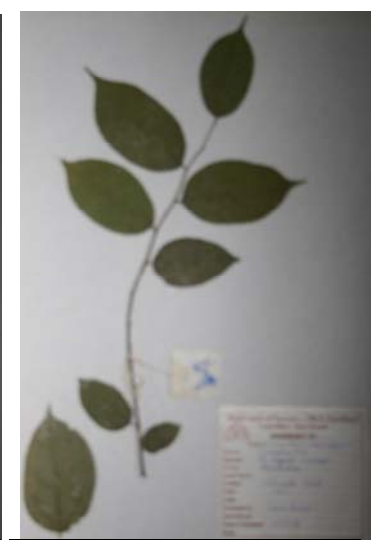


Plate.157. *Ziziphus rugosa*

Plate.158. *Borreria ocimoides*



Plate.159. *Haldina cordifolia*



Plate.160. *Hedyotis scandens*



Plate.161. *Hyptianthera stricta*



Plate.162. *Ixora javanica*



Plate.163. *Ixora nigricans*



Plate.164. *Meyna spinosa*



Plate.165. *Morinda angustifolia*



Plate.166. *Mussaenda roxburghii*

Plate.167. *Neolamarikia kadamba*



Plate.168. *Psilanthus bengalensis*



Plate.169. *Psychotria calocarpa*



Plate.170. *Psychotria erratica*

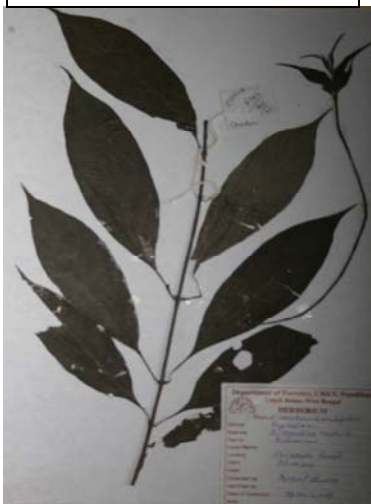


Plate.171. *Uncaria scandens*



Plate.172. *Uncaria rusiacum*

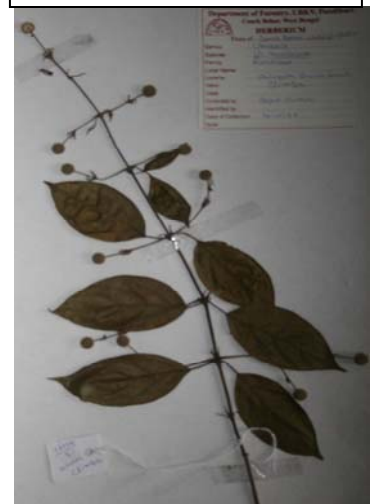


Plate.173. *Glycosmis pentaphylla*



Plate.174. *Zanthoxylum rhetsa*



Plate.175. *Aegle marmelos*

Plate.176. *Carallia brachiata*



Plate.177. *Meliosma pinnata*



Plate.178. *Lindernia ciliata*

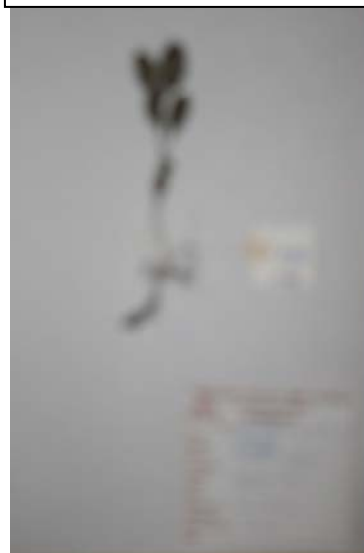


Plate.179. *Smilax aspericaulis*



Plate.180. *Smilax ovalifolia*



Plate.181. *Smilax perfoliata*



Plate.182. *Ardisia solanacea*



Plate.183. *Solanum khasianum*



Plate.184. *Solanum xanthocarpum*

Plate.185. *Pterygota alata*



Plate.186. *Sterculia vilosa*



Plate.187. *Tetracera sarmentosa*



Plate.188. *Eurya cerasifolia*



Plate.189. *Schima wallichii*



Plate.200. *Cyclosorus holttumii*



Plate.200. *Cyclosorus holttumii*



Plate.201. *Cyclosorus mantoniae*



Plate.202. *Pronephrium nudatum*

Plate.203. *Callicarpa longifolia*



Plate.204. *Callicarpa tongifolia*



Plate.205. *Clerodendrum chinense*



Plate.206. *Clerodendrum viscosum*



Plate.207. *Gmelina arborea*



Plate.208. *Tectona grandis*



Plate.209. *Ampelocissus* sp.



Plate.210. *Cayratia trifolia*



Plate.211. *Cissus repens*

Plate.212. *Tetragastium campylocarpum*



Plate.213. *Tetragastium serrulatum*



Plate.214. *Alpinia nigra*



Plate.215. *Globba macroclada*



Plate.216. *Globba macroclada*



Plate.217. *Globba macroclada*



Plate.218. *Globba macroclada*

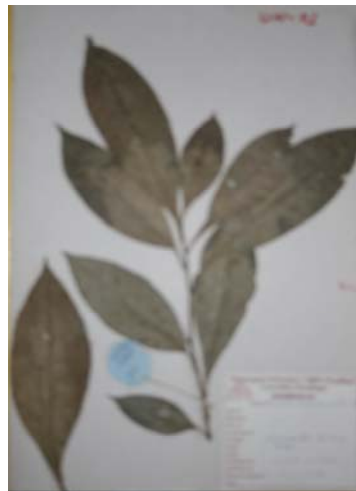


Plate.219. UN



Plate.220. UN

Plate.221. UN



Plate.222. UN



Plate.223. UN



Plate.224. UN



Plate.225. UN



Plate.226. UN



Plate.227. UN

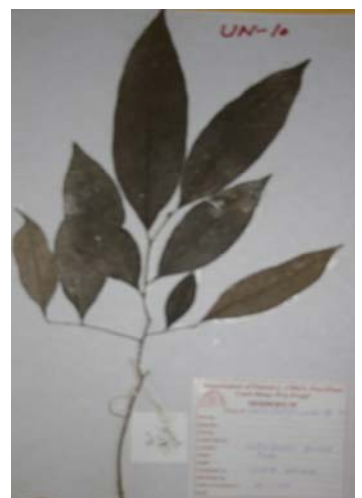


Plate.228. UN



Plate.229. UN

Plate.230. UN



Plate.231. UN



Plate.232. UN



Plate.233. UN



Plate.234. UN



Plate.235. UN



Plate.236. UN



Plate.237. UN



Plate.238. UN

Plate.239. UN



Plate.240. UN



Plate.241. UN



Plate.242. UN

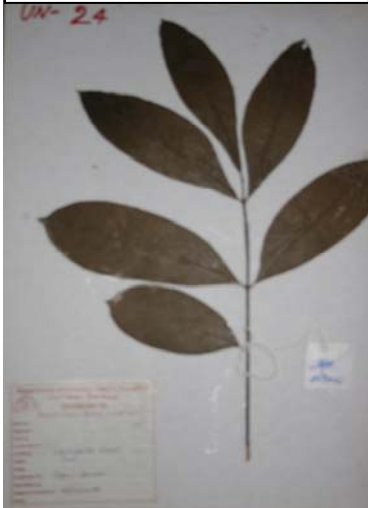


Plate.243. UN



Plate.244. UN



Plate.245. UN



Plate.246. UN



Plate.247. UN

Plate.248. UN-30



Plate.249. UN-31



Plate.250. UN-32



Plate.251. UN



Plate.252. UN



Plate.253. UN



Plate.254. UN



Plate.255. UN



Plate.256. UN

Plate.257. UN



Plate.258. UN



Plate.259. UN



Plate.260. UN



Plate.261. UN



Plate.262. UN



Plate.263. UN



Plate.264. UN



Plate.265. UN

Plate.266. UN



Plate.267. UN



Plate.268. UN



Plate.269. UN



F- NO = 27

GOVERNMENT OF WEST BENGAL
DIRECTORATE OF FORESTS

Office of the Principal Chief Conservator of Forests (Wildlife & Biodiversity)
& Chief Wildlife Warden, West Bengal

Rikash Bhavan, North Block, Third Floor, Saltlake City, Kolkata - 700 091

Tel No. 2334-6900/2358-3208, FAX. 91-033-23345946

e-mail <wildlife@calvsnl.net.in>



No. 2018/W/4R-1/66

Date 27/6/07

To:
Sri Gopal Shukla
Uttar Banga Krishi Viswa Vidyalaya,
Pundibari - 736 165,
Coochbehar

Sub: Research proposal on "Vegetation analysis and Production potential of Chilapata Forest Eco-system".

The Research Proposal submitted by you was discussed in detail by the Research Committee. The Wildlife Wing of the Forest Directorate, Govt. of West Bengal has no objection to carry out the mentioned research.

The Committee decided to give permission only for the area outside the Jaldapara Wildlife Sanctuary. It was decided that the Researcher may approach CF, Wildlife (North) Circle for necessary permission and submit a copy of proposal to him.

The Researcher has to follow the under mentioned regulations:

- 1) Day to day work area of the Researcher should be in full knowledge of the field staff.
- 2) No wildlife material collection will be allowed from the protected area. Special permission is to be obtained for capture and release of Schedule-I and Schedule-II species.
- 3) The field research will only be allowed in the designated forest areas and special permission is required from the concerned Conservator of Forests / Divisional Forest Officer to enter the core area of the PA.
- 4) Transportation and accommodation cost to be borne by the Principal Investigator of the research project as per usual norms as applicable.
- 5) The concerned Forest Officer in-Charge should be informed prior to visit of an area.
- 6) The interim and final reports should be submitted to this office and a copy to the Park Manager. On receipt of the interim report further extension of the research project will be allowed.
- 7) The relevant provisions of Wildlife (Protection) Act, Indian Forest Act and Biodiversity Conservation Act should strictly be followed.
- 8) Government will not be responsible for any loss of life and property.
- 9) Identity card should be carried during the field visit.
- 10) All fees must be paid as per usual norms as applicable.
- 11) The Researchers are not permitted to enter the forest between sunset and sunrise.

Principal Chief Conservator of Forests
Wildlife & Bio-diversity
& Chief Wildlife Warden, West Bengal

Date 27/6/07

No. 2018(2)/W/4R-1/66

Copy forwarded for information and necessary actions, to:

- 1) The Conservator of Forests, Wildlife (North) Circle
- 2) The Divisional Forest Officer, Coochbehar Division

Principal Chief Conservator of Forests
Wildlife & Bio-diversity
& Chief Wildlife Warden, West Bengal

Received
01/8/07

11/8/07

07

Appendix-II

Botanical Name	Vernacular Name
<i>Aegle marmelos</i>	<i>Bael</i>
<i>Albizia procera</i>	<i>Sada sirish</i>
<i>Albizia lebbeck</i>	<i>Sirish</i>
<i>Alstonia scholaris</i>	<i>Chhatian</i>
<i>Amoora wallichii</i>	<i>Lali</i>
<i>Artocarpus chama</i>	<i>Latore</i>
<i>Artocarpus lakucha</i>	<i>Dahua</i>
<i>Bauhinia variegata</i>	<i>Raktokanchan</i>
<i>Bauhinia vahlii</i>	<i>Kanchan</i>
<i>Bombax ceiba</i>	<i>Simul</i>
<i>Cinnamomum bejolghota</i>	<i>Tejpata</i>
<i>Clerodendron indicum</i>	<i>Bamunhati</i>
<i>Cyperus rotandus</i>	<i>Mutha</i>
<i>Dillenia indica</i>	<i>Chalta</i>
<i>Dillenia pentagyna</i>	<i>Tantari</i>
<i>Gmelina arborea</i>	<i>Gamari</i>
<i>Lantana camara</i>	<i>Ban-tulshi</i>
<i>Mallotus repandus</i>	<i>Sindure</i>
<i>Michelia champaca</i>	<i>Champ</i>
<i>Mimosa pudica</i>	<i>Lajjabati</i>
<i>Oroxylum indicum</i>	<i>Totala</i>
<i>Ricinus communis</i>	<i>Arenda</i>
<i>Solanum xanthocarpum</i>	<i>Kantakari</i>
<i>Syzygium cumini</i>	<i>Jam</i>
<i>Termenalia bellirica</i>	<i>Bahera</i>
<i>Termenalia chebula</i>	<i>Haritaki</i>
<i>Terminalia crenulata</i>	<i>Pakasaj</i>
<i>Tinospora cordifolia</i>	<i>Gulanacha</i>
<i>Toona ciliata</i>	<i>Toon</i>
<i>Vitex negundo</i>	<i>Nisinda</i>

<i>Ziziphus mauritiana</i>	<i>Kul</i>
<i>Abelmoschus moschatus</i>	<i>Latakasturi</i>
<i>Ageratum conyzoides</i>	<i>Dochunti</i>
<i>Amoora wallichii</i>	<i>Lasue</i>
<i>Anthocephalus kadamba</i>	<i>Kadam</i>
<i>Calamus guruba</i>	<i>Murgi Bet</i>
<i>Careya arborea</i>	<i>Kumbhi</i>
<i>Chukrasia tabularis</i>	<i>Chikrasi</i>
<i>Colocasia esculenta</i>	<i>Ban-kachu</i>
<i>Diplazium esculentum</i>	<i>Dhekia sag</i>
<i>Ficus religiosa</i>	<i>Peepal</i>
<i>Lagerstroemia parviflora</i>	<i>Jarul</i>
<i>Mallotus philippensis</i>	<i>Sindure</i>
<i>Mlastoma malabathricum</i>	<i>Datrangi</i>
<i>Phlogacanthus thysiformis</i>	<i>Rambasak</i>
<i>Pterocarpus marsupium</i>	<i>Piasal</i>
<i>Saccharum spontaneum</i>	<i>Kush Mat</i>
<i>Schima wallichii</i>	<i>Chilauni</i>
<i>Shorea robusta</i>	<i>Sal</i>
<i>Solanum khasianum</i>	<i>Kantikari</i>
<i>Solanum xanthocarpum</i>	<i>Jangli baungan</i>
<i>Tectona grandis</i>	<i>Segun/Teak</i>
<i>Vitex quinata</i>	<i>Nichinda</i>
<i>Alpinia nigra</i>	<i>Purundigazi</i>
<i>Bauhinia scandens</i>	<i>Naglata</i>
<i>Clerodendrum viscosum</i>	<i>Bhat</i>
<i>Cyperus rotandus</i>	<i>Mutha</i>
<i>Desmodium gangeticum</i>	<i>Salpani</i>
<i>Dioscorea belophylla</i>	<i>Bhegur & Ghita torul</i>
<i>Litsea monopetala</i>	<i>Kutmero</i>
<i>Pterygota alata</i>	<i>Nerkeli</i>

VITA

Name of student - Gopal Shukla

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Mother's name - Smt. Shashi Devi

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Date of Birth - 12.07.1981

Permanent home address - C/o Manager Baba Viswanath
Mandir, Shahjahanpur (U.P.)

Educational Qualification

Degree	University	Year	% or OCPA
B. Sc. (Agri)	Dr. B. R. A. University, Agra	2004	68.33
M. Sc. (Forestry)	U. B. K. V. Cooch Behar	2006	7.69/10.00
Ph. D. (Forestry)	U. B. K. V. Cooch Behar	2010	7.81/10.00

Title of M. Sc. thesis

“Standardization of nursery technology of *Albizia procera* (Roxb.) Benth. for terai zone of West Bengal”

Title of Ph. D. thesis

“Biomass production and vegetation analysis of Chilapatta Reserve Forest Ecosystem of West Bengal”

Awards/Distinctions/Fellowships/Scholarships:

- NET in Forestry (ICAR) certificate holder