"BIOMASS, NET PRIMARY PRODUCTIVITY AND CARBON SEQUESTRATION IN LEGUMINOUS AND NON LEGUMINOUS TREE SPECIES IN RED LATERITIC SOIL IN CHHATTISGARH"

M. Sc. (Forestry) THESIS

by

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Santosh Kumar Dhruw

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CERTIFICATE – I

This is to certify that the thesis entitled **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh"** submitted in partial fulfillment of the requirements for the degree of **"MASTER OF SCIENCE FORESTRY"** of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **Shri Santosh Kumar Dhruw** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

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

Dr. Lalji Singh
Chairman
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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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CERTIFICATE – II

This is to certify that the thesis entitled **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh"** submitted in partial fulfilment of the requirements for the degree of **"M.Sc. in Forestry"** submitted by **Shri Santosh Kumar Dhruw** to the Indira Gandhi Agricultural University, Raipur, in partial fulfillment of the requirements for the degree of M.Sc. (Forestry) in the **Department of Forestry** has been approved by the Student's Advisory Committee after oral examination in collaboration with the external examiner.

EXTERNAL EXAMINER

Date:

Major Advisor __________________________

Head of the Department __________________________

Director of Instructions __________________________

Date:

LIST OF ABBREVIATIONS

NOTATION	DESCRIPTION
%	Percent
<	Less than
>	Greater than
^{0}C	Degree Celsius
BAR	Biomass Accumulation Ratio
C	Carbon
CG	Chhattisgarh
DBH	Diameter at Breast Height
E	East longitude
eg.	For example
et al.	Others
Fig.	Figure
g	Gram
GBH	Girth Breast Height
ha	Hectare
ht	Height
I.P.C.C.	International Panel on Climate Change
K	Potassium
kg	Kilogram
kg ha^{-1} yr^{-1}	Kilogram per hectare per year
m	Meter
Mg	Mega gram
mg ha^{-1} yr^{-1}	Milligram per hectare per year
mm	Millimeter
MPTs	Multipurpose tree species
N	Nitrogen
P	Phosphorus
t ha^{-1}	Tonne per hectare
viz.,	Namely
µg g^{-1}	Microgram per gram
µg g^{-1} mo^{-1}	Microgram per gram per month

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CHAPTER - I

INTRODUCTION

The world over maintenance of soil fertility and regeneration of wasteland have become a crucial issues in meeting the biomass needs for food, fodder, fiber and preserving environment and ecology. These problems are increasing since last few decades due to rapid expansion of industrialization, mining activity and population pressure and further aggravate the problem of land degradation, sodification etc. Wastelands have poor physicochemical properties.

Out of India's total (329 million hactare) geographical area, 187.7m ha (57 per cent) land presently suffer from various kind of degradation problems (Paroda, 1998). Ravine shallow gravely red soil and rocky areas of semiarid region, hot desert and sand dunes, cold desert and wet land etc, comes under wastelands. Lateritic soil of Chhattisgarh plains of Chhattisgarh State (India), popularly known as Bhata lands (*Entisols*), is an important category of wastelands. In Chhattisgarh plains, more than 20 per cent of land area falls under red lateritic soil, which occupies about 369850 hactares of total geographical area of state (Verma *et al.*, 1998). These lands have gentle slopes with undulating topography (Pofali and Bhattacharjee, 1970). The soil is full of gravels and sub-soil layers are hard and compact forming even lateritic pans at some places (Singh and Totey, 1985).

The biological reclamation of these soils require vegetation with plant, which can grow in low fertile soil and improve the soil health. Tree planted on degraded lands could accompany significant tangible (production of fuel, fodder, fiber and other economic products) and intangible (carbon sequestration, hydrological balance, soil fertility recovery and slope stability) benefit securing the interests of both local and global communities. (Haughton, 1996, Montangnini and Porras, 1998, Maikhuri *et al.*, 2000).

One of the major issues of global carbon concern today is rapidly increasing level of CO_2 (@ 2 ppm yr^{-1}) in the atmosphere and its potential to change the world climate. Elevated levels of CO_2 and other green house gases in the atmosphere have increased global average surface temperature by 0.6 ± 0.2^0C (IPCC, 1999). The rising CO_2 levels have severe implications on the functioning of physical and biological systems of the world. In order to mitigate this problem, IPCC (1996) has advocated for an increase in the size of the carbon pool through massive afforestation and reforestation besides maintaining the existing C pools in terrestrial ecosystem. During last few decades, the rapid land use and land cover change has resulted in large scale C degradation in tropical ecosystems. Therefore suitable land use system that enhance carbon sequestration are essential for maintaining the C balance in the region.

Trees play a vital role in mitigating the dverse effect of environmental degradation and increasing concentration of carbon dioxide in the atmosphere and also its consequence on climatic change. It promotes the search for suitable method to sequester the carbon into soil and plant biomass. Tree based land use practice could be one among the viable alternative to store atmospheric carbon dioxide due to its cost effectiveness, high potential rate of carbon uptake and associated environmental as well as social benefits (Costa, 1996). Such practices could not only render economic benefit through increasing supplies of fuel wood, fodder, fiber, timber, medicine and other non wood products etc, but also to some extent ecological services by improving the hydrological balance, nutrient cycling and microclimate amelioration, conserving biodiversity and consequently maintaining the habitability of a region (Dixon *et al.,* 1994; Maikhuri *et al.,* 2000; Swamy *et al.,* 2003b). Tropical forest is one of the richest and complex terrestrial ecosystem, approximately 50% of the world living terrestrial carbon sinks. According to Sharma *et al.,* 1992. tropical forest i.e. moist and dry forest accounts for approximately 60% of global forests. The fast growing trees also having more potential to capture and store the atmospheric CO_2 at faster rate in comparison to slow growing species.

Biomass studies are important for studying the productivity, nutrient dynamics and fixation of rotation in tree stands. These studies are essential for sufficient management of forest plantation. According to Turner and Cole (1973), estimate of forest biomass and its distribution are essential for the understanding of many aspects of forest ecology and ecosystem dynamics as they provide a basis for determination of productivity, energy flow and chemical composition in mineral cycling studies. Biomass data are prerequisite for determining the storage and flux of biological material in ecosystem. According to Swank and Schreuder (1974), the quantity of biomass per unit area constitutes the primary inventory data needed to understand the flow of nutrients and water through forest ecosystem. Net primary productivity is considered to be measure of the efficiency of vegetation to energy and its biomass. The NPP is the energy source which sustain the life of all heterotrophs in the ecosystem. According to Lugo (1992), Plantation are an ideal subject for ecological studies at ecosystem level due to following reasons. First, their age and species composition are known and controlled from the time forest is planted. Second, plantations are simple ecosystem from a structural perspective and provide contrast to the inherent structural complexity to native forest. Third, plantation can be used to match the age, edaphic and climatic characteristic and used history of secondary forest. Finally, understanding the ecological characteristics of the tree plantation is also important because high rates of tropical forest destruction, energy shortages in the tropics and need to restore degraded land to forest production have forced an increase in the rate of plantation establishment in the tropics (Brown *et al.,* 1986) which has more than doubled between the 1960 and 1980 to ≈ 11 x 10^6 ha or ≈ of the total tropical forest area.

The multipurpose trees provide direct, indirect tangible and intangible benefits to the human beings. The present study deals with the one non leguminous (*Tectona grandis*) and two leguminous (*Dalbergia sissoo* and *Cassia siamia*).

Above-mentioned species have been planted in large areas in state of Chhattisgarh either by state forest Department or by private growers under wastelands, community lands, roadside, field bunds etc. However, the actual potential of these species for biomass and production is not scientifically documented So for. Hence, realizing the importance of the species for the fuelwood, energy and timber requirements the present investigation entitled **"Biomass, Net Primary Productivity and Carbon Sequestration in**

Leguminous and Non Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh" was carried out in the multipurpose tree plantation near Jindal Steel Plant Raipur Chhattisgarh from May 2004 – April 2005 with the following objectives:

1. To study the growth and biomass accumulation pattern of leguminous and non-leguminous trees
2. To find out the net primary productivity of leguminous and non leguminous tree species
3. To quantify and compare the carbon storage and carbon sequestration in leguminous and non-leguminous tree species.

CHAPTER – II

REVIEW OF LITERATURES

In this chapter an attempt has been made to review the work on **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree species in Red Lateritic Soil in Chhattisgarh"**. The literature is broadly reviewed under the following major aspects.

2.1 Morphological growth and biomass accumulation of leguminous and non leguminous trees

2.2 Carbon sequestration and nutrient storage in leguminous and non leguminous multipurpose tree (MPTs)

2.3 Net primary productivity of leguminous and non leguminous tree species

2.1 Morphological growth and biomass accumulation of leguminous and non leguminous trees

The morphological growth and biomass depend on the genetic potential of species, site characteristics and management practices adopted. Choice of species plays a key role and influences both trajectories of growth rate and biomass production. Generally, the growth rates are higher when allow to grow in fertile site than degraded land.

Anderson (1970) evaluated that the estimation of biomass is essential for determining the storage and flux of biological nutrients in an ecosystem and for understanding the dynamics of the ecosystem. The quantity of tree biomass per unit area of land constitutes the primary inventory data needed to understand the flow of materials and water through forest ecosystem (Swank and Schrcuber 1974). Biomass study becomes compounded, if forest biomass is to be measured and analysed in its proper context as a part of production, the every basis of the functioning of ecosystem.

Turner and Cole (1973) have emphasized the need for estimation of forest biomass and its several aspects for forest ecology and ecosystem dynamics, as they can provide a basis for determination of productivity, energy flow and chemical composition in mineral cycling studies.

Singh (1981) studied the effect of the growing space index (crown volume and DBH ratio) on the percentage distribution of biomass in different components of *Chirpine* plantations. The total aboveground biomass increased as the social status of the trees improved upto dominant and beyond that it decreased as the branch wood increased with an increased in the growing apace index upto 1.80 than farmer increased in the later.

Raizada and Srivastava (1985) studied 14-year-old *Populus deltoids* plantations for biomass accumulation having density 324 trees ha^{-1}, where in total biomass was 55 t ha^{-1} with an above ground biomass of 45 t ha^{-1} and total root biomass of 10 t ha^{-1}. Allometric equations were developed to relate tree dimensions with biomass.

Pandey *et al.* (1986) reported the distribution of biomass and productivity in various tree components and productivity in an age series plantation of *Eucalyptus* and *Acacia auriculiformis*. The total shoot biomass which increased more than three times from 3 year (6.59 kg $tree^{-1}$) to 7 year (19.37 kg $tree^{-1}$) of age in *Eucalyptus* and nearly five times from 3 years

(4.55 kg tree^{-1}) to 7 year (19.83kg tree^{-1}) of age in *A. auriculiformis*. For comparable age, the utilizable biomass recorded for *eucalyptus* was higher than *A. auriculiformis*. The maximum biomass produced at the age of 5 year in *Eucalyptus* is also discussed.

Bisht *et al.* (1989) studied 18 year old *Eucalyptus* hybrid plantation raised in foot hills of Nainital and reported that the total above ground biomass were was 110.0 t ha^{-1}. Whereas, maximum and minimum above ground biomass were 35505.7 kg ha^{-1} and 755.3 kg ha^{-1}, respectively. Where the maximum biomass was produced by bole (70.6 to 81.9 per cent), while other tree components produced more or less similar biomass.

Pal and Raturi (1989) raised indigenous tree *Acacia nilotica* as energy plantation and harvested 48.25 t ha^{-1} biomass in short rotation (3-years) where the bole wood alone contributed about 44.1 per cent and branch amounted 30.2 per cent as major produce. Contribution of root, bole-bark, and leaf were 14.2, 9.8 and 1.6 per cent, respectively.

Gairola *et al*. (1990) studied the biomass production in one year old plantation of ten multipurpose tree species viz., *Bauhinia racemosa, Acacia catechu, Ougeniia dalbergioides, Celtis austalis*, *Bauhinia retusa*, *Grewia optiva*, *Sapindus mukorossi*, *Bauhinia purpurea, B. variegata and Albizia lebbeck.* The highest above ground biomass (30.6 t ha^{-1}) and wood production (17.6 t ha^{-1}) were recorded by *Sapindus mukorossi*, while *Acacia catechu* accumulated least biomass (2.79 t ha^{-1}). The maximum (13.02 t ha^{-1}) leaf biomass was observed in *Sapindus mukorossi* and minimum (1.46 t ha^{-1}) in *Acacia catechu*.

Lugo *et al.* (1990) evaluated the trees of *Casuarina equisetifolia, Albizia procera, Eucalyptus robusta* and two varieties of *Leucaena leucocephala* (an exotic and a native were grown for maximum biomass production under the same climatic and edaphic condition in the Lajas valley of Puernto Rico, latitude 18^0N, longitude 67^0W) management was intensive during early growth and establishment phases. Rates of large branch/stem production (diameter > 22.5 cm) at age 5.5 year were 27.8, 20.4, 10.1, 7.7 and 5.5 t ha^{-1} yr^{-1} for Casuarina, Albizia, Eucalyptus, exotic Leucaena and native Leucaena, respectively. Stem wood biomass production of 40 tropical tree plantation established elsewhere were averaged as 7.9 t ha^{-1} yr^{-1}. Intensive management on fertile soil increases biomass yield of energy plantation but not all species respond equally well to such treatments.

Negi *et al*. (1990) estimated the biomass production in 20 year old *Tectona grandis* and *Gmelina arborea* plantation at Tripura. The plant density diameter, height and mean annual increment were 448 trees ha^{-1}, 21.1cm, 20.4m and 7.913 m^3, respectively for *T. grandis*, while corresponding values of the same were 452 trees ha^{-1}, 25.4 cm, 20.9 m and 10.48 m^3, respectively for *G. arborea*.

Singh and Puri (1990) Studied 9 year old *Populus deltoides* stand planted at three different spacing in semi-arid region of Haryana. The maximum above-ground biomass and net primary productivity in the plantation of 2 x 2m spacing were 206 t ha^{-1} and 33.3 t ha^{-1} yr^{-1}, respectively, followed by 4 x 4 m spacing with 88 t ha^{-1} and 14.2 t ha^{-1} yr^{-1}, respectively and lowest was 14 t ha^{-1} and 6.6 t ha^{-1} yr^{-1}, respectively at 6 x 6 m spacing.

Toky and Bisht (1993) estimated above ground and below ground biomass and its allocation pattern in 6-year old nine tree species such as *Acacia catechu, Albizia lebbeck, Azadirachta indica, Dalbergia sissoo, Melia azadirachta, Morus alba, Prosopis cineraria, Ziziphus mauritiana, Acacia nilotica* etc. from Arid North-Western India. The above ground biomass (kg tree^{-1}) varied from 11.6 in *Z. mauritania* to 37.5 in *Melia azaderach*. Maximum biomass (39.65%) was allocated to the boles and a lesser amount to the branches (22-40%) and roots (29%). Root biomass (kg tree^{-1}) ranged from 2.2 in *A. catechu* to 8.7 in *Albizia lebbeck*. Net primary productivity was 0.98 to 9.33 kg tree^{-1} year^{-1} across the species.

Duguma *et al.* (1994) have studied the plant height, diameter and biomass of ten multipurpose tree viz, *Acacia mangium, A. auriculiformis, Cassia siamea, Calliandra calothyrus, Paraserianthes falcatoria, Gliricida sepium, Leucaena leucocephala, Diolum guineense, Dubocia macrocrop* and *Milicia excelsa*. They found that the height and growth of *P. falcatoria* was highest (12.11m) as compared to other species. In three year plantation stem diameter was found maximum of *A. mangium* (10.59 cm) followed by *A. auriculiformis* (8.43 m). The maximum leaf biomass was observed in *C. siamea* (19.6 t ha^{-1}) followed by *A. auriculiformis* (17.6 t ha^{-1}) while the root biomass was recorded maximum in *C. siamea* (37.0 t ha^{-1}) followed by *P. falcatoria* (36.7 t ha^{-1})) after 3 years of plantation.

Nwoboshi (1994) reported the growth and biomass production in four to seven year old plantation of *Gmelina arborea* at Subri and for Mango of Ghana, South Africa. The mean height increased from 16.6 m at 4th year to 19.6 m at 7 year. Corresponding dimensions were increased from 10.0 to

23.0 cm in diameter, 19.0 to 20.0 m^2 ha^{-1} in basal area, 200.0 to 274.0 m^3 ha^{-1} in volume and 68.0 to 119.0 t ha^{-1} in dry matter content. South Mango crops were slightly lower in height and volume growth than Khamar at Subri.

Lodhiyal *et al.* (1995) estimated the biomass and net primary productivity (NPP) in five to eight year old poplar (*Populus deltoides* Marsh, Clone D 121) plantation raised at Tarai belt of Kumaun region in Central Himalayan, India. The total biomass increased from 84.0 t ha^{-1} in five year old to 170.0 t ha^{-1} in eight year old plantation and NPP from 16.8 t ha^{-1} yr^{-1} in five year old to 21.8 t ha^{-1} in eight year old plantations.

Adu-Annig *at al.* (1995) observed above–ground biomass accumulation and distribution of 34 year-old *Anogeissus liocarpus*, 16 year old *Tectona grandis* and 10 year-old *Azadirachta indica* grown in the rudan savanna of Ghana. The mean tree biomass was 29.1, 8.6 and 77.0 kg with share of 1.5 and 8 per cent leaf component and 99, 95 and 92 per cent woody component in *A leiocarpus, T. grandis* and *A. indica*, respectively.

Sharma *et al*. (1995) studied growth and biomass of 5 year-old plantation with *Amoora walichii, Callicarpa arborea, Ficus fistalosa, Gmelina arborea* and *Vatica lunceaefolia* at five different spacing. Among these species maximum pulpable dry biomass was recorded in *V. lunceaefolia* (108.0 t ha^{-1}) and the minimum was recorded in *F. fistalosa* (80.1t ha^{-1}), at 1 x 1m spacing, while in case of wider spacing (2 x 2 m) it was maximum in *G. arborea* (40.4 t ha^{-1}) and minimum in *A. walichii* (21.8 t ha^{-1}). The growth and biomass accumulation of *Gmelina arborea* in Ghana, Africa was reported by Nwoboshi (1994). In these studies, the mean height of trees increased from 16.6m to 19.6 m between 4 to 7 year. Similarly the tree dimensions were also increased in respect to volume and dry matter content from 200 to 274 m^3 t ha^{-1} and 68 to 11.9 t ha^{-1}, respectively.

Upadhyaya and Soni (1997) reported the growth and dry matter accumulation in *Eucalyptus camandulensis* grown under irrigated condition at Rajasthan. After five year, average girth and height of the plantation were recorded as 13.55 cm and 12.01 m, respectively. The higher girth classes contained higher percent of bole wood and utilizable biomass. The total oven dry biomass yield was 185.12 t ha^{-1}, whereas utilizable biomass was 147.19 t ha^{-1}.

Lodhiyal and Lodhiyal (1997) recorded variation in biomass and net primary productivity in short rotation high density plantation of *Populus deltoides* in Tarai region of Himalayan, India. The total vegetation biomass increased from 12.0 t ha^{-1} in one year old to 32.4 t ha^{-1} in four-year-old plantation. The biomass accumulation ratio (BAR) for different tree components increased with an increase in the plantation age. The BAR ranged from 0.6 in one year old to 3.7 in four year old plantation.

Pacholi and Pandey (1998) studied the impact of plantation density on biomass production in *Dalbergia sissoo.* The above ground biomass was maximum (104.6 t ha^{-1}) in 2 m x 2 m spacing plantation while the above ground biomass decreased as spacing increased.

Singh *et al.* (1998) evaluated the growth performance of fifteen MPTs in an experiment conducted at ICAR Research Complex, Manipal for identifying the trees, which yielded higher fuel wood, fodder, pole, timber etc. The maximum height (9.46 m), girth (89.67 cm) and number of branches, were recorded in *Grewia optiva* followed by *Ficus hispida, Celtis* *australis* and *Ailanthus excelsa*. Minimum canopy (42.44 m^2) was observed in *Ficus hispida,* while crown height (6.69 m) in *G. optiva*. The highest fodder yield (95.5 kg $tree^{-1}$) was recorded in *G. optiva,* whereas total dry matter production (50.3 kg $tree^{-1}$) in *F. hispida*.

Singh and Singh (1998) conducted trial of eight forest tree species, viz., *Dalbergia sissoo, Hardwickia binata, Albizia lebbeck, A. procera, Gmellia arborea, Emblica officinalis, Casuarina equisetifolia* and *Cassia siamea* at *Bhata* wasteland of Chhattisgarh plains. Mean annual biomass production at the age of 2.5 and 4.5 year were maximum (1274 and 4423.7 g $plant^{-1}$), respectively in *G. arborea* followed by *E. officinalis* (797.9 and 2896.4 g $plant^{-1}$) and *A. lebbeck* (561 and 2259 g $plant^{-1}$). They also observed that inter relationship of nutrient concentration in plant exhibited statistically significant positive correlation of Ca with N, P, K and significant negative correlation of N, with Mg.

Singh and Singh (1999) studied the growth performance of selected native and exotic species on coal mine spoils. They evaluated the height among six native species ranged from 4.22 meters for *Dalbergia latifolia* to 6.79 meter for *Dalbergia sissoo* and among exotic species it ranged from 4.66 meter for *Cassia auriculiformis* to 4.9 meter for *Eucalyptus* hybrid. The girth was maximum (18.2 cm) in *Dalbergia latifolia* among native species. Among exotic species it was minimum (19.2 cm) in *Cassia siamea* and maximum (26.6 cm) in *Eucalyptus* hybrid.

Kanmegne *et al*. (2000) evaluated the growth performance in aluminum toxic soils of humid tropics at Nkoemvone, Southern Cameroon. Excellent growth in height and stem diameter was observed in *Indigotera* *zollingeriana, Ingo edulis, Grewia mollis* and *Pterocarpus santalinoides* after 20 months of planting. The height ranged from 6 to 19 m and diameter between 8 and 10 cm. *Ingo edulis* and *Grewia mollis* produced the higher total biomass (61 and 39 t ha^{-1}) compared to other species.

Singh and Singh (2000) studied the irrigated plantation of *D. sissoo* and observed the significant variation in the plant height due to stand age. The height of the plants varied from 6.9 m in 4 year stand to 16.0 m in 30 year stand and showed gradual increase in height with stand age. Height and stand age were positively correlated. The DBH was minimum as 8.9 cm and maximum as 28.6 cm in 30 year old stand.

Kushwaha (2001) carried out the studies to evaluate the performance of *Gmelina arborea* for growth as well as nutrient accumulation on Bhata soil of Chhattisgarh plains. Result of six year-old plantation showed that stand attained 14.1 cm DBH, 9.3 m total height and produced 57.38 t ha^{-1} total biomass. The contribution of stem, branch, root and leaf were 56.2, 18.7, 18.4 and 6.8 per cent, respectively of the total biomass. In case of N, P, K foliage contributed 30.3, 23.3 and 12 percent respectively, while these were 43.0, 45.3 and 54.3 per cent in stem. Roots possessed to have 13.3, 16.6 and 18.2 per cent contents of N, P and K, respectively.

Swamy *et al.* (2003) estimated the above ground and below ground biomass production, coarse and fine root distribution in a 4 year–old *Gmelina arborea* planted at spacing of 2 x 2 m, 2 x 3 m, 2 x 4 m and 2 x 5 m under agriculture system. The total biomass (both above the below ground) varied from 10.89 t ha^{-1} to 3.68 t ha^{-1} depending on the tree density. Coarse root biomass decreased with increasing the spacing from 1.419 t ha^{-1} in the stand of 2 x 2 to 0.886 t ha^{-1} in the stand of 2 x 5 m.

2.2 Carbon sequestration and nutrient storage in leguminous and non leguminous multipurpose tree (MPTs)

Global concern over increasing concentration of carbon dioxide in the atmosphere and its consequences on climatic change has prompted to search suitable method of sequestering carbon in plant biomass. The carbon sequestration is a process, where atmospheric carbon is locked in different components of vegetation (both in above and below ground components) dead organic matter, soil (litter, dead wood and mineral soil) and durable wood products. Tree based land use practices could be one among the best method to store atmospheric carbon dioxide due to its cost effectiveness, high potential rate of carbon uptake and associated environmental as well as social benefits (Costa, 1996; Zan *et al.* 2001; Swamy *et al*. 2003 b). Under such system the carbon sequestration depend on type of system (Tree species and density of trees). The carbon duration is indirectly linked with nutrient uptake and their allocation pattern in different components of trees. The nutrient uptake is closely related to C:N, C:P and C:K ratio in plant and soil components. Therefore, to understand complex relationship between carbon sequestration and nutrient budgets are essentials for evolving site-specific nutrient management strategies for maximum biomass production and carbon storage.

Lugo *et al.* (1988) studied the variation of carbon sequestration in different tree plantation in tropics. *Eucalyptus* plantation stored the highest carbon (4.5-14 Mg C ha^{-1} yr^{-1}) in 5.16 year old followed by tropical pines (3-12 Mg C ha^{-1} yr^{-1} in 5-30 year old plantation, whereas the carbon storage was lowest (2-4 Mg C ha^{-1} yr^{-1} in 25-75) year-old teak plantation.

Schroeder (1992) compared the carbon sequestration in different agroclimatic zone. Tropics stored highest amount of carbon (10 Mg ha^{-1} yr^{-1}) in 5 year cutting cycle, while the system in sub-humid tropics accumulated upto 6 Mg C ha^{-1} yr^{-1}. The system in semi-arid tropics had sequestered lowest amount of carbon (2.6 Mg C ha^{-1} yr^{-1}).

Duguma *et al*. (1994) studied the nutrient concentration of five multipurpose tree species grown on sodic soil. N, P and Ca observed in *C. siamia*, were 416, 41 and 286 kg ha^{-1}, respectively were maximum *P. falcatoria*, N and C 416.4 and 199 kg ha^{-1} while the K maximum 135 kg ha^{-1} in *A. auriculiformis*. In *P. falcatoria* they found maximum N and C (416.4 and 199 kg ha^{-1}) while maximum K (135 kg ha^{-1}) in *A. auriculiformis*.

Nilsson and Schopfhauser (1995) reported above ground carbon accumulation accounted 10 Mg ha^{-1} yr^{-1} in coniferous plantation at Australia and New Zealand 1.5 to 4.5 Mg ha^{-1} yr^{-1} in coniferous temperate plantation of Europe and the United States, 0.9 to 1.2 Mg ha^{-1} yr^{-1} in Canada and the farmer Soviet Union and 6.4 to 10.0 Mg ha^{-1} yr^{-1} in tropical Asia, Africa and Latin America.

Pacholi and Pandey (1998) studied the nutrient content in *D. sissoo* in different density plantation. Nutrients like N, P, K and Mg were 1020.0, 50.6, 215.1, 621.9 and 106.3 kg ha^{-1}, respectively in 2 x 2 m spacing followed by 804.4, 39.9, 169.2, 491.6, and 83.9 kg ha^{-1} in 3 x 3 m spacing. In wider spacing the concentration of nutrient was increased.

Pal *et al*. (1999) evaluated that growth of thirteen tree species in red lateritic tract in Jhargram district in West Bengal, India. Among different species, *Eucalyptus* hybrid, *Acacia auriculiformis, Leucaena leucocephala* and *Gmelina arborea* were found as fast growing species, while *Albizia lebbeck*, *Sapindus mukorossi, Holarrhena antidysentrica* and *Lagerstromia* species as slow growing species.

Shepherd and Moutagnini (1999) studied above ground carbon sequestration potential in mixed and pure tree plantation in humid tropics. *Twelve indigenous* tree species of economic value were planted in three combinations in 1991-92. Plantations first was planted with *Jacaranda copaia, Vachysia quatemalensis, Calophllum, Brasiliense* and *Stryphonodendron microstachyum*, plantation II with *Terminalia amzonia, Dipterix panamensis, Virola koschynyi, Albizio quachapele* and plantation III of *Hyeronima aldhorneoides, Pithecellobium elegans, Genipa* a*mericana* and *Vochysia ferruginea*. They concluded that the mean annual carbon increment for plantation I ranged from 1-7 to 6-9 Mg C ha^{-1} yr^{-1} plantation I had the highest level of carbon accumulation as compared to the other plantation.

Naugraiya and Puri (1997) compared the growth and biomass production for four MPTs viz., *Dalbergia sissoo, Eucalyptus tereticornis, Gmelina arborea* and *Leucaena leucocephala* planted under high density energy plantation in red lateritic soil of Chhattisgarh plains, after 3 year planting the height of the MPTs ranged from 2.38 to 4.92 m and diameter at breast height (DBH) from 1.2 to 2.9 cm. Biomass varied from 9.96 to 21.35 q ha^{-1} for branch, 4.58 to 9.06 q ha^{-1} for leaf and 0.12 to 3.46, q ha^{-1} for fruit components respectively. The maximum growth and biomass were recorded in *L. leucocephala* followed by *G. arborea, E. tereticornis* and *D. sissoo.*

Singh and Singh (2000) studied the nutrient accumulation rate in relation to stand age on foliage in irrigated *D. sissoo* in an arid-zone. The foliar nutrient concentrations varied with the stand age. Nitrogen and potassium were decreased with stand age from 31.92 kg^{-1} to 24.27 kg^{-1} and 8.09 kg^{-1} to 4.82 kg^{-1} respectively in 4 year to 30 year except in 19 year (30.58 kg^{-1} yr^{-1}). N, Mg, P, Cu, Zn, Mn, and calcium did not showed any trend with stand age.

Norris *et al.* (2001) assessed the changes in carbon and nitrogen storage following Juniperus *virginiana* expansion into tall grass prairie. The carbon storage in above ground biomass in tall praise gross ranged from 1730 to 4110 kg carbon ha^{-1}, while in red cedar stands it ranged from 61563 to 106192 kg carbon ha^{-1} Native tall grass prairie in this region stored about 20-30 kg nitrogen ha^{-1} in above ground plant biomass compared to 467-849 kg nitrogen ha^{-1} in the red cedar stand.

Zan *et al.* (2001) compared the carbon storage in five ecosystem in South-Western Qubec that comprised two perennial crops, switch grass (*Panicum virgatum*) and Willow (*Salix alba*) and annual corn (*Zea mays*), at two site of different soil fertility, a 20 year old abandoned field and a nature hardwood forest. After 4 year corn had significantly higher levels of aboveground carbon than willow at less fertile site, but no significant differences were detected at the more fertile site. Both perennial systems had significantly higher root carbon than the corn system but switch grass had significantly higher root carbon levels below 30 cm compared with willow and corn.

Kaur *et al.* (2002) estimated the role of tree and grass species on biomass productivity, carbon sequestration and nitrogen cycling in silvipastoral system in highly sodic soil located at Saraswati reserved forest, Kurukshetra India. The total carbon storage in tree + grass system was 1.8 to 18.55 Mg carbon ha^{-1} and carbon input in net primary production varied between 0.98 to 6.50 Mg carbon ha^{-1} yr^{-1}. Carbon flux in net primary productivity increased significantly due to integration of prosodic and *Dalbergia* with grasses. Compared to only grass system, soil organic matter, biological productivity and carbon storage were greater in the silvipastoral (tree-grass) system of the total nitrogen uptake by the plant. 4 - 21 per cent was retained in the perennial tree component.

Cronan (2003) studied below ground biomass production and carbon cycling in mature Norway spruce. A partial carbon budget for Norway spruce indicated that annual needle litter fall mass as 98 g cm^3 $year^{-1}$ and annual carbon release from fresh litter decay was approximately 22 g cm^3 $year^{-1}$. During the growing season, monthly CO_2 flux from soil respiration was 69 g cm^{-2} $month^{-1}$, below ground carbon allocation to net production of root (3 mm) was 33.5 g cm^{-2} $month^{-1}$ and C release from decomposition of root (3 mm) was 31g C m^{-1} $month^{-1}$.

Lamlom and Savidge (2003) assessed the variation of carbon content in 41 coniferous softwood and heartwood North American species. The carbon in kiln dried hard wood species ranged from 46.27 to 49.97 percent and in conifers it varied from 47.21 to 52.2 per cent. The higher carbon in conifers was due to their higher lignin content (30 % vs 20 % for hardwood). Carbon content of early woods were invariably higher than those in corresponding late woods again in agreement with early wood having higher ligning content. The carbon content is widely promulgated as a generic value of wood. The carbon content varies substantially among species as well as within individual trees. Clearly also percent generic value is on over simplification of limited application in relation to global warming and the concept of “Carbon credits”.

Swamy *et al.* (2003) reported the growth, biomass, carbon storage and nutrient (N, P and K) variations in one to six year old chrono sequence plantation of *G. arborea* on three degraded red lateritic site in central India. Stand biomass ranged from 3.91 (1 year) to 53.67 Mg ha^{-1} (6 year old) and stand carbon in 6 year old plantation ranged from 24.12 to 31.12 Mg ha^{-1} at different sites. Among tree components, stem wood accounted for maximum C (56.25 % at site) followed by branches (19.8% at site 3), roots (18.51 % at site 2) and foliage (7.01 % at site 3). Mean annual C accumulation at six year age of plantation was highest in site 3 and it was 0.35, 2.66, 0.965 and 0.87 Mg ha^{-1} for leaf stem branches and roots respectively, quantity of nutrient increase with age. Total nitrogen accumulation in 6 year old stand at the 3 sites ranged from 212.9 to 279.5 kg ha^{-1} with a mean annual storage of 238.43 kg ha^{-1} and total K ranged from 170.8 to 220.5 kg ha^{-1} with mean annual storage of 189.93 kg ha^{-1}. Phosphorus accumulation was lowest with mean storage of 16.75 kg ha^{-1}. At 6 year *G. arborea* stands sequestered 31.37 Mg carbon ha^{-1}.

2.3 Net primary productivity of leguminous and non leguminous tree species

Kira *et al*. (1967) have argued that the traditional interest in forest production has centered on timber yield, but in recent years particularly since the IBP research era, attention has to cussed on estimating the production of the tree component also (branch, leaf, root, fruit etc) which share significant fractions of the total forest production.

According to Phillipson (1970) and Lieth (1973) productivity of the individual ecosystem is very variable. Biomass is obviously of equal importance. Net primary production is considered to be a measure of the efficiency of vegetation to fix energy in its biomass. The NPP is the energy source, which sustains the life of all heterotrophs through the ecosystem.

Bargali and Singh (1991) have studied the aspect of productivity and nutrient cycling in an 8 year old *Eucalyptus* plantations in a moist plain adjacent of central Himalayan, India. In their study they compared the biomass, productivity and nutrient cycling in an 8 year old. *E. tereticornis* with *Populus deltoides* plantation of the same age and natural Sal (*Shorea robusta Gaetn.* F.), forest and other natural forest of the central Himalaya found in the same region. They reported that total vegetation biomass of the *Eucalyptus* plantation (126.7 t ha^{-1}) was lower than that of the *P. deltoides* plantation (176 t ha^{-1}) and natural forest (163.4-786.7 t ha^{-1}). The primary productivity and *Eucalyptus* plantation (23.4 t ha^{-1} yr^{-1}) was comparable to that of the *P. deltoides* plantation (25 t ha^{-1} $year^{-1}$) and the natural Sal forest (22 t ha^{-1} yr^{-1}). The net nutrient uptake of *Eucalyptus* was lower than that of populus plantation and natural forest.

Toky, and Bisht (1993) studied the 6 year-old trees of nine species i.e. *Acacia catechu, A. nilotica, Albizia lebbeck, Azadirachta indica, Dalbergia sissoo, Melia azederach, Morus alba, Prosopis cineraria* and *Ziziphus mauritiana*. They evaluated the above-ground biomass which varied from 11.6 (kg/tree) to 37.5 (kg/tree) for *Z. mauritiana* and *Melia azederach*, respectively. Maximum biomass (39-65 %) was allocated to the boles and a lesser amount to the branches (22-40 %) and roots (9-29 %). Root biomass (kg/tree) ranged from 2.2 in *A. catechu* to 8.7 in *Albizia lebbeck*. Net primary production was ranged from 0.98 to 9.33 kg/tree/year across the species.

Prasad *et al.* (1998) studied the 10 year old *Eucalyptus* provenances in lateritic soil and evaluated the productivity in different provenances which varied from, 3.95 kg/tree/yr to 7.14 kg/tree/yr for lake Albacatya and Gilbert River, respectively.

Chen *et al*. (2003) studied the comparative productivity of mixed and single species stands of three forest types in British Columbia and Alberta. They observed the relative density of lodge pole pine-black spruce stand. The combination of two shade intolerant species (pine-larch) had lower stand volume, than that anticipated from single species stands. This shows that one species may inhibit the growth of other species. Mixture of shade intolerant and shade-tolerant species with different growth pattern (spruce-pine) may be more productive than single species stand in specific ecological contexts and development stages.

Pandey (2003) studied dense and open forest and they estimated the net primary productivity between 6.887 and 3.242 t ha^{-1} yr^{-1} for dense and open canopy forest, respectively. The carbon flux as NPP was 3.95 t ha^{-1} yr^{--1} and 1.56 t ha^{-1} yr^{--1}, for dense and open forest, respectively.

CHAPTER – III

MATERIAL AND METHODS

The present study on **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree Species Plantation in Red Lateritic Soil in Chhattisgarh"** was carried out during 2004-2005. The details of geographical situation of study site, climate, plantation and methods are described below:

3.1 Experimental site

Experiment was carried out during 2004-2005 in a plantation comprised of *Dalbergia sissoo* Roxb, *Cassia siamia* Lamk, *Tectona grandis* Linn. F. at Jindal plant, Raipur Chhattisgarh.

3.2 Geographical situation

Raipur is situated in the mid-eastern part of Chhattisgarh and located between 21^0 33' to 21^0 76 N latitude, 81^0 30' to 31^0 36' E longitudes with an altitude of 289.56 m above mean sea level.

3.3 Climate

The climate of study site is dry humid sub-tropical with an average rainfall of 1089.02 mm, of which more than 80 per cent is received during June to September. The relative humidity is generally maximum higher (83.5%) in July and August whereas, minimum (33%) in May and mean monthly maximum temperature varied between 27^0C (December) and 42.3^0C (May) and the minimum temperature varies between 13.2^0C (December) and 28.3^0C (May). The maximum temperature goes beyond 45^0C in May and minimum fall below 10^0C in the month of December. Mean maximum and minimum annual temperature, total annual rainfall and relative humidity for study area from the year 1995-2004 are given in Table 3.1 and Fig. 3.1.

Table 3.1: Mean annual Meteorological data of study area

Year	Maximum Temp. (^{0}C)	Minimum Temp. (^{0}C)	Total rainfall annual (mm)	Relative humidity (%)
1995	32.1	19.7	1188.7	81.66
1996	33.2	19.6	1122.8	69.66
1997	32.2	19.6	1208.4	79.90
1998	32.3	20.6	1088.0	83.41
1999	32.5	16.6	0858.8	79.40
2000	32.9	19.2	0789.1	79.42
2001	32.9	20.1	1033.2	79.01
2002	33.49	20.27	767.2	77.83
2003	32.78	20.37	1511.0	78.67
2004	32.64	19.75	1026.9	81.87

3.4 Geology

Raipur has three distinct geological formations viz., Bijapur, Cuddaph, and Dharwar, Lithologically it is classified into seven areas viz., in Raipur shale and limestone, in Ganderdehi shale, in Khairagarh sandstone, in Cuddapa chamar limestone, in Chandrapur sandstone and grit; and in Dharwar granite and geneisis.

3.5 Physiography

In Chhattisgarh plains agro climatic zones are divided in different districts viz., Raipur, Bilaspur, Durg, Rajnandgoan, Kawardha, Mahasamund, Dhamtari, Janjgir, Korba and Raigarh. This is also known as upper Mahanadi basin, which is Saucer-shaped. The longer part of this basin is undulating, plat terrain, gentle slopes from West to East. The general geological feature of the zone comprises of laterites, alluvium capping over horizontally bedded sequence of sedimentary rocks of limestone and dolomite on the top followed by limestone shade, quartzite sand stone, granite, gneisses and meta sediments of old age. These formations have very limited primary porosity and permeability to water.

3.6 Soil

The experiment was conducted on *Entisols,* which is locally known as Bhata land. It is also known as red lateritic soil. As per land used classification pattern point of view it comes under marginal wastelands. These lands have long gentle slopes with undulating topography (Pofali and Bhattacharijee, 1970). The soil having high percentage of gravels and sub soil layers are hard and compact, forming even lateritic pans at many places (Singh and Totey, 1985). In red lateritic soil the content of organic matter was very less which is responsible for causing moisture and thermal stress and affect microbial activity and the availability of nutrients and subsequently affect the growth of plants (Gupta and Aggrawal, 1988).

3.7 Characteristics of *Entisols*

The experimental site was marginal wasteland i.e. *Entisols* soil, which is reddish to dark reddish brown in colour and very shallow in depth. *Entisols* is classified as coarse, loamy, mixed hypothermic, typical ustorthents. Ustorthents are locally known as *Bhata* and have ferruginous gravels low pH (acidic highly), low nitrogen, high potassium, low phosphorus and low organic matter are the basic characteristics of *Entisols*.

3.8 Experimental detail

The present study was conducted in plantation of three multipurpose trees species at Jindal plant, Raipur (C. G.). Plate 1: showing general view of study site of plantation. The details are as follows:

Planted species	:	*Dalbergia sissoo* Roxb,
		Cassia siamia Lamk,
		Tectona grandis Linn. F.
Date of planting	:	July, 2000
Spacing	:	4.5m x 4m
Soil type	:	Red lateritic
Plantation area	:	Five acre

3.9 Species description:

Teak (*Tectona grandis* Linn.F.) is one of the most important and valuable non-leguminous timber species of the world. It belongs to the family Verbenaceae, is predominantly tropical or sub-tropical in distribution. The genus *Tectona* is represented world over by three species only, namely. *Tectona grandis* Linn. F., *Tectona hamiltonian* wall and *Tectona phillippinensis* Benth and Hooker. F. In India only *Tectona grandis* is widely distributed. In India Teak is a strong light demander and cannot withstand water logging. Teak wood is moderately hard, extremely durable and is the most important timber of India. The timber is extensively used for bridges, fibs, cabinet work, beams, railway carving ordinary work, general carpentry and ship building.

Shisham (*Dalbergia sissoo* Roxb.) is a member of leguminosae family and sub-family papilionioideae. The *Dalbergia* is named after the Swedish botanist, Nicholas Dalberg. De Candolle (1825) and Roxburgh (1882) considered it to be native of Bengal. It is moderately fast growing MPTs and grows in a subtropical to tropical climate. It is a strong light demander and good coppicer. The wood of *D. sissoo* is highly valued for furniture, constructional and general utility purposes. It possesses all the qualities required of an ideal fuel wood and its leaves are used as fodder.

Siamese senna (*Cassia siamia* larmk.) is a member of leguminous family sub-family caesalpinioideae. *Cassia siamea* is indigenous to Shri Lanka, Malaysia, Cambodia, South Burma and Southern most part of Tamil Nadu. Introduced originally as an avenue tree for road- side planting has now been extensively cultivated throughout India. *Cassia siamea* is capable of growing under a wide variety of climatic conditions of the tropics from humid to sub-humid, dry and arid. The species is strong light demander and fast–growing. The larger dimension tree are not available as the tree is generally growth for fuel wood. Occasionally, it is used for mallets, walking sticks, pit-props and posts, temporary building etc. It main use is however for fuel and charcoal.

3.9.1 Methodology

3.9.1.1 Measurement of growth parameters

Growth parameters such as GBH, total height, clean bole height, crown length and crown width were measured with standard methods.

3.9.1.2 Girth at breast height (GBH)

Girth at breast height (GBH) of standing trees were recorded with the help of measuring tap at 1.37 m above the ground level.

3.9.1.3 Total tree height

The total height of standing trees were measured with the help of a standard graduated bamboo, meter scale and 30 m long tape. The height was recorded from the base to the tip the tree.

3.9.1.4 Clean bole height

Clean bole height was measured from the base to the point of first green branch on trunk with the help of tape.

3.9.1.5. Crown length

Crown length was calculated by subtracting clean bole height from total tree height.

3.9.1.6 Crown width

Crown width was measured by fixing long graduated stick horizontally on top of the measuring pole used. The crown width was recorded in both direction and average of two were taken as crown width.

3.9.1.7 Estimation of biomass

Girth at breast height (GBH) was measured at 1.37 m height from the base of the tree using measuring tap. Girth of all the individuals in three species were distributed into 7 classes, 5 cm to 40 cm (Table 3.2).

Table 3.2 : Girth classes for three species

S. No.	Girth class in (cm)
1	5-10
2	10-15
3	15-20
4	20-25
5	25-30
6	30-35
7	35-40

For the measurement of tree biomass, Allometric equation relating GBH to dry weight were developed for each component viz., stem, branch, leaves and roots. For developing allometric equation three individual from each GBH class were harvested .The above ground part and below ground part of sampled tree were carefully separated by axe the above ground part separated into the stem, branches and leaves and below ground part (roots) were dug out upto 1 m depth and 1 m radius from the base of sampled tree. The fresh weights of all components were determined in the field. Pre-weighed composite samples from upper, middle and lower strata (about 500 g of weight) of each component of the tree were brought to the laboratory and dried to constant weight at 80^0C. Multiplication by appropriate factors yielded the weights of different components. Logarithmic regression of the form, ln Y = a + b ln x, related the dry weight of each component to mean girth at breast height (Table 3.3).

The estimate of mean biomass (by components) for each girth class was calculated by taking the mean girth for each girth class in the regression equation then this value was multiplied with the number of individuals in that girth class.

The girth class values were summed to obtain the biomass estimate for whole plantation.

Table 3.3: Allometric relationship between dry weight of different components (kg, y) and girth (cm, x) for *Tectona grandis*, *Cassia siamea* and *Dalbergia sissoo*.

Species	Stem	Root	Leaf
Tectona grandis	a – 5.668	- 4.323	- 5.290
	b 2.0164	1.485	1.788
	*r 0.888	0.900	0.780
	*P 0.006	0.000	0.007
Cassia siamea	a - 7.596	- 6.848	- 9.509
	b 2.848	2.370	2.847
	*r 0.951	0.974	0.834
	*P 0.000	0.000	0.001
Dalbergia sissoo	a - 5.560	- 8.410	- 8.120
	b 2.460	3.060	2.570
	*r 0.960	0.980	0.916
	*P 0.001	0.001	0.001

All equation are of the form ln Y = a + b ln x.
*r : Correlation coefficient
*P : P-value

3.9.1.8 Estimation of net primary productivity

The net primary productivity of plantation was measured by girth increments and biomass data. The method is briefly described below. In May 2004, 30 individual of each species were marked and their girth at breast height (GBH) were measured. The individual, selected were the representative of all the girth classes used in the biomass estimation. The GBH of marked individual were remeasured at six months interval i.e. November 2004 and in May 2005. Mean girth increment after 6 months and after 12 months for each girth class was then calculated using the allometric regression equations (Table 3.3). The girth class and subsequently biomass of stem, branch, leaves and roots in each diameter class for each species were calculated and separated from girth measurements on May 2004 (B_1); November 2004 (B_2). The net biomass accumulation for six month (B_2-B_1) and after one year biomass (B_3-B_1) were calculated. The estimation of total net primary productivity for each species was calculated by summing the NPP of trees (by components obtained form allometric equations).

3.9.1.9 Estimation of carbon

Carbon concentration was estimated by ash content method. In this method oven dried plant components (stem, branch, root and leaves) were burnt in electric furnace at 400^0C temperature, Ash content (inorganic elements in the form of oxides) left after burning was weighed and carbon concentration was calculated by using the following equation;

Carbon % = 100 – (Ash weight + molecular weight of O_2 (53.3) in $C_6H_{12}O_6$.

Carbon storage in the vegetation was calculated by multiplying biomass and carbon concentration of different component separately for respective species, whereas The carbon sequestration was determined by multiplying Net primary productivity and carbon concentration of respective species.

3.10 Chemical analysis of soil

3.10.1 Soil sampling

The soil samples were randomly collected near tree species from upper 10 cm soil layer. Soil samples of same depth in given site were thoroughly mixed and a composite sample was obtained.

3.10.2 Nutrient analysis

The collected samples were chemically analysed in triplicate. Soil pH was measured with glass electrode (soil:water ratio1:2), particle size distribution (texture analysis) by pipette method (Piper 1950). Organic carbon of the soil was determined by Walkley and Black's method. Total nitrogen was determined by Kelplus (Pelican equipment) based on micro Kjeldhal principle. The total phosphorus was determined after $HClO_4$ digestion (Jackson, 1958). Potassium was determined by flam photometer method (Jackson 1958).

CHAPTER – IV

RESULTS AND DISCUSSIONS

The finding on **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non-Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh"** is presented in this chapter. The results and discussions are divided into four following sub-heads-

1. Morphological growth and biomass accumulation pattern of leguminous and non-leguminous trees
2. Net primary productivity of leguminous and non-leguminous tree
3. Storage of carbon and carbon sequestration in leguminous and non-leguminous trees
4. Effect of species on physico-chemical properties of soil

Morphological growth and biomass accumulation pattern of leguminous and non-leguminous trees

Morphological growth

Growth performance of *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* was recorded in respect of Girth at Breast Height, clean bole height, total height, crown width and crown length.

The growth performance of leguminous (*Cassia siamia* and *Dalbergia sissoo*) and non-leguminous species (*Tectona grandis*) are presented in Table 4.1 and Fig. 4.1a - 4.1e. The GBH of leguminous and non leguminous species were varied significantly. Average girth (cm) was highest in *Cassia siamia* (18.59 cm) followed by *Dalbergia sissoo* (16.70 cm) and lowest in *Tectona grandis* (11.37 cm).

The maximum average height was measured in *Dalbergia sissoo* (4.83 m) followed by *Cassia siamia* (4.36 m) and lowest in *Tectona grandis* (3.72 m). The maximum clean bole height was recorded in *Tectona grandis* and minimum in *Cassia siamia*. The trend of average clean bole height was found as 2.91 > 1.91 > 0.81 m in *Tectona grandis*, *Dalbergia sissoo* and *Cassia siamia*, respectively. The largest crown width was produced by *Cassia siamia* (4.00 m) followed by *Dalbergia sissoo* (3.89 m) and lowest was produced by *Tectona grandis* (1.80 m) Table 4.1. The crown length were 3.55 m, 2.92 m and 0.81 m for *Cassia siamia, Dalbergia sissoo* and *Tectona grandis,* respectively.

The above observations revealed that the leguminous tree species performed better than the non leguminous trees in the Bhata land for example, *Cassia siamia* achieved maximum average GBH, crown width and crown length, *Dalbergia sissoo* was achieved maximum average total height whereas growth performance of *Tectona grandis* was poor viz., average GBH, average total height, crown width and crown length. Singh *et al.*, 1995 have shown the comparable results on growth performance on the coal mine spoil type of degraded land. Prasad and Shukla (1985) have reported better performance of *Eucalyptus species* and *Acacia auriculiformis* on Dhampuri mine spoil. Similar result was found in the study of Singh and Singh 1999, on Jayant coal mine spoile of Singrauli. They found mean circumference of 4 year *Cassia siamia*, *Dalbergia sissoo* and *Tectona grandis* were 11.28 $\pm$ 0.99, 13.36 $\pm$ 0.99 and 11.11$\pm$ 0.68 cm, respectively and mean height were

3.47 ± 0.14, 3.76 ± 0.14 and 4.71 ± 0.19 m, respectively. Mean circumference of above species in present study was 18.59, 16.70, 11.37 cm, respectively and mean height was 4.36, 4.83, 3.72 m.

Biomass accumulation pattern of leguminous and non-leguminous trees

Result on biomass accumulation of *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* is presented in Table 4.2 and Fig. 4.2 a – 4.2c.

Tectona grandis

The total biomass of *Tectona grandis* was 3.18 t ha^{-1} of which 1.75 t ha^{-1} was in above ground part and 1.43 t ha^{-1} in below ground part.

The above ground and below ground biomass of *Tectona grandis* were 55.03 per cent and 44.97 per cent, respectively of the total biomass.

The stem, leaves and root biomass of *Tectona grandis* were 1.41 t ha^{-1}, 0.34 t ha^{-1} and 1.43 t ha^{-1}, respectively and they contribute 44.34 per cent, 10.69 per cent and 44.97 per cent, respectively to the total biomass.

Cassia siamia

The total biomass of *Cassia siamia* was 6.77 t ha^{-1} of which above ground biomass was 4.89 t ha^{-1} and below ground biomass was 1.88 t ha^{-1}. The total above ground and below ground biomass accounted for 72.23 per cent and 27.77 per cent, respectively of the total biomass. The stem, leaves and root biomass of *Cassia siamia* were found 4.24 t ha^{-1}, 0.65 t ha^{-1} and 1.88 t ha^{-1}, respectively and they contribute 62.63 per cent, 9.60 per cent and 27.77 per cent, respectively of the total biomass.

Dalbergia sissoo

The total biomass of *Dalbergia sissoo* was 5.21 t ha^{-1} of which above ground and below ground biomass was estimated 3.99 t ha^{-1} and 1.22 t ha^{-1}, respectively. Of the total biomass 76.58 per cent contained in above ground parts and 23.42 per cent contained as below ground parts.

The stem, leaves and root biomass of *Dalbergia sissoo* were 3.60 t ha^{-1}, 0.39 t ha^{-1} and 1.22 t ha^{-1}, respectively and contributed 69.10 per cent, 7.49 per cent and 23.42 per cent, respectively of the total biomass.

AVERAGE TOTAL BIOMASS

The average total tree biomass (across all the three species) is given in Table (4.3). The average total biomass of all species was 5.05 t ha$^{-1.}$ The distribution of this biomass in the different components was as follows 3.08 t ha^{-1} in stem, 0.46 t ha^{-1} in leaves and 1.51 t ha^{-1} in roots. The stem, leaves and root biomass contributed 60.99 per cent, 9.11 per cent and 29.90 per cent, respectively, of the total average biomass.

The biomass of leguminous and non leguminous trees is depicted in Table 4.2 the total biomass of leguminous trees were more as compare to non leguminous tree. The data reveals that in 4 year old plantation total biomass was found in following order *Cassia siamia* > *Dalbergia sissoo* > *Tectona grandis*. The total biomass contribution of different plant part were summarized as following manner stem > root > leaves. The similar finding were reported by Singh *et al.*, 1994 in his study that stem were major contribution to the above ground biomass in almost all species. However in case of *Tectona grandis* total biomass contribution of different plant parts were summarized as following manner root > stem > leaves this may be occurred due to initial stage. The root growth of this species is more than shoot growth. In the present study above ground biomass of *Tectona grandis* (1.75 t ha^{-1}), *Cassia siamia* (4.89 t ha^{-1}) and *Dalbergia sissoo* (3.99 t ha^{-1}) is quite low compared with 8 year old plantation of multipurpose tree species on sodic land they found above ground biomass 43.1 t ha^{-1} and 62.2 t ha^{-1}, respectively for *Tectona grandis* and *Dalbergia sissoo*. It may be due to initial stage of growth, soil is very poor, because the root system is not well establish in this soil. The soil was nutritionally very poor.

Singh and Singh (1999) have reported similar result on coal mine spoil of Singrauli. They found above ground biomass at 4 year *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* were 2.22 t ha^{-1}, 1.47 t ha^{-1} and 6.13 t ha^{-1}, respectively

The below ground biomass were 1.43, 1.88 and 1.22 t ha^{-1} which accounted 44.97 per cent 27.77 per cent and 23.42 per cent for *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo*, respectively. The contribution of root was 17.11 per cent to the total biomass in 10 year old Teak (Negi *et al., 1*995). Roots contribute 23.21 per cent to the total biomass in 7 year old *Casuarinas equisetifolia* plantation (Verma *et al.*, 1987).

Find out the Net Primary Productivity of Leguminous and Non-Leguminous Tree Species

Girth increment

The number of trees marked and the percentage of total trees in each diameter classes are shown in Table 4.4 and range of mean girth increments (cm $tree^{-1}$) for six months and twelve months are shown in table 4.5.

Girth increments were measured after six and twelve month (2004-2005). Overall girth increment for Tectona grandis, cassia siamia and dalbergia sissoo tree species ranged between 1.75 and 3.53 cm, and 1.85 and 3.82 cm, after six and twelve months, respectively. The highest mean girth increment after six and twelve months in tectona grandis was 2.12 and 2.98 cm, respectively and lowest after six and twelve months was 1.75 cm and 1.85 cm. In cassia siamia the maximum mean girth increments were 3.53 cm and 3.82 cm after six month and twelve months, respectively. Whereas the lowest girth increment was 2.85 cm and 2.93 cm, after six and twelve months, respectively. In dalbergia sissoo highest mean girth increment after six and twelve months was 3.11 cm and 3.25 cm, respectively. Whereas the lowest girth increment after six and twelve months was 2.51 cm and 3.12 cm. The reliability of production estimate for a stand depends mainly on the accuracy in determination of annual biomass increments of trees. By using verneercaliper at exactly the same location on the tree, systematic errors in successive measurement of girth of marked trees were reduced. The mean girth increment ranges were 1.85-2.98, 2.93-3.82 and 3.12-3.25 cm $tree^{-1}yr^{-1}$, obtained for tectona grandis, cassia siamia and dalbergia sissoo, respectively. It may be due to the bhata soil which is nutritionally very poor. Similar results were observed by thakur and singh 2005 in eucalyptus tereticornis in 2.5 year old plantation. The mean dbh increment values of 0.6–1.8 cm and 0.8 to 3.0 cm, after six and twelve months, respectively and the result were clarify by kushawaha 2001. They observed that the increment in g. Arborea during 1 to 6 years plantation was 3.2 to 14.1 cm.

Above ground net primary productivity (NPP)

It is evident from Table 4.6 and Fig.4.6a - 4.6c that the total above ground NPP of all species ranged between 0.66-1.40 t ha^{-1} ^{yr} . In case of *Tectona grandis* total above ground NPP was 0.66 t $ha^{-1}yr^{-1}$. The contribution of stem, leaves and roots were 57.28, 6.79 and 35.92 per cent of the total NPP, respectively. In case of *Cassia siamia* total above ground NPP was 1.40 t $ha^{-1}yr^{-1}$, 62.82, 10.47 and 26.70 per cent of the total NPP, respectively were contributed by stem, leaves and roots. In case of *Dalbergia sissoo* stem leaves and roots production were 59.54, 8.39 and 32.06 per cent of the total NPP, respectively. Total above ground NPP of *Dalbergia sissoo* was 0.89 t $ha^{-1}yr^{-1}$ in the present study. The proportional share of different component of above ground NPP averaged as 59.88 per cent by stem, 8.55 per cent by leaves. Comparable result were obtained by Bargali *et al.* (1992), they studied 3 year old *Eucalyptus* plantation and reported that share of bole, branch and foliage in total NPP was 63 per cent, 12 per cent and 25 per cent, respectively

Below ground net primary productivity (NPP)

The total below ground NPP in all the three species ranged between 0.37-0.51 t $ha^{-1}yr^{-1}$ (Table 4.6). The below ground NPP of *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* were 0.37, 0.51 and 0.42 t $ha^{-1}yr^{-1}$, respectively.

Below ground NPP in present study were 35.92, 26.70 and 32.06 per cent of the total NPP for *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo*, respectively. The comparable result was reported by Bargali *et al.* (1992) in 3 year old plantation, they estimated below ground contribution to the total NPP as 26.6 per cent.

Total net primary productivity

Total NPP is the sum total of values for all components of the tree. The total NPP was between 1.03-1.91 t $ha^{-1}yr^{-1}$ for all three species (Table 4.6). The net primary productivity of *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* were 1.03, 1.91 and 1.31 t $ha^{-1}yr^{-1}$, respectively.

In present study the total NPP ranged from 1.03 to 1.91 t $ha^{-1}yr^{-1}$. The comparable result was reported by Pandey P.K. (2003) in his study on land carbon budget and sequestration potential of the natural forest of M.P. (India). They found total NPP as 4.216 and 1.302 t $ha^{-1}yr^{-1}$ for dense and open forests, respectively.

Carbon concentration (per cent) in different component of leguminous and non-leguminous tree

The data of carbon concentration in different part of leguminous and non-leguminous tree is given in Table 4.7 and Fig 4.7. The mean carbon concentration in different leguminous and non-leguminous species varied from 42.76 per cent to 43.34 per cent. Maximum carbon concentration (43.34 per cent) was observed in *Dalbergia sissoo* followed by *Cassia siamia* 43.05 per cent, while minimum 42.76 per cent in *Tectona grandis*. Carbon concentration ranged from 40.9 per cent to 44.86 per cent in different components of the tree. Maximum 44.86 per cent carbon concentration was observed in root and minimum 40.9 per cent in leaves of different spp. Carbon concentration in *Tectona grandis* ranged from 42.55 to 44.45 per cent of different components. The maximum carbon concentration (44.45 per cent) was recorded in root, while minimum (40.74 per cent) was recorded in stem. The trend of minimum to maximum carbon concentration in different components were 40.74, 42.55, 43.32 and 44.45 per cent, respectively in stem, leaves branch and root, respectively.

Carbon concentration of *Cassia siamia* ranged from 39.32 to 46.52 per cent. The higher (46.52 per cent) concentration of carbon was recorded in stem and lowest (39.32 per cent) was in leaves. The trend of maximum to minimum carbon concentration were 46.52, 45.31, 41.06 and 39.32 percent, respectively for stem, root, branch and leaves. In case of *Dalbergia sissoo* the concentration of carbon ranged from 40.83 to 45.20 per cent. The maximum carbon concentration (45.20 per cent) was found in stem and minimum (40.83 per cent) in leaves. The carbon concentration of stem, root, branch and leaves were 45.20, 44.83, 42.51 and 40.83 percent, respectively.

Kraenzel *et al.* (2003) have reported that woody tissues like trunk, branch, twigs and coarse roots have higher carbon concentration than soft tissues like leaves, flowers and fine roots. However, concentration of carbon in different components of non-leguminous *Tectona grandis* summarized as root > branch > leaf > stem. Benson *et al.*, 1992 and Beets and Whitetead, 1996 have reported that variation in resource availability and stand age can alter below ground carbon allocation. In a New Zealand beech forest C stored in root was about 32 per cent of total biomass. Globally, the proportion of root to above ground biomass can vary from 16-34 per cent (Cooper, 1983). In present experiment root contain 44.97 per cent, stem 44.34 per cent and leaf 10.69 per cent of the total which is comparable with the above finding.

The leguminous species *Cassia siamia* and *Dalbergia sissoo* showed the following trend of carbon concentration stem > root > branch > and leave concentrations. Carbon desirably varies with tissues types, species and tree height. The range of trunk C concentration documented across species in this study falls within the 45-60 per cent range for carbon concentration reported in different species and tissues (Kinerson *et al.*, 1977; Houghton *et al.*, 1985; Kauppi *et al.*, 1995). The present investigation reveals that 46.52 and 45.20 per cent carbon in stem of *Cassia siamia* and *Dalbergia sissoo*. The lower carbon concentration in different tree species in the present study attributed due to poor site quality. Similar results were reported by Puri *et al.* (2002) where lower carbon concentration in *G. arborea* stand is attributed to poor site quality and low in nutrients.

Storage of carbon and carbon sequestration in leguminous and non-leguminous trees

Storage of carbon and carbon sequestration in leguminous *Cassia siamea* and *Dalbergia sissoo* and non leguminous *Tectona grandis* are presented in Table and Fig. 4.8 and Table 4.9.

Tectona grandis

The total storage of carbon in *Tectona grandis* was 1354.74 kg ha^{-1} of which, 144.67, 574.43 and 635.64 kg ha^{-1} were stored in leaves, stem and root, respectively. In case of carbon sequestration total carbon sequestration was 434.63 kg $ha^{-1}yr^{-1}$ of which 29.79, 240.37 and 164.47 kg ha^{-1} yr^{-1} were by leaves, stem and root, respectively.

Cassia siamia

The total storage of carbon and carbon sequestration in *Cassia siamia* were 3079.86 kg ha^{-1} and 867.96 kg $ha^{-1}yr^{-1}$, respectively. Storage of carbon in leaves, stem and root were 255.58, 1972.45 and 851.83 kg ha^{-1}, respectively and carbon sequestration in leaves, stem and root were 78.64, 558.24 and 231.08 kg ha^{-1} yr^{-1}, respectively.

Dalbergia sissoo

The total carbon storage in *Dalbergia sissoo* was 2333.37 kg ha^{-1} (Table 4.8). Of which 159.24, 1627.20 and 546.93 kg ha^{-1}, were stored in leaves, stem and root, respectively. Whereas the total carbon sequestration in *Dalbergia sissoo* was 585.76 kg $ha^{-1}yr^{-1}$ (Table 4.9) which contributed 44.91, 252.56 and 188.29 kg ha^{-1} yr^{-1} for leaves, stem and root, respectively. Carbon content was higher in *Cassia siamia* (3079.86 kg ha^{-1}) followed by *Dalbergia sissoo* (2333.37 kg ha^{-1}) and lowest in *Tectona grandis* (1354.74 kg ha^{-1}). Carbon content in different tree component was in order stem > root > leaves. The higher status of carbon content in stem, branches and roots were also reported by Swamy *et al.* (2003), Kaur *et al.* (2002) and Narris *et al.* (2001).

Carbon sequestration of leguminous and non-leguminous tree species were ranged from 434.63 to 867.96 kg ha^{-1} yr^{-1}. The two leguminous trees were able to sequester more carbon viz., 867-96 kg ha^{-1} yr^{-1} by *Cassia siamia* and 585.76 kg ha^{-1} yr^{-1} by *Dalbergia sissoo* than non leguminous tree

Tectona grandis (434.63 kg ha^{-1} yr^{-1}). Bijalwan (2002) where the above ground C sequestration range from 0.98 to 2.18 Mg C in mixed forest, from 0.94 to 2.02 Mg C in Teak forest, from 0.65 to 1.59 Mg C in degraded forest in dry tropical ecosystem in Chhattisgarh. The C sequestration in present investigation was lower when compared to other tropical plantation (Lugo *et al.*, 1998, Shepperd and Mantagnini, 2001). Lugo *et al.* (1988) compared the carbon sequestration in different plantation in tropics. *Eucalyptus* plantation (5-16 year old) stored highest carbon (4.5 – 14 Mg C ha^{-1} yr^{-1}) followed by tropical pines (3-12 Mg C $ha^{-1}yr^{-1}$ in 5-30 year old) and lowest amount 2-4 Mg C $ha^{-1}yr^{-1}$ was recorded in Teak plantation (25-75 year old). The carbon sequestration depend on the species, site quality, management and climatic conditions. Low specific gravity and lignin content with poor biomass increment resulted in lower carbon storage in present investigation.

Effect of species on physico-chemical properties of soil

Effect on physico-chemical properties

The physico-chemical properties of soil in three species is given in Table 4.10. The bulk density of soil under *Tectona grandis, Cassia siamia* and *Dalbergia sissoo* were respectively 1.11 g cm^{-3} 1.16g cm^{-3} and 1.3 g cm^{-3}.

The soil texture in all the three species was silty loam. The soil of *Tectona grandis* contained 26 per cent sand, 57 per cent silt and 17 per cent clay. Soil under *Cassia siamia* comprised 25 per cent sand, 59 per cent silt and 16 per cent clay. The soil of *Dalbergia sissoo* contained 24 per cent sand, 58 per cent silt and 18 per cent clay.

The soil pH were 7.46, 7.38, 7.63, respectively under *Tectona grandis, Cassia siamia* and *Dalbergia sissoo.* The mean soil moisture were 14.32 per cent, 17.34 per cent and 13.91 per cent, respectively under *Tectona grandis, Cassia siamia* and *Dalbergia sissoo*. The organic carbon content of soil under *Tectona grandis, Cassia siamia* and *Dalbergia sissoo* were 0.315, 0.332 and 0.398 per cent, respectively.

Total nitrogen was 0.154 per cent, 0.163 per cent and 0.181 per cent, respectively under *Tectona grandis Cassia siamia* and *Dalbergia sissoo*. Total phosphorus were 0.035 per cent, 0.027 per cent and 0.038 per cent, respectively under *Tectona grandis*, *Cassia siamia* and *Dalbergia s*issoo. The exchangeable potassium under the soil of *Tectona grandis* was 0.342 per cent, under *Cassia siamia* it was 0.339 per cent, and under *Dalbergia sissoo* it was 0.379 per cent.

In present study, soil organic matter was highest in *Dalbergia sissoo* as compared to *Cassia siamia* and *Tectona grandis*. Total N and total P and exchangeable potassium were also highest in *Dalbergia sissoo*. The soil organic matter contributes to the soil fertility in a number of ways. It increases cation exchange capacity (Johnston, 1986) and availability of nutrients (Schnitzer and Khan, 1978). Organic carbon is important for the sustainability of vegetation (Dragovich and Patters, 1995). During the oxidation, organic matter releases N, P and S and other trace elements. Soil organic carbon and N are present in several distinct forms such as proteins, peptides, carbohydrates, lignin, organic acids and amino sugars (Mc Gill and Cole, 1981; Kononova, 1966). Organic P is Present as phosphate esters

(C-O-P), polyphosphate (P-O-P) (Pepper *et al.*, 1976; Anderson and Russel, 1969), non-orthophosphate (Beaver and Burns, 1976).

Organic C and N are generally influenced by climate, natural vegetation, texture, cropping and crop sequence (Brady 1984). Temperature and rainfall exert a dominate influence on the amount of organic matter in soil (Jenny, 1941). Soil in the cooler climates generally has more soil organic matter than in warmer climates (Brady, 1984). Soil moisture also exerts a positive control upon accumulation of organic matter in soils. In the present study total P was highest in *Dalbergia sissoo*. Walker and Sayer (1976) suggested that P availability to organisms would control N_2-fixation and in turn organic matter accumulation and during period of substantial P loss by weathering and leaching, the available P would control organic matter loss.

CHAPTER-V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

The present investigation entitled **'Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh''** was conducted near Jindal Plant at Raipur (C.G.), from May 2004 to April 2005.

The investigation was carried out by quadrate sampling method. All the trees in sampling quadrates were enumerated for their growth characters *viz.,* GBH, height clean bole, crown length and crown width. Biomass in different species was estimated by allometric logarithmic regression equations relating dry weight of each tree component with GBH (Girth at Breast Height) as independent variable. The changes in chemical properties of soil under three different species were analyzed. The salient finding are summarized below:

Morphological growth:

1. The morphological growth parameters of all the three species varied significantly
2. The average GBH were from 11.37 to 18.59 cm, total mean height from 3.72 to 4.83 m, clean bole height from 0.81 to 2.91m, crown width from 1.80 to 4.00 m and crown length for 0.81 to 3.55 m for all three species.
3. The growth performance of leguminous trees were superior over non-leguminous tree.

4. The maximum GBH, crown width, and crown length were, 18.59 cm, 4.00 m and 3.55 m, respectively for *Cassia siamia*.
5. The maximum total mean height was in *Dalbergia sissoo* (4.83 m) and minimum was in *Tectona grandis* (3.72 m).
6. The maximum clean bole height was in *Tectona grandis* (2.91m) and minimum in *Cassia siamia* (0.81 m)
7. The overall girth increment for *Tectona grandis*, *Cassia siamia* and *Dalbergia sissoo* ranged between 1.75 and 3.53 cm and 1.85 and 3.82 cm, respectively, after six months and twelve months.

Biomass and NPP

1. The total tree biomass (t ha^{-1}) was maximum in *Cassia siamia* (6.77) followed by *Dalbergia sissoo* (5.21) and minimum in *Tectona grandis* (3.18).
2. The biomass in different component (stem, leaves and root) of three species varied significantly.
3. The biomass of stem ranged from 1.41 to 4.24 t ha^{-1} the maximum stem biomass was recorded in *Cassia siamia* (4.24 t ha^{-1}) followed by *Dalbergia sissoo* (3.60 t ha^{-1}) and the lowest in *Tectona grandis* (1.41 t ha^{-1}).
4. The biomass of leaves ranged from 0.34 to 0.65 t ha^{-1}. The maximum was observed in *Cassia siamia* and minimum was in *Tectona grandis*.
5. The biomass of root ranged from 1.22 to 1.88 t ha^{-1}. The maximum root biomass was observed in *Cassia siamia* (1.88 t ha^{-1}) followed by

Tectona grandis (1.43 t ha^{-1}) and lowest in *Dalbergia sissoo* (1.22 t ha^{-1}).

6. Total above ground biomass was maximum in *Cassia siamia* (4.89 t ha^{-1}) followed by *Dalbergia sissoo* (3.99 t ha^{-1}) and lowest in *Tectona grandis* (1.75 t ha^{-1}).
7. The percent contribution of stem, leaves and root were 44.34, 10.69 and 44.97% for *Tectona grandis,* 62.63,9.60 and 27.77% for *Cassia siamia* and 69.10, 7.49 and 23.42% for *Dalbergia sissoo*.
8. The percent contribution of above ground biomass to total biomass was 55.03, 72.23 and 76.58%, respectively for *Tectona grandis, Cassia siamia* and *Dalbergia sissoo.*
9. The percentage contribution of below ground biomass to total biomass were 44.97, 27.77 and 23.42%, respectively for *Tectona grandis, Cassia siamia* and *Dalbergia sissoo*.
10. The above ground net primary production ranged from 0.66 to 1.40 t ha^{-1} for all species.
11. The above ground net primary production was maximum in *Cassia siamia* (1.40 t ha^{-1} yr^{-1}) followed by *Dalbergia sissoo* (0.89 t ha^{-1} yr^{-1}).
12. The contribution of above ground production to net primary production were 64.07, 73.29 and 67.93%, respectively for *Tectona grandis, Cassia siamia* and *Dalbergia sissoo*.
13. The below ground net primary production ranged from 0.37 to 0.51 t ha^{-1} yr^{-1} for all species were the maximum in *Cassia siamia* (0.51 t ha^{-1} yr^{-1}) followed by *Dalbergia sissoo* (0.42 t $ha^{-1}yr^{-1}$) and lowest in *Tectona grandis* (0.37t $ha^{-1}yr^{-1}$).

14. The percentage contribution of below ground production to net primary production were 35.92, 26.70 and 32.06%, respectively for *Tectona grandis, Cassia siamia* and *Dalbergia sissoo*.

15. Total NPP were ranged between 1.03 to 1.91 t $ha^{-1}yr^{-1}$ for all species. The maximum NNP was measured in *Cassia siamia* and minimum in *Tectona grandis*.

Storage carbon and carbon sequestration:

1. Carbon concentration of *Tectona grandis* ranged from 40.74 to 44.45% among different component.

2. Carbon concentration of *Cassia siamia* ranged from 39.32 to 46.52% among different component.

3. Carbon concentration of *Dalbergia sissoo* ranged from 40.83 to 45.20% among different components.

4. Storage of carbon ranged from 1354.74 to 3079.86 kg ha^{-1} among three tree species.

5. Storage of carbon in *Tectona grandis* were 144.67, 574.43 and 635.64 kg ha^{-1} for leaves, stem and root, respectively.

6. Storage of carbon in *Cassia siamia* were 255.58, 1972.45 and 851.83 kg ha^{-1}, for leaves, stem and root, respectively.

7. Storage of carbon in *Dalbergia sissoo* were 159.24, 1627.20, and 546.93 kg ha^{-1} for leaves, stem and root, respectively.

8. Carbon sequestration were from 434.63 to 867.96 kg ha^{-1} yr^{-1} for leaves, stem and root, respectively.

9. Carbon sequestration in *Tectona grandis* were 29.79, 240.37 and 164.47 kg ha^{-1} yr^{-1} for leaves, stem and root, respectively.
10. Carbon sequestration in *Cassia siamia* were 78.64, 558.24 and 231.08 kg ha^{-1} yr^{-1} for leaves, stem and root, respectively.
11. Carbon sequestration in *Dalbergia sissoo* were 44.91,252.56 and 188.29 kg ha^{-1} yr^{-1} for leaves, stem and root, respectively.

Soil properties:

1. Bulk density under *Tectona grandis, Cassia siamia* and *Dalbergia sissoo* were respectively 1.11 g cm^{-3}, 1.16 g cm^{-3} and 1.3 g cm^{-3}.
2. The soil texture in all the three species was silty loam. The values of sand ranged between 24-26%, silt between 57-59% and clay between 16-18% across all the species.
3. The soil pH was 7.38 to 7.63 across all the species.
4. The average soil moisture in annual cycle ranged between 13.91 to 17.35% across all the three species.
5. The organic carbon content in soil was 0.315 to 0.398% across all the three species.
6. Total nitrogen in soil ranged between 0.154 to 0.181% across all the three species.
7. Total phosphorus in soil was 0.027 to 0.038% across the three species.
8. The exchangeable potassium in soil was 0.339 to 0.379% across all the three species studied.

Conclusion:

The following conclusion can be drawn on the basis of growth, biomass and production study of leguminous and non-leguminous tree plantation. Based on the available findings following conclusion could be drawn

1. Among the three species *cassia siamia* and *dalbergia sissoo* have better growth performance as compared to *tectona grandis*.
2. Biomass and net primary production of *cassia siamia* and *dalbergia sissoo* were more as compared to *tectona grandis*.
3. The storage of carbon and carbon sequestration was also higher in *cassia siamia* and *dalbergia sissoo* and lower in *tectona grandis*.
4. Among the three species *cassia siamia* and *dalbergia sissoo* have greater influences on physio-chemical properties of soil as compared to *tectona grandis*.

Suggestions for future research work:

The present investigation on biomass production of three species is based on allometric equations. The result obtained from this investigation belong to only one year of research work. To achieve a definite conclusion and recommendation it needs further continuation of the study. In order to screen out the suitability of the species a more detail study on other aspect i.e. Litter fall, fine root, and nutrient dynamics, effect of tree on microclimate is equally important. Therefore, it is an urgent need to investigate the system on the above line also that the system can be judged on sustainable basis.

"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non-Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh"

By

Santosh Kumar Dhruw

ABSTRACT

Study entitled **"Biomass, Net Primary Productivity and Carbon Sequestration in Leguminous and Non Leguminous Tree Species in Red Lateritic Soil in Chhattisgarh"** was conducted during 2004-2005. Two leguminous (*Dalbergia sissoo* and *Cassia siamia*) and one non-leguminous tree (*Tectona grandis*) were under taken for the above study.

The morphological growth characters viz., average GBH, total mean height, clean bole height, crown width and crown length were recorded. Average GBH for all species ranged between 11.62 and 18.59cm. The total mean height ranged between 3.72 and 4.83 m. Clean bole height ranged between 0.81 and 2.91 m. Crown width ranged between 1.80 and 4.00 m and crown length between 0.81 and 3.55m.

The above ground biomass ranged between 1.75 and 4.89 t ha^{-1} for all the species. The highest above ground biomass was recorded in *Cassia siamia* (4.89 t ha^{-1}), while the lowest was recorded in *Tectona grandis* (1.75 t ha^{-1}). The higher proportion of above ground biomass was allocated to stem (3.08 t ha^{-1}) followed by roots (1.51 t ha^{-1}) and leaves (0.46 t ha^{-1}).

The below ground biomass ranged between 1.22 to 1.88 t ha^{-1} across all the species with height being 1.88 t ha^{-1} in *Cassia siamia* and lowest (1.22 t ha^{-1}) in *Dalbergia sissoo*. The total tree biomass varied from 3.18 to 6.77 t ha^{-1} and also highest in *Cassia siamia* and lowest in *Tectona grandis*. The annual net primary production of trees varied from 1.03 to 1.91 t ha^{-1} yr^{-1} and

was highest in *Cassia siamia* (1.91 t ha^{-1} yr^{-1}) followed by *Dalbergia sissoo* (1.31 t ha^{-1} yr^{-1}) and *Tectona grandis* (1.03 t ha^{-1} yr^{-1}).

The storage of carbon ranged between 1354.74 and 3079.86 kg ha^{-1} for all the species. The maximum storage of carbon was in *Cassia siamia* (3079.86 kg ha^{-1}) followed by *Dalbergia sissoo* (2333.37 kg ha^{-1}) and minimum in *Tectona grandis* (1354.74 kg ha^{-1}) .The carbon sequestration of the species varied from 434.63 to 867.96 kg $ha^{-1}yr^{-1}$, which was maximum under *Cassia siamia* and minimum under *Tectona grandis*. The bulk density under three species ranged between 1.11-1.16 g cm^{-3}. The soil texture under all the three species was silt loam. The soil pH ranged between 7.38 to 7.63. The soil moisture ranged from 13.91 to 17.35 per cent. The organic carbon content in soil was 0.315 to 0.398 per cent. Total nitrogen ranged between 0.154 to 0.181 per cent total phosphorus in soil was 0.027 to 0.038 per cent across the three species and exchangeable potassium in soil ranged between 0.342 to 0.379 per cent. On short term basis it can be concluded that the leguminous tree species are superior over the non leguminous tree plantation in red lateritic soil in Chhattisgarh.

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Table 4.1: Morphological growth performance of leguminous and non-leguminous trees.

Tree species	Average GBH (cm)	Total mean height (m)	Clean bole height (m)	Crown width (m)	Crown length (m)
Tectona grandis	11.37	3.72	2.91	1.80	0.81
Cassia siamia	18.59	4.36	0.81	4.00	3.55
Dalbergia sissoo	16.70	4.83	1.91	3.89	2.92

Table 4.2: Stand biomass and relative percentage of total biomass of leguminous and non-leguminous species

Component	Biomass (t ha^{-1})		
	Tectona grandis	***Cassia siamia***	***Dalbergia sissoo***
Stem	1.41 (44.34)	4.24 (62.63)	3.60 (69.10)
Leaves	0.34 (10.69)	0.65 (9.60)	0.39 (7.49)
Total above ground tree biomass	1.75 (55.03)	4.89 (72.23)	3.99 (76.58)
Total below ground tree biomass	1.43 (44.97)	1.88 (27.77)	1.22 (23.42)
Total tree biomass	3.18	6.77	5.21

Value in the parenthesis are per cent value of the total biomass

Table 4.3: Mean Total Biomass f Different Component and Percentage Distribution of The Total Biomass in all species

Component	Biomass t ha^{-1}	Percentage of the total
Stem	3.08	60.99
Leaves	0.46	9.11
Root	1.51	29.90
Total above ground tree biomass	3.54	70.10
Total below ground tree biomass	1.51	29.90
Total Stand Biomass	**5.05**	**-**

Table 4.4: Number of trees marked for GBH increment and their percentage in different GBH classes

GBH Class (cm)	Species and number of individuals marked		
	Tectona grandis	***Cassia siamia***	***Dalbergia sissoo***
5-10	10 (33.33)	2 (6.67)	2 (6.67)
10-15	19 (63.33)	3 (16.00)	12 (40.00)
15-20	1 (3.33)	7 (23.33)	12 (40.00)
20-25	-	5 (16.67)	2 (6.67)
25-30	-	6 (20.00)	2 (6.67)
30-35	-	6 (20.00)	-
35-40	-	1 (3.33)	-

Table 4.5: Range of mean GBH increment after six months and twelve months

Species	*Range of mean GBH*	
	Increment after 6 month (cm)	**Increment after 12 months in (cm)**
Tectona grandis	1.75-2.12	1.85-2.98
Cassia siamia	2.85-3.53	2.93-3.82
Dalbergia sissoo	2.51-3.11	3.12-3.25

Table 4.6: Net primary productivity of leguminous and non-leguminous tree ($t\ ha^{-1} yr^{-1}$).

Tree Component	Species		
	Tectona grandis	***Cassia siamia***	***Dalbergia sissoo***
Stem	0.59 (57.28)	1.20 (62.82)	0.78 (59.54)
Leaves	0.07 (6.79)	0.20 (10.47)	0.11 (8.39)
Total above ground NPP	0.66 (64.07)	1.40 (73.29)	0.89 (67.93)
Total below ground NPP	0.37 (35.92)	0.51 (26.70)	0.42 (32.06)
Total tree NPP	1.03	1.91	1.31

Value in the parenthesis are per cent value of the total NPP

Table 4.7: Carbon concentration (%) in different component of leguminous and non-leguminous tree species.

Tree species	Carbon %				
	Leaves	**Branch**	**Stem**	**Root**	**Mean**
Tectona grandis	42.55	43.32	40.74	44.45	**42.76**
Cassia siamia	39.32	41.06	46.52	45.31	**43.05**
Dalbergia sissoo	40.83	42.51	45.20	44.83	**43.34**
Mean	**40.9**	**42.09**	**44.15**	**44.86**	

Table 4.8: Carbon storage in different components of leguminous and non-leguminous tree species.

Species	Storage of carbon ($kg\ ha^{-1}$)			
	Leaves	**Stem**	**Root**	**Total**
Tectona grandis	144.67	574.43	635.64	1354.74
Cassia siamia	255.58	1972.45	851.83	3079.86
Dalbergia sissoo	159.24	1627.20	546.93	2333.37

Table 4.9: Carbon sequestration in different components of leguminous and non-leguminous tree species.

Species	Carbon sequestration (kg $ha^{-1}yr^{-1}$)			
	Leaves	**Stem**	**Root**	**Total**
Tectona grandis	29.79	240.37	164.47	434.63
Cassia siamia	78.64	558.24	231.08	867.96
Dalbergia sissoo	44.91	252.56	188.29	585.76

Table 4.10 :Influence of species on physico-chemical properties of soil across the *Tectona grandis, Cassia siamia and Dalbergia sissoo*

	Species		
Properties	*Tectona grandis*	*Cassia siamia*	*Dalbergia sissoo*
Bulk density (g cm^{-3})	1.11	1.16	1.13
Texture			
Sand (%)	26	25	24
Silt (%)	57	59	58
Clay (%)	17	16	18
PH	7.46	7.38	7.63
Soil moisture (%)	14.32	17.35	13.91
Organic carbon (%)	0.315	0.332	0.398
Total N (%)	**0.154**	**0.163**	**0.181**
Total P (%)	**0.035**	**0.027**	**0.038**
Total K (%)	**0.342**	**0.339**	**0.379**