PRODUCTIVITY STATUS OF TEN YEARS OLD SILVIPASTURE SYSTEM IN RED LATERITIC SOIL OF CHHATTISGARH

M. Sc. (Forestry) THESIS

By

RAJIV UMRAO

DEPARTMENT OF FORESTRY
COLLEGE OF AGRICULTURE
INDIRA GANDHI AGRICULTURAL UNIVERSITY
RAIPUR (C.G.) 492 006

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“PRODUCTIVITY STATUS OF TEN YEARS OLD SILVIPASTURE SYSTEM IN RED LATERITIC SOIL OF CHHATTISGARH”

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Dedicated to My Family Members

CERTIFICATE - I

This is to certify that the thesis entitled **"PRODUCTIVITY STATUS OF TEN YEARS OLD SILVIPASTURE SYSTEM IN RED LATERITIC SOIL OF CHHATTISGARH"**, submitted in partial fulfilment of the requirements for the degree of **“MASTER OF SCIENCE IN FORESTRY”** of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **Mr. RAJIV UMRAO** 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.

(M. N. Naugraiya)

Date : **Chairman**

Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman : Dr. M. N. Naugraiya ....

Member : Dr. R. K. Prajapati ....

Member : Dr. S. K. Patil ....

Member : Dr. S. K. Sarawagi ………………………..

Member : Dr. R. R. Saxena ………………………..

CERTIFICATE - II

This is to certify that the thesis entitled **" PRODUCTIVITY STATUS OF TEN YEARS OLD SILVIPASTURE SYSTEM IN RED LATERITIC SOIL OF CHHATTISGARH "** submitted by **Mr. RAJIV UMRAO** to the Indira Gandhi Agricultural University, Raipur (C.G.) in partial fulfilment of the requirements for the degree of “**MASTER OF SCIENCE IN FORESTRY”**, in the **DEPARTMENT OF FORESTRY** has been approved by the Student's Advisory Committee after an oral examination in collaboration with the external examiner.

Date : **EXTERNAL EXAMINER**

Dr. M. N. Naugraiya
MAJOR ADVISOR ....

Dr. Sunil Puri
HEAD OF THE DEPARTMENT …..................................

Dr. Sunil Puri
DIRECTOR OF INSTRUCTIONS ...…...............................

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Department of Forestry
Rajiv Umrao
College of Agriculture, IGAU, Raipur (CG)

C O N T E N T S

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LIST OF ABBREVIATION

Notation		Description
%	=	per cent
±	=	Standard deviation
<	=	Less than
>	=	More than
^{0}C	=	Degree centigrade
AGB	=	Above ground biomass
BG	=	Below ground
BGB	=	Below ground biomass
CG	=	Chhattisgarh
Ca	=	Calcium
CD	=	Collar diameter
CEC	=	Cation exchange capacity
CM	=	Centimeter
DBH	=	Diameter breast height
DM	=	Dry matter
E longitude	=	East longitude
g tree^{-1}	=	Gram per tree
Ht.	=	Height
K	=	Potassium
K cal	=	Kilo calorie
Kg ha^{-1} yr^{-1}	=	Kilogram per hectare per year
Kg tree^{-1}	=	Kilogram per tree
Kg F.wt. tree^{-1}	=	Kilogram fresh weight per tree
M	=	Meter
MABI	=	Mean annual biomass increment
Mg	=	Magnesium
mm day^{-1}	=	Milli meter per day
MPTs	=	Multipurpose tree species
MSL	=	Mean sea level
N	=	Nitrogen
N latitude	=	North latitude
Na	=	Sodium
NFTS	=	Nitrogen fixing tree species
NS	=	Non significant
P	=	Phosphorus
t ha^{-1}	=	Tonne per hectare
t ha-1 yr^{-1}	=	Tonne per hectare per year
Viz.	=	For example
et al.	=	Other

CHAPTER-I

INTRODUCTION

The human being and animal both are directly or indirectly depends on the natural resources for their daily requirement of bio-chemical energy. The plants are useful to mankind either in the form of tangible (food, fuel wood, timber and fodder etc) and intangible (carbon sequestration, soil amelioration and hydrological balance etc) benefits. The availability of such type of natural wealth is rapidly decreasing, owing to the rapid degradation of resources due to sharp increase in human and livestock population, which has built tremendous pressure on our natural resources. The shortage of forest is creating many couple of problems like social, economical and environmental etc.

Country has very high pressure on its natural resources. It has 16.1 per cent of the world's human population and 15.1 per cent, cattle population, while it occupies 2.47 percent of the world's geographic area and has only 1.8 per cent of the total world's forests. The pressure exerted by human and cattle population is further exacerbated due to monsoonic pattern of the rain as approximately 90 per cent of total annual rainfall received in 2 to 4 months and this resulted the remaining months practically dry.

The National Forest Policy 1988 envisages bringing one third of the geographic area of the country under forest/tree cover to maintain ecological balance and environmental stability. In a view of this, it is necessary to explore the possibility for bringing out the land under tree cultivation system. Forest and agriculture are two important land use system and in these system agriculture is the most dominating and competing with forest under relentless pressure of an ever-increasing population of human and domestic cattles.

To meet the requirement of food production besides enhancing the productivity, the area under agriculture has increased from 118 m ha in 1951 to 142 m ha at present. Generally land utilization trend of India is concerned with fertility status of the soil and fertile lands are prioritized for agriculture crops and less fertile soils are left as fallow land or used for forest crops. It is therefore, unlikely, that the agriculture land can be forced for expansion of forest cover under innovative agroforestry programmes in agriculture field, cultural wastelands, fallow lands and other problematic lands.

The raising of tree out side the conventional forest area particularly on such mentioned wasteland with pasture crop not only enhance soil water conservation, but also fulfill the requirement of food, fodder, fuel and timber etc. for local community.

The demand for wood and other tree products heightened the interest in the concept of intercropping and integrated farming systems in the country. Agroforestry systems refer to such distinct farming practices in which agriculture, forestry and pasture crops are combined either temporally or spatially in same piece of lands.

Since India has 416 million livestock population, which is about 15.1 per cent of the total livestock population of the world. The livestock constitutes a very important component in rural economy, as in agriculture. Our country largely depends on livestock for manure and draught power. Though the importance of livestock in the economy of the farmers needs no emphasis, thus desirability of having such a large livestock population is questionable, particularly when the quality of the majority of livestock is poor due to under nourishment. The availability of fodder is short from the requirement and an estimate of several agencies, there is more than 300 per cent gap between availability and requirement (Anon, 1986 a, ICAR, 1980). Most of the country's livestock depend either partially or completely on grasses, produced through pastoral-silviculture, but higher incidence of grazing leads to reduce grass cover, increased compactation of soil and as well as soil erosion. Thus the existing natural resources are deteriorating and creating the land degradation. To minimize the land degradation and fulfill the demand of fuel wood, timber, green and dry forages for human and livestock in the country, silvipasture system has been identified as an ideal alternative (Rai, *et al.*1999).

The silvipastoral systems concern themselves with the lopping of forest trees and grazing of under storey grasses and bushes in the forests (and also tree plantations), but this is traditional practices of utilization of rangelands, grasslands and forest areas. In the improved silvipasture system, wastelands viz., old fallow lands, culturable wastelands and other problematic soil are used with systematic tree plantation along with cultivation of grass-legumes, pastures where involvement environment of livestock are also noticed either as rearing or stall feeding.

Out of the India's total 329 million ha geographical area, 187.7 million ha about 57 per cent land presently suffers from various kind of degradation problem (Paroda, 1998). Ravine, shallow gravely red soils, rocky areas of semiarid region hot descent, sand dunes, cold desert and wetlands etc. come under wastelands. In India, entisols occupy an area of 117.2 m ha (DES, 1988). Normally the entisols are lacking of soil nutrients as compared to other soil. But a considerable proportion of these type of soil comes under wasteland, which can be best utilized by forest crops and it can enhance the economic return from forest crops as well as it can also provide an environment to take some remunerative non –forest crops.

Chhattisgarh has three agro climatic zones, *viz.* northern hills, central plains and southern plateau. Northern hills and southern plateau have dense forest area (< 50%). In central plains of Chhattisgarh, more than 20 per cent of land area falls under red lateritic soil, which occupies about 3,69,850 ha of total geographical area of state (Verma *et al.* 1998). In Chhattisgarh, red lateritic soil is popularly known as Bhata lands (Entisols). These lands have gentle slopes with undulating topography (Pofali and Bhattacharjee, 1970), with full of gravels and subsoil layers in hard and compact form (Singh and Totey, 1985).

Rehabilitation of such type of degraded lands can be done by re-vegetation with multipurpose trees, woody species, perennial plants, perennial grasses, annual grasses and legumes. The development of such land with suitable trees, grasses and legumes enhance organic matter production to maintain soil fertility; to reduce erosion and to create more microclimate, has been found very effective. Crop cultivation in the rain fed areas especially in the arid and semi arid regions is a big gamble due to low and erratic rainfall and crop failure. Thus, for sustainable production, the best alternative is to promote appropriate integrated agro-silvipasture systems in the arid and semiarid areas.

Shisham (*Dalbergia sissoo* Roxb. ex DC.) is a member of Leguminosae family and sub-family Papilionaceae. *Dalbergia sissoo* is named after the Swedish Botanist, Nicholas Dalberg. De candole (1825) and Rox burgh (1832) considered it to be native of Bengal. It is moderately fast growing MPTs and grows in subtropical climate is strong light demander. The wood of *Dalbergia sissoo* is highly valued for furniture, constructional and general utility purposes. It possesses all the qualities required for an ideal fuel wood and its leaves are used as fodder.

Khamar (*Gmelina arborea* Linn.) is one of the fast growing indigenous multipurpose tree species. It belongs to family Verbenaceae that produces one of the best quality timbers in India. It is also a strong light demander and regenerates naturally only in the open and on the edge of the forests (Luna, 1996). However, it is very sensitive to water logging and weed competition (Douay, 1956). The timber is used for many purposes, especially for construction work, planking, furniture, paneling, boat building and agricultural implements. The leaves are classed as good fodder and the tree is lopped in Maharashtra, Madhya Pradesh, Chhattisgarh, Orissa and Uttar Pradesh.

Karanj (*Pongamia pinnata* L.) belongs to the family Fabaceae (Papilionaceae). It is a medium size evergreen tree. It is planted for shade and avenue purposes. It is a drought resistant, salt tolerant and nitrogen fixing leguminous tree. Leaves are used as fodder and green manure. The wood of this tree is used as a fuel throughout the country and also for the construction of wood handles and agricultural implements.

Arjuna (*Terminalia arjuna* Bedd.) member of Combretaceae family is a large, handsome, evergreen tree with generally buttressed and drooping branches. The tree is generally found throughout the greater parts of India. It is moderately fast growing and shade bearing MPTs. The timber is used for agricultural implements and mine props. The wood has high calorific value, and known for quality charcoal and excellent firewood and produces good quality charcoal. National Forest Policies of our country advocated for needs of short rotation farm forestry and agroforestry management on marginal wastelands to meet out the country requirement.

Therefore, there is an urgent need to study the management of short rotation forestry, silvipasture systems with fast growing tree species on degraded and wasteland to provide average 10 to 20 tons ha^{-1} yr^{-1} of dry matter.

The present studies were focused to explore the potentiality of the tree species as well as pasture crops on red lateritic soils (Bhata lands).

The present study entitled “Productivity status of ten years old silvipasture system in red lateritic soil of Chhattisgarh” was carried out with the following objectives.

1. To study the growth and productivity of multipurpose tree species (MPTs) in silvipasture system.

2. To study the structure and productivity of under storey herbage species.
3. To study of the effect of invaded vegetation on quality of pastures.
4. To assess the nutrient status and calorific values of different components of silvipasture system.

CHAPTER-II

REVIEW OF LITERATURE

In this chapter an attempt is made to review the work done on "**Productivity status of ten years old silvipasture system in red lateritic soil of Chhattisgarh".** Emphasis is given to review the available literature on biomass, structure, diversity and nutrient in silvipasture system. The literature is broadly reviewed under following aspects.

2.1 Growth and productivity of multipurpose tree species (MPTs) under silvipasture system

2.2 Structure and productivity of pasture

2.3 Quality of pasture

2.4 Nutrient status and calorific values of silvipasture system

2.1 Growth and productivity of multipurpose tree species (MPTs) under silvipasture system

The production of MPTs plantation on degraded lands not only check the soil erosion but also improve the productivity of land and mitigate the requirements of food, fodder, fuel and small timber etc for human and bovine population of the globe.

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. Results 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 elements foliage contributed 30.0, 23.3 and 12 per cent respectively, while these were 43.0,45.3 and 54.3 per cent in stem. Roots possessed to 13.3, 16.6 and 18.2 per cent contents of N, P and K, respectively.

Naugraiya and Puri (2001) studied the multipurpose tree species (7.5 years -old plantation) grown for fodder, fuel and timber in the wastelands of Chhattisgarh plains. They found that growth and dry matter production were in the order of *Leucaena leucocephala* > *Eucalyptus tereticornis* > *Albizia procera* > *Dalbergia sissoo* > *Azadirachta indica* > *Hardwickia binata* > *Terminalia arjuna*, where total dry wood biomass production ranged between 1.5 to 35.1 kg $tree^{-1}$. The dry matter production of under storey pasture (grass + stylo) was also worked out with maximum pasture yield (35.5q ha^{-1}) under *H. binata* and minimum under *T. arjuna* (9.54 q ha^{-1}).

Ponnabalam *et al*. (2001) studied the reclamation of limestone mine dump through plantation of *Acacia auriculiformis, A. holoseriecea, A. mellifera,* *Azadirachta indica, Delonix regia* and *Eucalyptus tereticornis* at *Coimbatore*. As per their results *A. auriculiformis* and *A. holoseriecea* improved soil fertility appreciably as compared to other species. Though the maximum stem and leaf weight were observed in *D. regia* and *E. tereticornis*, respectively. Thus nitrogen-fixing trees performed better in terms of soil development as well as biomass production. They also reported that performance of *A. indica* was very poor.

Pacholi and Pandy (1998) studied the biomass production of *Dalbergia sissoo* in high density monoculture plantations at 1 x 1m, 1.5 x 1.5 m, 2 x 2 m and 3 x 3 m plantation spacing where, the above ground biomass were observed 59.5 t ha^{-1}, 58.5 t ha^{-1}, 104.6 t ha^{-1} and 82.7 t ha^{-1} respectively. They also reported that above ground biomass and mean annual biomass increment (MABI) were found to be influenced by the plantation density. Above ground biomass (AGB) and mean annual biomass increment were found maximum (104.6 t ha^{-1} and 13.04 t ha^{-1} year) respectively at 2 x 2 m spacing plantation. The 7 years-old dense plantation (2 x 2 m) of *Populous deltoids* were found suitable for production of maximum above ground biomass (102.2 t ha^{-1}) Lodhiyal *et al.* 1993).

Naugraiya and Puri (1997) worked out the growth and mid term biomass production under the pruning management of branches for four MPTs viz. *Dalbergia sissoo, Eucalyptus tereticornis, Gmelina arborea* and *Leucaena leucocephala* grown as high density plantations in red lateritic soil (Entisols) of Chhattisgarh plain. The biomass varied from 0.95 to 2.13 t ha^{-1} for branches, 0.46

to 0.91t ha^{-1} for foliage and 0.01 to 0.035 t ha^{-1} for fruit components. The maximum biomass of branches was recorded in *L. leucocephala* followed by *G. arborea, E. tereticornis* and *D. sissoo,* respectively.

Sharma *et al*. (1995) studied growth and biomass at five year-old plantations with *Amoora walichii, Callicarpa arborea, Ficus fistulosa, Gmelina arborea* and *Vatica lanceaefolia* at five different spacing. Among these species maximum pulpable dry biomass was recorded in *V. lanceaefolia* (80.1 t ha^{-1}), at 1x1m spacings, while in case of 2 x 2 m spacing 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 his studies, the mean height of trees increased from 16.6 m to 19.6 m between 4 to 7 years. Similarly the tree dimensions were also increased in respect to volume and dry matter content from 200 to 272 m3 ha^{-1} and 68 to 119 t ha^{-1} respectively.

Maiti *et al.* (1993) reported in their studies of alley cropping that width spacing of alley had very little influence on productivity of *Leucaena leucocephala* and other intercrops in sub-humid tropics of West Bengal. The closely planted *L. leucocephala* produced comparatively higher dry foliage yield of 293.8 and 284.5 q ha^{-1} yr $^{-1}$ in both sole and alley cropping system (when alley cropped with Maize, Cowpea and Mustard), respectively. Lowest dry foliage yield of 286.7 and 274.4 q ha^{-1} was recorded for sole and alley cropping respectively in wider alley spacing.

Gairola *et al.* (1990) studied the biomass production in one year old plantation of ten multipurpose tree species *viz; Bauhinia racemosa*, *Acacia catechu, Ougeinia dalbergioides, Celtis australis, Bauhina 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}.

Negi *et al.* (1990) estimated the biomass production in 20 year-old plantations of *Tectona grandis* and *Gmelina arborea* at Tripura. The plant density, diameter, height and mean annual increment were 448 tree ha^{-1}, 21.1 cm, 20.4 m and 7.913 m^3 respectively for *T. grandis*, while corresponding values of the same were 452 tree ha^{-1}, 25.4 cm, 20.9 m and 10.45 m^3, respectively for *G. arborea*

Singh and Puri (1990) studied the 9 years old *Populous deltoids* stands planted at three different spacing in semi-arid region of Haryana. They recorded maximum above-ground biomass and (206 t ha $^{-1}$) net primary productivity (33.3 t ha^{-1} $y^{-1)}$ in the plantation of 2 x 2 m spacing, which further reduced to the 88 t ha^{-1} and 14.2 t ha^{-1} yr^{-1} respectively and lowest was at 6 x 6m spacing 41 t ha^{-1} yr^{-1} and 6.6 t ha^{-1} yr^{-1}, respectively.

Bisht *et al.* (1989) studied the 18 years-old *Eucalyptus* hybrid plantation raised in foot hills of Nainital and reported that the total above ground parts of trees accumulated 110.0 t ha^{-1} biomass, of which 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 short rotation energy plantation 6170 trees ha^{-1} and harvested 48.25 t ha^{-1} biomass after the growth of 3-years, where the bole and branches alone contributed about 44.1 and 30.2 per cent, respectively as major produce, while contribution of root, bole-bark and leaf were 14.2, 9.8 and 1.6 per cent, respectively.

Gurumurti *et al*. (1986) studied, *Acacia nilotica* (5264 plants ha^{-1}) under semi-arid region and found that the total tree biomass (oven dry) including root at the age of 12 and 60 months was produced 16 and 154 t ha^{-1}, respectively, while the share of corresponding yield of utilizable biomass of wood-bark and branches were of 10.9 and 110.1 t ha^{-1}, respectively.

2.2 Structure and productivity of pasture crops

The complex features of environment play an important role for determining the level of diversity in structure and function of community. The activities of top storey population are certain to influence the plant populations, because plants are relatively immobile and they are usually forced to live in the same lateral relationship with their neighbours till their life (Ramakrishanan, 1974). Plants react to their close proximity of growing and dominating species by failure of its seed germination, death or survival with plasticity development, which leads to change in structure and production behavior of community.

Balaji and Nitant (2002) conducted study on protected and unprotected each ravine sites, which were sloppy and divided into top, middle and bottom toposequence. They reported that the density and abundance of grass species was higher in protected sites, where moisture level was comparatively high than unprotected site. Study also revealed that moisture status of soil at top middle and bottom played important for distribution of species and their productivity, along with diversity of flora natural rangelands.

Naugraiya and Pathak (2001) studied diversity of herbage species under silvipastoral system at Jhansi, where distribution pattern of herbage, under proximity of trees showed high level of species diversity as compared to open area. Most of the species viz.; *Apluda aristata, Eremopogon faveolatus, Heteropogon contortus, Iseliema laxum, Sehima nervosum in grasses, Alysicarpus monilifer, Atylosia scarabaeoides, Hylandia latebrosa, Indigofera linifolia, Stylosanthes hamata* in legumes and *Justica diffusa, Lapidogathes trinervis* were predominant species with accounting more than 20 per cent frequency of distribution. While in case of open field, the species diversity was very less with dominance of grass species.

Trivedi and Soam (1998) conducted the phyto-sociological studies in grassland communities where number of total species occurred was very high and out of which perennial grass species *Heteropogon contortus* acquired highest IVI (82) otherwise annual species *Eragrostis pilosa* (64) and *Zornia gibbosa* (43) etc. occupied the space and dominating over perennials.

The grass component of the community contributed more than 90 % of total standing biomass, but the total biomass of the herbage community in a rangeland fluctuated from 1492 kg/ha to 2992 kg/ha probably due to selective grazing (Guevara *et al.* 1996) and browsing (Singer and Renkin, 1995). In such a condition, the legume biomass was almost negligible and trampling of grass caused increased litter production of the community up to 6 % of total forage production (Richards *et al.* 1995).

Verma *et al.* (1998) counted numerical strenth of herbage flora under *Emblica officinalis* and *Tamarindus indica* where total species was 20 and 23 respectively. Their results showed the variation in adaptability of different species. The species developed under these two species according to their ecological niches. *Desmodium triflorum* was the dominant herb under both the plantation with maximum density, frequency and abundance. In *Emblica officinalis* plantation important value index of *Desmodium triflorum* was reported highest (99.09) followed by *Corchorus* pp. (59.35), *Rungia pectinata* (25.58) *Sporobolus* species (18.15) and the *Lindernia crustacea* (90.12) recorded the least IVI value. Whereas under *Tamarindus indica* plantation, *Hyptis suaveolens* recorded maximum IVI value (83.57) followed by *Desmodium triflorum* (70.60), *Evolvalus nummularis* (19.06) and *Corchorus* sp. (18.09). Minimum value of IVI was recorded *Achyranthes aspera* (1.14).

Rai *et al.* (1997) studied the performance of lambs (4-5 months) and kids (4-6 months) grazing in the natural *Sehima-Heteropogon* grassland and established silvipastoral system from August 1992 to June1994. Results showed that body weight of animals increased from August 1992 to November 1993 on grazing in both the type of pastures, but the body weight of lambs and kids grazed in silvipasture system were found to be increased more as compared to graze in natural grassland, because silvipastoral system was managed better than natural grassland for quality and quantity production of forage.

Naugraiya and Pathak (1993) studied the colonization and production of winter annuals in *Leucaena* forest. They studied that the impact of soil moisture and solar radiation on distribution and biomass production were found positive up to 90 days. According to results the biomass was directly associated with diversity and dominance of species, it increased with decreasing dominance but decreased with increased diversity. Thus the winter annuals (weeds) are played an important role to influence the production and utilization of resources within short span of life.

2.3 Quality of pasture

The availability of nutrients in the soil is not only related to the growth and production of plant species primarily but also influenced the nutritive quality of plants. Community structure and population strength of species also reflected the quality of pasture crops. Requirement of relatively high phosphorus and potassium nutrients to legumes play a significant role in crops, grown under rain fed conditions.

Bhatt *et al.* (2002) studied tropical range species and concluded that in most of the range grasses and legumes, maximum biomass production was recorded under 75 per cent of total light intensity. *Cenchrus ciliaris, Panicum maximum, Bracharia mutica* produced maximum dry matter yield even after third year of growth under shade, exhibiting their adaptability to shade over the years as compared to other grass species. Leaves of *Stylosanthes hamata* contains maximum nitrogen content 2.4 per cent under 75 per cent light intensity, followed by grasses grown under 50 per cent light intensity. Study also reported that nitrogen content was higher in some grasses grown in open field. In most of grass species maximum phosphorus content (1.6 % in *Panicum antidotale*) was estimated under 50 per cent of sun light intensity. In case of potassium accumulation in grasses, it was higher in low light intensities in most of grasses. Though in overall total pasture crop potassium content was higher under moderate shading environment i.e. 50 per cent light intensity.

Singh *et al.* (1999) assessed the dry matter and protein yield from the harvest of pasture having combination of *Clitoria* + *Cenchrus* + *Leucaena* (9.75 t ha^{-1}) followed by *Chrysopogon* + *Leucaena* (8.86 t ha^{-1}) and *Clitoria* + *Chrysopogon* + *Leucaena* (8.67 t ha^{-1}). The maximum crude protein yield was also recorded in the *Clitoria* + *Cenchrus* + *Leucaena* combination. However, *Clitoria* + *Cenchrus* + *Leucaena* treatment proved to be most beneficial combination for improving biomass and crude protein.

Rai *et al.* (1998) studied the effect of N application regarding yield of *Stylosanthes hamata* and *Cenchrus ciliaris* in *Acacia nilotica* based silvipastoral system. They found that dry matter yield of forage crop increased with application of N, where *Stylo* and *Cenchrus* gave positive response with application of 30 kg and 60 kg N/ha respectively. The mean yield of *Stylo* was 3.70 t/ha with tree and 3.91 t/ha without tree, while dry matter production of grass was 3.75 t/ha with tree and 3.16 t/ha without tree respectively.

Rai *et al.* (1997) also analysed the level of crude protein in legume and tree leaves available at harvesting grass. Highest crude protein was recorded in *Stylosanthes hamata* 16.07 per cent and minimum was noted in *Chrysopogon fulvus* 5.18 per cent. Crude protein recorded in tree leaves showed that the highest crude protein value was 15.88, 17.54 and 22.93 per cent was recorded with *Dichrostachys cinerea*, *Albizia amara* and *Leucaena leucocephala*, respectively.

Muthana *et al*. (1985) reported that in a silvipastoral trials of *Acacia tortilis* + *Cenchrus ciliaris*, the growth of trees was suppressed during the first three years but after that, trees attained better growth rate with the grasses.

2.4 Nutrient status and calorific values of silvipasture system

Woody plants are of the best livings to restore the renewable energy for long periods either in living or non-living conditions. As they utilized sunlight, water and nutrient available in its surrounding habitats to synthesize complex chain of organic molecules and stored them in their body and till ultimately recycling.

Bharadwaj *et al.* (2001) studied the biomass production potential and nutrient dynamics of *Populus deltoides* under high-density plantations and observed that both accumulation of nutrients and its uptake showed increasing trends for macronutrients (N, P and K) kg ha^{-1}, with increase in plant population. Total amount of nitrogen retained in branch and bole was highest (1005.6 kg ha^{-1}) at 60 x 60 cm and thus (765.4 kg ha^{-1}) at 120 x 120 cm plantation spacing respectively, while P and K was in tune of 18.47 kg ha^{-1} and 895.7 kg ha^{-1} at closest spacing and 13.5 kg ha^{-1} and 011.9 kg ha^{-1} at wider spacing, respectively. They also observed the total above ground uptake (retained + retained through litter fall) was highest at narrow spacing and least at wider spacing. While N, P and K retention in branch, bole and aboveground biomass showed decreasing trend with increase in spacing.

Kumar *et al*. (1998) studied the biomass production and nutrient efficiency of multipurpose tree species grown for wood lot and silvipastoral experiment and found that the rate of biomass and nutrient accumulation was higher for *Acaica auriculiformis* and least for *Leucaena leucocephala*. The nutrient concentration decreased in the order to foliage > branch > roots > bole. *A. auriculiformis* showed highest N (1539 kg ha^{-1}), P (113 kg ha^{-1}) and K (478 kg ha^{-1}) accumulation at the 7 years of age, when grown in silvipastoral system.

Singh and Singh (1998) concluded in their trial of eight forest tree species, *viz; Dalbergia sissoo, Hardwickia binata, Albizia lebbeck, A. procera, Gmelina arborea, Emblica officinalis, Casuarina equisetifolia* and *Cassia siamea* at Bhata wastelands of Chhattisgarh plains, that mean annual biomass production at the age of 2.5 and 4.5 years 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 $plant^{-1}$). They also observed that inter relationship of nutrient concentration in plants exhibited statistically significant positive correlation of Ca with N, P and K and significant negative correlation of N with Mg.

Roy *et al.* (1998) studied the eight years old *Acacia tortilis, Albizia amara* and *Hardwickia biñata* based silvipastoral system, for estimation of fodder and fire wood productivity and reported that production from tree component was obtained maximum in *Albizia amara* (5.89 t ha^{-1}) followed by *Acacia tortilis* (52.1 t ha^{-1}) and *Hardwickia binata* (52.21 t ha^{-1}) after eight years of growth. Overall total productivity of different tree under silvipastoral system, were also worked out and it was in order of *Albizia amara* (7.95 t ha^{-1}) > *Acacia tortilis* (7.60 t ha^{-1}) > *Hardwickia binata* (3.32 t ha^{-1}). Lowest productivity of *Hardwickia binata* was on account of slow growth of the tree.

Sreemannarayana *et al*. (1994) evaluated nine MPTs viz. *Dalbergia sissoo, Leucaena leucocephala*, *Albizia lebbeck*, *Acacia auriculiformis, A. albida*, *A. tortilis*, *Azadirachta indica, Eucalyptus camaldulensis* and *Dendrocalamus strictus* on a red sandy loam soil of Andhra Pradesh for their growth performance. Evaluation of tree species after five years of plantation revealed that fast growing *Eucalyptus* and *Leucaena* were found suitable in Southern Telangana of Andhra Pradesh. They also added in their observations that *A. lebbeck* and *L. leucocephala* added comparatively more organic carbon, available P_2O_5 and available K_2O in the soil than the other species studied.

Pacholi and Pandey (1998) worked out the nutrient content of *Dalbergia sissoo* for four spacing viz. 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m and 3 x 3 m. They stated that the total nutrient contents were influenced with plantation density. The level of nutrients viz., N, P, K Ca and Mg were found maximum in 2 x 2 m spacing, while they decreased with increasing the plant density.

Halendra (1993) reported in a study on biomass production and nutrient distribution in *Gmelina arborea* plantations that upper storey biomass contained 394 kg ha^{-1} of K 236 kg ha^{-1} of Ca, 70 kg $ha^{-1}$of Mg and 17 kg ha^{-1} of P. The large proportions of these nutrients were immobilized in the stem wood and bark; while, remaining nutrients were immobilized in twigs and branches (14.5 to 25.8 per cent), foliage (8.6 to 20.5 per cent) and dead branches (1.7 to 4.7 per cent).

Bargali *et al.* (1992) narrated the findings of nutrient dynamics in 2 to 8 years old plantations of *Eucalyptus tereticornis.* The nutrient concentrations in different components also decreased with plantations age. The nutrient content increased in trees and shrubs and decreased in herbs with an increase in plantation age. In tree components total N, P and K were increased from 12.8 to 246.2 kg N ha^{-1}, 0.9 to 21.0 kg p ha^{-1} and 12.9 to 275.9 kg k ha^{-1}, respectively.

Singh and Gupta (1990) studied *Debregeasia hypoleuca* and concluded that the maximum energy contents were stored in stem (4153.82 cal gm^{-1}), followed by branches (4069.51 cal gm^{-1}), roots (3955.96 cal gm^{-1}) and leaves (3848.87 cal gm^{-1}).

Katewa and Tyagi (1990) studied the important fodder grasses, namely *Sehima nervosum, Heteropogon contortus* and *Apluda mutica* and their calorific values. The peaks in calorific values were coincided with the period of seed formation and maturation in all the three grasses on the basis of dry weight. *Sehima nervosum* (3865 cal g^{-1}) generated highest calorific value as compared to *Heteropogon contortus* (3623 cal g^{-1}) and *Apluda mutica* (3169 cal g^{-1}).

Singh *et al.* (1982) studied the calorific values in different components of important tree and shrub species and quantified that the leaves showed highest values (4254 - 4759 cal g^{-1}) in all the species, except in *Buchanania lanzan,* in comparison to other components (3995 - 4205 for bole; 3938 - 4185 for branch and 3934 - 4207 for root). The mean calorific values of 11 tree species in different components were reported in decreasing order of leaf > bole > branch > root. The ground herbaceous layer showed higher values in above ground component than below ground component.

CHAPTER - III

MATERIALS AND METHODS

The present study was conducted on the “Productivity status of ten years old silvipasture system in red lateritic soil” at “Baronda Research Farm”, Raipur district in Chhattisgarh, during 2003-04. The details of study, site, climate, soil, biomass production, pasture structure, nutrient analysis, calorific value, ash contents and crude fibre are described in this chapter.

3.1 Experimental site

The study was conducted in marginal wasteland area at “Baronda Research Farm,” IGAU, Raipur, Chhattisgarh situated at 27 km from Raipur on Raipur-Balodabazar road. The “Baronda Research Farm” is located at 295 meters above mean sea level (MSL) from $17^0$41' to $24^0$45' North latitudes and $79^0$30' to $84^0$15' East longitudes, in Chhattisgarh plain agro-climatic zone.

3.2 Climate and weather

The climate of study site is dry humid sub-tropical with an average annual rainfall of 1250 mm. About 80 percent of the annual rainfall is received from south west monsoon during June to mid August. The highest amount rainfall occurs in July.

Number of rainy days varies from 65 to 79 days. The mean monthly maximum temperature varies from 13.2^0C in December to 28.3^0C in May. The maximum temperature goes beyond 45^0C in May and minimum below 10^0C in December. The relative humidity lies between 70-90 per cent from mid June to March end. Sunshine period in a day prolong more than 9 hours in summer and less than 7 hours in winter. Evaporation remains higher during April to June (10-13 mm day^{-1}) low during July to February (2.4 to 5.0 mm day $^{-1}$). The mean annual weather data recorded at meteorological observation, IGAU, Raipur (C.G.) is presented in table 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 (%)**
1994	31.1	18.4	1688.2	71.76
1995	32.2	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	19.0	858.8	79.40
2000	32.9	19.2	789.1	79.42
2001	32.9	20.1	1033.2	79.01
2002	33.4	20.2	767.2	77.83
2003	34.2	19.2	1511.00	79.38

3.3 Geology

Raipur has three distinct geological formations viz. Bijapur, Cuddapahas, Dharwar and Archean, Lithologically the area is divided into seven groups namely Raipur shale and lime stone, Gunderdehi shale, Khairagarh sand stone, Cuddapahas, Charmur like lime stone, Chandrapur sand stone grit, Dharwar, rocks, Granite and genesis.

3.4 Physiography

In Chhattisgarh plain agro-climatic zone there are ten districts *viz;* Raipur, Bilaspur, Durg, Rajnandgaon, Kawardha, Mahasamund, Dhamtari, Janjgir, Korba and Raigarh. This agro-climatic zone is also known as upper Mahanadi basin, which is sauccer shaped, the larger part of this basin is undulating flat, terrain, gently slopes from west to east. The general geological features of the region comprises of laterites alluvium capping over horizontally bedded sequence of sedimentary rocks of limestone and dolomite on the top followed by limestone, quartzite sandstone, granite, geneisis and meta sediments of old age. These formations have very limited primary porosity and permeability to water.

3.4.1 Soils

Soil of Chhattisgarh plains varies from lateritic/ entisols (20 %), sandy loam inceptisols (45 %), clay loam/alfisols (10 %) and clayey / vertisols (25 %). The soil depth varies from 20 cm in entisols to 100 cm vertisols, with light undulation and general slopes of 2 per cent. The specific features of soil distribution in every village showed that land toposequences ranges from entisols to inceptisols, alfisols and vertisols with slope and this heterogeneous status of soil system always drains into river let. Thus, a typical semi-arid condition of soil appears just after the rainy season due to shallow soil depth and high rate of percolation.

3.4.2 Characteristics of Entisols

The study site was marginal wasteland of entisols soil, which is reddish to dark reddish brown in colour and very shallow in depth. Entisols is classified as coarse, loamy, mixed hypothermic and typical undulating soil. It is locally known as Bhata and have ferruginous gravels. Low pH (acidic highly), low nitrogen, high potassium and low phosphorus with low organic matter are the basic characteristics of entisols. The soil characteristics of study site are presented in table 3.2:

Table 3.2. Physico-chemical properties of Entisols (Bhata soil)

S.No.	Soil features	Status
1.	Slope	Undulating rolling
2.	Colour	Reddish to dark reddish brown
3.	Texture	Gravelly, Course loamy to sandy
4.	Consistency	Non-sticky and non plastic
5.	Cracks	Absent
6.	Depth	Very shallow
7.	Internal drainage	Rapid
8.	Mechanical composition (per cent)	
	(a) Sand	60-80
	(b) Silt	15-22
	(c) Clay	9-20
9.	Infiltration rate (cm hr^{-1})	5.0-7.0
10.	Field capacity (cm)	5.50
11.	Wilting point (cm)	3.30
12.	Available water (cm)	2.15
13.	Porosity (per cent)	45.0
14.	pH	5.6-6.5
15.	Organic carbon (per cent)	0.28-0.50
16.	CEC (C mol (+) kg^{-1})	7.0-10.6
17.	Available nitrogen (per cent)	0.06
18.	Exchangeable cations (C mol (p+) (kg^{-1})	
	Ca^2	3.5-6.2
	Mg^2	1.7-3.4
	Na^+	0.3-0.4
	K^+	0.1-0.3

3.4.3 Physico- chemical features of the soil

The study was conducted on entisols locally known as Bhata land. It is also known as red lateritic soil. As land use classification pattern point of view, it comes under marginal wasteland. These lands have long gentle slopes with undulating topography (Pofali and Bhattacharjee, 1970). The soil having high percentages of gravels and sub soil layers are hard and compact, forming even lateritic pans at places (Singh and Totey, 1985). In red lateritic soil the content of organic matter was found in fewer amounts, which is responsible for causing moisture and thermal stress, which affect microbial activity and the availability of nutrients and subsequently affect the growth of plant (Gupta and Agrawal, 1988).

3.5 Experimental details

A. Four species of MPTs viz.; *Dalbergia sissoo*, *Gmelina arborea, Pongamia pinnata* and *Terminalia arjuna* were planted at 5 x 5 m spacing in July 1992.

B. Pasture crop introduced in July 1994, where grass species *Chrysopogon fulvus*, planted by root slips at 50 cm distance while, legume species *Stylosanthes hamata* was grown by broad-casting the seeds @ 5 kg/ha.

Treatment: Five treatments comprising tree + pasture crop viz.;

- *Dalbergia sissoo* + Pasture –T_1
- *Gmelina arborea* + Pasture- T_2
- *Pongamia pinnata* + Pasture – T_3
- *Terminalia arjuna* + Pasture –T_4
- Pasture crop with out tree (Control plot)-T_0

Plot size	: 25 x 25m
Replication	: Four
Design	: R.B.D.

3.6 Plantation of MPTs

The seedling of MPTs viz. *Dalbergia sissoo, Gmelina arborea, Pongamia pinnata, Terminalia arjuna* were planted at 5 x 5 m spacing in July 1992. Plot size of each tree species was 25 x 25 m. Thus each plot comprises of 25 plants. Control plot i.e. pasture without tree plantation was also laid out in same field. Randomize Block design was followed with four replications.

3.7 Selection of trees for biomass study

Selection of tree was done on the basis of height, collar diameter (CD) and diameter at breast height (DBH) which recorded for each tree species and mean values was worked out to select the representative stands of tree for felling in each replication. Thus selected trees represented the average heights CD and DBH of their group for biomass study. These represented trees were marked series number with the help of red colour oil paint after felling for further study of root.

3.7.1 Measurement of growth parameters

Growth parameters (Height, CD and DBH) were recorded with the standard methods. The collar diameter (CD) and diameter at breast height (DBH) of standing trees were recorded with the help of vernier calliper at 10 cm and 1.37 m respectively from the ground level. Two measurements of diameter was taken at two opposite direction with right angles to each other and the average value of two measurements was taken under consideration.

3.7.2 Tree height

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

3.7.3 Clean bole height

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

3.8 Felling of trees

3.8.1 Above-ground biomass (AGB)

The selected trees of each MPTs were felled one by one with the help of hand saw. The felling was done as close to ground level as possible. After felling, stump of the tree was marked series number at cutting surface for further identification at the time of root excavation. Felled trees were measured for total tree height, clean bole height, dbh, biomass accumulation in different components viz.; bole, branches, twigs, foliage and roots. These components were further analysed for nutrient and calorific values. The felled tree was separated into different components viz. bole, branches, twigs and foliage or leaves by using hand saw, secateurs and hand. Main stem was again classified into clean bole and rest stem. After the separation, total number of branches was counted. For biomass estimation fresh weight of each component was recorded with the help of field and top pan balance. Immediately sub samples of each component was made for determination of dry biomass and nutrient analysis in the laboratory. In case of bole wood disk were cut out from basal, middle and top portion of bole of each felled tree. Similarly samples of roots were made from upper, middle and lower portion of the root system. Sub sample of each components were weighed for fresh weight (sample taken ½ kg for bole, branches and twigs, 200 gm for leaves and roots were taken separately) and dried at 75^0C in hot air oven for 24 hrs then weight of samples were taken. On the basis these sub samples tree total dry weight of each components was worked out.

3.8.2 Below-ground biomass (BGB)

The pattern of root distribution of the harvested trees was studied by excavation method as reported by Ghosh and Chattopadhyay (1972) and Chandra *et al.* (1979). Roots of the selected trees were dug out manually with the help of a pickaxe and spade up to 2.00 m soil depths separately. The excavated roots were thoroughly washed under tap water, dried in shade than weighed with the help of spring balance.

3.8.3 Dry matter estimation

Dry matter of individual components was worked out by using following formula.

$$\textbf{Dry matter} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times \textbf{Total fresh weight of component}$$

3.9 Pasture crops plantation

Grass and legume pasture crops were grown with each multipurpose tree species and in control (without tree species) plot. After two years plantation, *Chrysopogon fulvus* planted by root slips at 50 cm distance, while legume species *Stylosanthes hamata* was grown by broadcasting the seeds @ 5 kg/ha. The line direction was kept north-south for grass and legume pasture crops.

3.9.1 Population structure

Population structure of pasture species was recorded during peak growth period i.e. October. Twenty quadrates of 0.5 x 0.5m size were laid out randomly in each treatment. The population structure of herbage species was estimated for frequency, density basal area by using following expressions (Curtis, and McIntosh, 1950).

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

$$\textbf{Density} = \frac{\text{Total number of individual of species}}{\textbf{Total number of quadrate studies}}$$

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

Basal area of pasture crops was calculated as a cross sectional area of stem at 10 cm from the ground level. The relative density, relative frequency, relative basal areas were calculated using following equations.

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

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

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

The Importance Value Index (I.V I.) was determined as the sum of relative frequency, relative density and relative basal area.

Importance Value Index (I V I)= RD + RF + RBA

3.9.2 Analysis of diversity, dominance, association and similarity index

Different types relationship among the herbage species was worked out as per standard methods given below.

Diversity Index (Margalef 1968) was used for species diversity.

$$H = -\sum\left[\left(\frac{n_1}{N}\right).\log\left(\frac{n_1}{N}\right)\right] + \left[\left(\frac{n_2}{N}\right)\right].\log\left(\frac{n_2}{N}\right) + - - -\left(\frac{n_n}{N}\right).\log\left(\frac{n_n}{N}\right)n$$

Where,

H = Shannon index of general diversity

n = Importance value index of each species for 1 to n species

N= Importance value of all species

(a) Dominance Index (Simpson 1949) was used for community diversity.

$$C = -\sum\left[\left(\frac{n_1}{N}\right)^2 + \left(\frac{n_2}{N}\right)^2 + - - - \left(\frac{n_n}{N}\right)^2\right]$$

N and n were same as explained above

(b) Association Index was used for association with *Chrysopogon fulvus* and *Stylosanthes hamata.*

Association Index = (Number of quadrates in which species 'x' occurred in association with species 'y') / (Total number of quadrates in which species 'x' is found) X 100

$$\text{Association Index} = \frac{\text{Number of quadrates in which species 'x' occurred in association with species 'y'}}{\text{Total number of quadrates in which species 'x' is found}} \times 100$$

(c) Similarity Index (Misra, 1989) was used for finding percentages of similar species in five communities.

$$\text{Similarity Index} = \frac{\text{Number of communities x Number of common species in all communities}}{\Sigma \text{ of total species in each community}} \times 100$$

3.9.3 Production of pasture crop

Production of pasture crop was recorded in peak growth period in October. The quadrates of 0.5 x 0.5 m were used to harvest the pasture crop, which was further separated into grass, legumes and others than grass and legumes. Fresh weight of these group were recorded sub samples of each harvested groups were dried at 70^0C in hot air oven for 72 hours to estimate the dry weight of pasture crop.

3.10 Analysis of important chemical characteristics of soil, MPTs and pasture crops

Standard methods were used to determine the physical and chemical analysis of pH and organic carbon in soil and nitrogen, phosphorus, potassium crude protein, crude fibre and calorific values in trees and pasture crops as given below.

3.10.1 Physico-chemical analysis of soil

Soil samples were collected from three places in replications at three depths viz. 0-5 cm, 5-10 cm and 10-15 cm. Bulk samples of each treatments were used for analysis of pH and organic carbon, were determined as per the standard methods by using glass electrode methods (Jackson, 1967 and 1973) and ammonium ferrous sulphate and potassium dichromate method (Walkey and Black 1934) respectively.

3.10.2 Nutrient, ash, crude fibre and calorific value analysis of MPTs

In each tree species samples of bole, branches, twigs and foliage etc. were collected and dried in hot air oven at 70^0C for 72 hours to determine N, P, K and calorific values. The dried samples were grinded in willey mill and passed through 2 mm sized sieve to obtain fine powder. The powdered plant materials of different tree components were analyzed for nitrogen, phosphorus, potassium, calorific values, ash, crude fibre as per standard methods by using Micro-kjeldhal methods (AOAC, 1975), Spectrophotometer (Olsen *et al.* 1954), Flame photometer (Jackson, 1967 and 1973). Bomb calorimeter, Muffle furnace combustion methods and Weende method respectively.

3.10.3 Nutrient, ash, crude fiber and calorific value analysis of pasture crops

To estimate nutritive value of pastures, oven dry plant samples were powdered by willey grinder and sieved through 2 mm sieve. The powdered materials were then anlysed for nitrogen, phosphorus, potassium, ash, crude fibre and Calorific value as per standard methods by using micro-kjeldhal method (AOAC-1975), Spectrophotometer (Olsen *et al.* 1954), Flame photometer (Jackson, 1967 and 1973), Muffle furnace combustion method, Weende method and Bomb Calorimeter method respectively.

3.11 Statistical analysis

The data generated from the different observations were computed and tabulated for its statistical analysis and presented as per the standard statistical methods/ packages (Panse and Sukhatme, 1947). The spreadsheet based software M.S Excel and Lotus – 123 were used for all the calculations.

3.12 Photography

Photographic descriptions were also recorded for evidence of research work by using SLR canon AE-1 Program Camera.

CHAPTER-IV

RESULTS

The results on morphological growth characters, biomass production, nutrients and combustible energy stored in the tree species grown in red lateritic soil under silvipasture system are presented in this chapter. *Chrysopogon fulvus* (grass) and *Stylosanthes hamata* (legume) pasture crop were introduced after two years growth of MPTs and after ten years of establishment and growth of pasture crop, the status of under storey vegetation was studied for phytosociological structure, biomass production, nutritive value *viz;* N, P, K, Ash, Crude fibre, Crude protein and Energy and their data are presented in appropriate tables and graphics format after statistical analysis.

4.1 Morphological characteristics of tree

The growth performance of four MPTs, *viz; Dalbergia sissoo*, *Gmelina arborea*, *Pongamia pinnata* and *Terminalia arjuna* with regard to various growth parameters were found as follow.

4.1.1 Collar diameter (C D)

It is evident from table 4.1 that collar diameter of eleven years old MPTs in the silvipasture system, was considerable varied from species to species, where *G. arborea* attained highest growth of 15.03 cm followed by *D. sissoo* (13.25 cm) and *T. arjuna* (12.45 cm) respectively. The minimum CD was recorded in *P. pinnata* (12.01 cm) but the growth behaviour in collar diameter among all MPTs was found statistically insignificant.

4.1.2 Diameter at breast height (DBH)

The diameter at breast height (DBH) was recorded, maximum for *D. sissoo* (13.1 cm) followed by *G. arborea* (11.5 cm) and *T. arjuna* (9.43 cm) respectively. The minimum DBH was recorded in *P. pinnata* (9.06 cm). In growth of DBH, statistically significant variation was seen (Table 4.1).

4.1.3 Clean bole height (CBH)

Tree height up to clean bole in all the MPTs showed statistically non-significant results. The growth performance of clean bole height was found in decreasing order of *D. sissoo* (2.61 m), *G. arborea* (2.60 m), *T. arjuna* (2.09 m) and *P. pinnata* (2.01m), respectively (Table 4.1).

4.1.4 Total tree height

The total tree height of eleven years old trees is presented in table 4.1. Perusal of table showed that maximum mean height was attained by *G. arborea* (7.19 m), followed by *D. sissoo* (6.08 m) *P. pinnata* (5.53 m) and *T. arjuna* (5.40

m) respectively. The results of total height of tree were found statistically in significant.

4.2 Biomass of trees

Trees were harvested for estimation of their component wise per tree fresh and dry biomass production. The component wise final results after statistical analysis were presented and narrated in following heads.

4.2.1 Bole

The fresh bole biomass production in the tree was found statistically significant (Table 4.2), where *D. sissoo* gained maximum biomass (43.70 kg $F.wt.tree^{-1}$) followed by *G. arborea* (39.30 kg $F.wt.tree^{-1}$) and *T. arjuna* (23.56 kg $F.wt.tree^{-1}$) respectively. The minimum biomass was recorded in *P. pinnata* (16.93 kg F. wt. $tree^{-1}$).

The average bole dry matter production was also found statistically significant (Table 4.3) and followed the trend of fresh weight. After hot air dry oven at 75^0C, *D. sissoo* possessed highest dry matter (21.59 kg $tree^{-1}$) followed by *G. arborea* (18.78 kg $tree^{-1}$) and in *T. arjuna* (12.79 kg $tree^{-1}$) respectively with insignificant differences. The lowest dry matter was recorded in *P. pinnata* (8.19 kg $tree^{-1}$).

4.2.2 Branches

This part of tree played major role in the formation of tree canopy and provides physical strength to the tree. The fresh weight of branches of in the tree was also found statistically insignificant (Table 4.2), where it was found maximum in *D. sissoo* (17.88 kg F. wt. tree^{-1}) followed by *G. arborea* (14.76 kg F. wt.tree^{-1}), *P. pinnata* (11.80 kg F. wt. tree^{-1}) and *T. arjuna* (8.18 kg F. wt.tree^{-1}) respectively.

Dry matter production also found insignificant results (Table 4.3) and followed the trend of fresh weight with the maximum dry matter in *D. sissoo* (9.11 kg tree^{-1}) followed by *G. arborea* (8.63 kg tree^{-1}) *P. pinnata* (5.24 kg tree^{-1}) and the minimum dry matter was given by *T. arjuna* (3.80 kg tree^{-1}).

4.2.3 Twigs

The fresh weight of twigs are presented in table 4.2, which revealed that the mean twigs biomass production was found statistically significant with maximum biomass in *D. sissoo* (18.95 kg F.wt.tree^{-1}), followed by *G. arborea* (7.16 kg F.wt.tree^{-1}) and *P. pinnata* (5.83 kg F. wt. tree^{-1}). Minimum biomass was recorded in *T. arjuna* (3.76 kg F. wt.tree^{-1}).

The dry matter production pattern in twigs was also found statistically significant (Table 4.3). The trend of dry matter in twigs was similar to the branch dry matter production. The average dry matter production of twigs were 8.90, 3.29, 3.03 and 2.4 kg tree^{-1} for *D. sissoo, G. arborea*, *P. pinnata* and *T. arjuna,* respectively. There was statistically insignificant differences among *G. arborea,* *P. pinnata* and *T. arjuna* for both fresh and dry weight.

4.2.4 Foliage

The formation and abscission of foliage was not only found genetically vary from species to species but also influenced by climatic and edaphic condition. At the time of harvesting of trees, the highest fresh weight in foliage was recorded in *G. arborea* (3.40 kg F. wt tree^{-1}) followed by *D. sissoo* (3.3 kg F. wt tree^{-1}) and *P. pinnata* (1.73 kg F. wt tree^{-1}). While minimum foliage biomass was recorded in *T. arjuna* (0.66 kg F. wt. tree^{-1}). The results were found statistically significant (Table 4.2).

There was a statistically significant difference in foliage dry matter of MPTs (Table 4.3), where *G. arborea* produced highest dry foliage (1.63 kg tree^{-1}) and was recorded in *T. arjuna* produced lowest (0.33 kg tree^{-1}). The insignificant differences were seen among *D. sissoo, G. arborea* and *P. pinnata*.

4.2.5 Above ground biomass

The results of total standing above ground (AG) biomass are presented in table 4.2. It is evident from the data that the maximum above ground biomass was obtained in *D. sissoo* (83.82 kg F. wt tree^{-1}) followed by *G. arborea* (61.28 kg F. wt tree^{-1}) with insignificant variation, while minimum was obtained in *T. arjuna* (36.18 kg F. wt tree^{-1}), with insignificant difference to *P. pinnata* (36.33 kg F. wt tree^{-1}) and *G. arborea* (61.28 kg F. wt tree^{-1}). The results were found significant statistically.

The dry matter of total standing above ground (AG) is presented in table 4.3. Perusal of data showed that the maximum above ground dry matter was obtained in *D. sissoo* (41.23 kg tree^{-1}) which was 1.34 and 2.13 times higher from *G. arborea* and *T. arjuna* respectively. The minimum dry matter was obtained in *P. pinnata* (17.43 kg $tree^{-1}$) with insignificant difference to *T. arjuna* and *G. arborea*. Though results were found statistically significant.

4.2.6 Below ground biomass

The below ground structure of tree weighed for it fresh and dry weight and showed similar trend with significant relationship between maximum and minimum values of *P. pinnata* and *T. arjuna* (Table 4.2). The below ground biomass production showed statistically significant results with maximum in *P. pinnata* (15.88 kg F. wt $tree^{-1}$) followed by *G. arborea* (11.61 kg F. wt $tree^{-1}$), *D. sissoo* (8.25 kg F. wt $tree^{-1}$). The minimum was recorded in *T. arjuna* (7.23 kg F. wt $tree^{-1}$).

The below ground dry matter production showed statistically significant variation (Table 4.3), where it was recorded maximum in *P. pinnata* (9.3 kg $tree^{-1}$) followed by *G. arborea* (6.26 kg $tree^{-1}$), *D. sissoo* (4.61 kg $tree^{-1}$) respectively, while it was minimum in *T. arjuna* (3.79 kg $tree^{-1}$).

4.2.7 Total tree biomass

The data on total biomass production of trees grown in silvipasture system are presented in table 4.2. Perusal of table revealed that maximum total biomass was recorded in *D. sissoo* (92.08 kg F. wt $tree^{-1}$) followed by *G. arborea* with significant difference. Though it was double to lowest total biomass of *T. arjuna* (43.41 kg F. wt $tree^{-1}$), which was insignificant to *G. arborea* and *P. pinnata.*

The total dry matter production of four MPTs showed insignificant variation (Table 4.3). The highest total dry matter production was recorded in *D. sissoo* (45.18 kg tree^{-1}), as it was also leading in various components *viz;* bole, branch, twigs, total AG and BG among the other tree species. The minimum total dry matter was found in *T. arjuna* (23.13 kg tree^{-1}). Thus the production of total tree at the age of eleven years in silvipasture systems was in the order of *D. sissoo* > *G. arborea* > *P. pinnata* > *T. arjuna.*

4.3 Nutritive status of trees

Major nutrients *viz*; N.P.K and other parameters *viz;* ash, crude protein and crude fibre available in different part of trees are presented here in following heads.

Nutrients

The nutrients available in different components of trees are presented in table 4.4. It is evident from the table that level of nutrients was ranged from 0.94 to 1.73 %, 0.05 to 0.85 % and 0.44 to 1.03 % for N, P and K, respectively in different components of four tree species.

The level of nitrogen was found maximum in bole (0.99 to 1.73 %) followed by branches (0.96 to 1.69 %), twigs (0.94 to 1.55 %) roots (1.17 to 1.60 %) and foliage (1.07 to 1.38 %), respectively. Leguminous tree species showed higher level of nitrogen, while *G. arborea* showed lowest availability of nitrogen in all the tree components (Table 4.4).

The availability of phosphorus as macronutrient ranged between 0.06 to 0.85 % in leguminous tree and 0.05 to 0.65 % in non-leguminous trees in their all the components. The maximum phosphorous was recorded in twigs of *D. sissoo* (0.85 %) and minimum was recorded in *D. sissoo* root. In case of non-leguminous tree species *i.e.* in *G. arborea* the maximum phosphorous was recorded in bole (0.32 %) and minimum was recorded in foliage (0.05 %). In *P. pinnata* the maximum content of phosphorous was recorded in twigs (0.65 %) followed by branch (0.55 %) and minimum was found in root (0.06 %). In *T. arjuna* the maximum phosphorus was recorded in twigs (0.05 %) followed by bole (0.55 %) and minimum was recorded in roots (0.07 %).

Over all potassium was detected maximum in bole of *T. arjuna* (1.03 %) and minimum in the bole of *D. sissoo* (0.44 %). In *D. sissoo* maximum potassium was found in twigs (0.92 %) followed by roots (0.84 %), branch (0.74 %) and foliage respectively, which were found comparatively lowest from all the tree species. In case of *G. arborea*, maximum potassium was detected in twigs (0.98 %) followed by branch (0.95 %), root (0.93 %), bole (0.91 %) and foliage (0.78 %) respectively. But in case of *P. pinnata* it was found maximum in root (1.02 %) followed by bole (1.00 %), twigs (0.81 %). Foliage of all the species contained minimum level of potassium in range of 0.55 % to 0.53 % except 0.78 % in *G. arborea*. *T. arjuna* showed the potassium content in range of 1.03 to 0.89 per cent among bole, branch twigs and roots.

4.3.2 Ash content

The ash available in different parts of trees species are shown in table 4.4. The maximum ash content was found in twigs of *P. pinnata* (8.89 %) followed by *T. arjuna* twigs (7.20 %) and leaves of *T. arjuna* (6.85 %). The minimum was recorded in bole of *G. arborea* (2.22 %).

4.3.3 Crude protein

In plants crude protein is synthesized by the process of nitrogen assimilation and stored for further utilization. In *D. sissoo* the maximum crude protein was found in bole (10.81 %) followed by branch (10.56 %), while minimum was found in foliage (8.62 %). In *G. arborea* the maximum amount of crude protein was found in foliage (8.00 %) followed by roots (7.31 %), bole (6.18 %), and minimum twigs (5.87 %) respectively (Table 4.4). In case of *P. pinnata*, the maximum crude protein was recorded in bole (10.31 %) followed by root (10.01 %), branch (9.62 %) and twigs (9.50 %), while the minimum was recorded in foliage (8.18 %). *T. arjuna* showed maximum crude protein in root (7.56 %), followed by branch (7.18 %) and minimum in bole (6.56 %)Table 4.4.

The crude protein is associated with nutrition to cattle / bovine population, therefore palatable component of trees *i.e.* foliage and soft branches or twigs are to be used as fodder purpose was estimated at the time of harvest. The maximum crude protein was found in foliage of *D. sissoo* (144.06 gm tree^{-1}) followed by *G. arborea* (130.40 gm tree^{-1}) and minimum was found in *T. arjuna* (22.59 gm tree^{-1}). In case of twigs the maximum crude protein was in available in *D. sissoo* (862.00 gm tree^{-1}), followed by *P. pinnata* (287.85 gm tree^{-1}) and minimum was recorded in *T. arjuna* (160.76 gm tree^{-1}). Over all in the total tree, the maximum crude protein was available in *D. sissoo* (4219.33 gm tree^{-1}) followed by *P. pinnata* (2414.66 gm tree^{-1}), *G. arborea* (2339.58 gm tree^{-1}), respectively. The results were found statistically significant for of all tree parts (Table 4.5).

4.3.4 Crude fibre

Crude fibre was estimated in only palatable foliage (Table 4.4). The maximum crude fibre was found in *T. arjuna* (20.63 %) followed by *D. sissoo* (19.61 %) and *G. arborea* (18.98 %). The minimum was recorded in *P. pinnata* (18.27 %).

4.4 Harvesting of nutrient from tree

Harvesting of tree crop is directly and indirectly responsible for exporting the major part of nutrient from soil. Export of N, P and K through harvest of four MPTs *viz; D. sissoo, G. arborea, P. pinnata* and *T. arjuna* from the soil of silvipasture system are ultimately needed to be quantify for determining the role of tree species in nutrients budget of system. Total accumulation of N, P and K at time of harvest in different parts of the tree is presented in tables from 4.6 to 4.8.

4. 4.1 Nitrogen

The nitrogen removed from tree component was directly related to the inherent harvest performance of tree species for its biomass production and mineral utilization behaviour. The total amount of N in a tree was removed maximum by both the nitrogen fixing tree species viz. *D. sissoo* (754.91 gm $tree^{-1}$) and *P. pinnata* (436.90 gm $tree^{-1}$). Lowest amount of N was removed by *T. arjuna* (253.31gm $tree^{-1}$) and *G. arborea* (293.92 gm $tree^{-1}$). There was in significant variation among *G. arborea, P. pinnata* and *T. arjuna* for branches, twigs, total wood, above ground, below ground and total tree. Though statistical analysis of data showed significant results for all components (Table 4.6).

4.4.2 Phosphorus

The phosphorus accumulated in different tree components. It showed statistically significant results for all the above ground components except roots (Table 4.7).

D. sissoo was leading tree species for total phosphorus accumulation. The maximum quantity of phosphorus content was harvested through bole, which was 94.80, 71.23, 61.59 and 39.97 gm tree^{-1} in *D. sissoo, T. arjuna, G. arborea* and *P. pinnata,* respectively. Minimum quantity of P was stored in foliage in tune of *P. pinnata* (5.15 gm tree^{-1}), *T. arjuna* (1.79 gm tree^{-1}), *D. sissoo* (0.34 gm tree^{-1}) and *G. arborea* (0.84 gm tree^{-1}) respectively. The overall phosphorus content in different trees was found in the order of *D. sissoo* > *T. arjuna* > *P. pinnata* > *G. arborea*. The variation of available phosphorous in different components showed insignificant relation among *G. arborea, P. pinnata* and *T. arjuna.*

4.4.3 Potassium

The total available potassium content varied from 201.87 to 338.62 g tree^{-1} among four tree species. Whereas variation between individual components ranged from 8.87 to 98.26 gm tree^{-1} for *D. sissoo,* 12.79 to 170.89 gm tree^{-1} for *G. arborea,* 5.18 to 94.92 gm tree^{-1} for, *P. pinnata* and 1.84 to 132.69 for *T. arjuna* respectively. The maximum amount of K was found to be deposited in woody parts and minimum in foliages. The statistically insignificant results for branch, total wood, AG and total tree were seen with maximum content of K in

G. *arborea* (285.88 gm tree^{-1}) and lowest amount in *P. pinnata* (140.49 gm tree^{-1}). Though the potassium content was found statistically significant in bole, twigs, foliage and root components (Table 4.8).

4.5. Calorific values in different parts of tree

Calorific values of four trees are given in table 4.9. It is evident from the data that the combustible energy was found varied among species along with its different components. It was recorded highest in bole of *T. arjuna* (5196.23 cal kg^{-1}) and lowest in foliage of *P. pinnata* (1495.16 cal kg^{-1}). The overall combustible energy was found in order of *D. sissoo* > *T. arjuna* > *G. arborea* > *P. pinnata.*

4.5.1 Harvest of combustible energy

The total combustible energy harvested from the tree after eleven years of growth was estimated for bole, branch, twigs, leaves and roots (Table 4.10). The results were found statistically significant for bole, branch, twigs, above ground wood and total tree. The trend of combustible energy harvested in the bole was found 111650.87, 66035.41, 78862.10 and 39887.50 k cal tree^{-1} for *D. sissoo, T. arjuna, G. arborea* and *P. pinnata,* respectively. The calorific values (k cal tree^{-1}) generated from whole tree was found in order of *D.* sissoo (186473.8) > *G. arborea* (129973.25) > *T. arjuna* (96333.66) > *P. pinnata* (79355.49).

4.6 Pasture component

Pasture crops are the part of silvipasture and it serves the nutritive food to the cattle. But quantity and quality of pastures are gradually found to be influenced by the growth and canopy behavior of trees. In this part behaviour of under storey herbage vegetation is presented in light of population structure, dry matter yield and nutritive values of pasture. In this chapter pasture and under storey plants are to be narrated as herbage species.

4.6.1 Phytosociological structure of herbage species

The distribution and performance of plant in an ecosystem depends on the microclimatic conditions as well as genetic potential of the species to develop adaptability for the environments. In present study, herbage flora was quantified for their numerical strength and biomass production. It is evident from the data (Table 4.11) that the total number of herbage species available in *D. sissoo* (T_1), *G. arborea* (T_2), *P. pinnata* (T_3), *T. arjuna* (T_4) and control plots, were 14, 14, 17, 12 and 15 respectively. Population of *Aschinomon indica* leguminous species *Pennisetum pedicellatum* grass species was found to be dominating under all above situations as invaded species. Similarity index of species revealed that out of total species encountered during study in all five different treatments of tree + pasture crops only 61.64 per cent were found similar.

Phytosociological structure of under storey herbage species in all five sets of treatments is presented from tables 4.11 to 4.16. The population strength of total herbage species was found maximum under *D. sissoo* plots (582.6 plant m^{-2}) and minimum under *G. arborea* plots (268.8 plant m^{-2}). Though the level of abundance was found maximum in open field (287.82 plant m^{-2}) followed by *D.*

sissoo plots (381.44 plant m^{-2}) and minimum in *G. arborea* plots. The total above ground biomass for herbage species was recorded maximum (107.2 gm m^{-2}) in *D. sissoo* plots and minimum in *G. arborea* plots (665.17 gm m^{-2}).

The level of dominance showed remarkable relationship with diversity. Where the dominance was at higher level (0.2585), the diversity was at lower level (0.85) in control plots. In case of *P. pinnata* the dominance was at minimum level (0.1237) with higher level of diversity (1.0674). Association index between *Stylosanthes hamata* and *Chrysopogon fulvus* was recorded maximum in *D. sissoo* plots (100 %), while minimum was recorded in control plots (57.14 %).

Frequency and density denotes the level of distribution and numerical strength of a species in a given community. The total species encountered during the course of study were grouped into three major categories. *i.e.* grass, legumes and other than grass and legume species. Grasses include *Cenchrus ciliaris*, *Cynodon dactylon, Chrysopogon fulvus, Eremopogon faveolatus, Heteropogon contortus, Iseliema laxum, Pennisetum pedicellatum* and *Themeda quadrivalvis,* out of these eight grass species only *Chrysopogon fulvus, Eremopogon faveolatus, Pennisetum pedicellatum* and *Heteropogon contortus* were presented in all five study sites. Where the presence of these four species in different treatments were in order of *Pennisetum pedicellatum* > *Chrysopogon fulvus* > *Eremopogon faveolatus* > *Heteropogon contortus* in *D. sissoo* plots; *Pennisetum pedicellatum* > *Heteropogon contortus* > *Eremopogon faveolatus* > *Chrysopogon fulvus* in *G. arborea* plots and *P. pinnata* plots; *Chrysopogon* *fulvus* > *Pennisetum pedicellatum* > *Eremopogon faveolatus* > *Heteropogon contortus* in *T. arjuna* plots and *Pennisetum pedicellatum*> *Heteropogon contortus* > *Chrysopogon fulvus* > *Eremopogon faveolatus* in control plots.

In case of leguminous flora, there was seven species lodged their presence, which were *Alysicarpus monilifer, A. bupleurifolius, A. tetragonolabus, Aschinomon indica, Cassia pumila, Hylandia latibrosa, Stylosanthes hamata.* The perusal of IVI of the legumes it was found that only *Alyicarpus bupleurifolius, Alysicarpus monilifer, Aschinomon indica* and *Stylosanthes hamata* were occurred in all the study sites, where the *Aschinomon indica* locally known sole was dominated as a weed and reported common in agricultural field of Chhattisgarh.

Natural herbage flora other than grasses and legumes were *Celosia argentia, Chorchorus aletorius, Cyprus rotendus, Fembristylis tenera, F. Schoenoides* and *Sida carpinifolia* of which only *Celosia argentia,* occurred in all the study sties.

It is exhibited from data the frequency, density and the IVI of *Aschinomon indica* were found maximum under different treatments and it was 100 per cent in *G. arborea* plots 199. 8 m^{-2} and 144.37 in control plots, respectively. While minimum value of frequency, density and the IVI of different herbage species were showed different trends in different treatments. The level of frequency was found up to 5 per cent for *Hylandia latibrosa, Fembristylis schoenoides and Cenchrus ciliaris* in *G. arborea, P. pinnata* and control plots, respectively. Minimum density was recorded 1.2 m^{-2} for *Sida carpinifolia* in control plots.

The results of different herbage flora, which were ultimately responsible for biomass production and nutritive values, were presented in (Table 4.12 to 4.16). On the basis of relative values of frequencies, density and basal cover (dominance), the population structure of the species in a community was indexed as IVI. In present study herbage species having more than 20 IVI were + in *D. sissoo* plots; *Alysicarpus monilifer* > *Pennisetum pedicellatum* > *A. bupleurifolius* > *Stylosanthes hamata* > *Heteropogon contortus* in *G. arborea* plots; *Aschinomon indica* > *Chrysopogon fulvus* > *Pennisetum pedicellatum* > *Stylosanthes hamata* in *T. arjuna* plots. In case of control plots, these were in order of *Aschinomon indica* > *Pennisetum pedicellatum* >*Heteropogon contortus.* The different pastoral system were found heavily infested by local and natural species of grass and legumes, which were dominating over introduced grass + legumes pasture crop during 10 years growth of silvipasture system.

4.7 Pasture production

The production of pasture crops was recorded by harvesting the standing pastures during peak growth period of October under different sets of treatments viz., *D. sissoo* + *Pasture* (T_1), *G. arborea* + Pasture (T_2), *P. pinnata* + pasture (T_3), *T. arjuna* + Pasture (T_4), and pasture without tree (T_0). It was observed that the impact of tree canopy structure after eleven years of growth on dry matter production of grasses and legumes components as well as total pastures was not found statistically significant.

Though maximum dry matter production of grasses was found in *D. sissoo* plots (893.84 gm m^{-2}) followed by *P. pinnata* plots (643.72 gm m^{-2}) and the minimum was found in *G. arborea* plots (273.90 gm m^{-2}). The maximum dry matter of legumes was found in control plots (538.07 gm m^{-2}) followed by *G. arborea* plots (381.73 gm m^{-2}) and the minimum was found in *P. pinnata* (171.73 gm m^{-2}). The maximum total dry matter production was recorded in *D. sissoo* (1107.02 gm m^{-2}) followed by control plots (864.74 gm m^{-2}). *P. pinnata* (856.82 gm m^{-2}) and *T. arjuna* (781.89 gm m^{-2}), while the minimum was recorded in *G. arborea* (665.17 gm m^{-2}). The results table 4.17 showed that the dry matter production of other than grass and legumes species was found statistically significant and it was recorded maximum 41.37 gm m^{-2} in *P. pinnata* plots with insignificant different to control plots (21.05 gm m^{-2}). Minimum dry matter production of other species was (9.54 gm m^{-2}), which showed the insignificant difference to all treatments.

4.8 Nutritive status of pasture species

4.8.1 Nitrogen

The estimation of nitrogen content in pasture crop was done by the micro-kjeldhal distillation method. The estimated nitrogen per cent are presented in (Table 4.18). In the grass community over all level of nitrogen ranged between 0.23 to 1.09 per cent, where the maximum nitrogen per cent of grass was found in *Cynodon dactylon* (1.09 %) and minimum was estimated in *Themeda quadrivalvis* (0.23 %). In case of leguminous species the maximum nitrogen percent was estimated in *Aschinomon indica* (1.37 %) followed by *Alysicarpus* *bupleurifolius* (1.31 %) and minimum was estimated in *Hylandia latibrosa* (0.14 %). Other non-leguminous species showed level of nitrogen in range of 0.16 per cent (*Cyprus rotendus*) to 1.28 per cent (*Sida carpinifolia*).

4.8.2 Phosphorous

The phosphorus content in pasture crops was estimated by the spectrophotometer methods (Table 4.18). In all three groups of herbage species *viz*., grasses, legumes and others the maximum phosphorous content was found in *Cynodon dactylon* (0.94 %) followed by *Stylosanthes hamata* (0.84 %) and C*horchorus aletorius* (0.74 %) and minimum was estimated in *Pennisetum pedicellatum* (0.53 %), while the *Aschinomon indica* (0.63 %) and *Celosia argentia* 0.23 %).

4.8.3 Potassium

Potassium content in pasture crops was estimated as per standard method of flame photometer (Table 4.18). The maximum potassium content in grass species was found in *Cenchrus ciliaris* (0.89 %) followed by *Iseliema laxum* (0.85 %) and minimum was found in *Eremopogon faveolatus* (0.57 %). In case of legumes the maximum potassium content was estimated in *Alysicarpus monilifer* (0.83 %) and minimum was recorded in *Stylosanthes hamata* (0.33 %). Whereas in other non-leguminous other forbs, it was ranged between 0.89 to 0.36 per cent.

4.8.4 Crude protein

The crude portion in plants is calculated on the basis of available total quantity of nitrogen it followed similar trend. The maximum crude protein in grasses was ranged between 1.43 per cent (*Themeda quadrivalvis)* to 6.81per cent (*Cynodon dactylon).* The maximum crude protein for legumes was estimated in *Aschinomon indica* (8.56 %) followed by *Alysicarpus bupleurifolius* (8.18 %) while minimum was recorded in *Hylandia latibrosa* (0.87 %).

4.8.5 Crude fibre

The residues of indigestible part of plants were received by acid and alkali treatments methods**.** The content of crude fibre herbage species are presented in table 4.18. The over all crude fibre was filtered maximum from *Chrysopogon fulvus* (42.9 %) followed by *Cenchrus ciliaris* (41.2 %) and minimum was estimated in *Cynodon dactylon* (22.6 %). The maximum crude fibre of leguminous was found in *Aschinomon indica* (35.6 %) and minimum was estimated in *Hylandia latibrosa* (29.2 %). In forbs it ranged 39.6 to 29.2 per cent.

4.8.6 Ash content

The content of ash in pasture components received after combustion in muffle furnace are presented in table 4.18. Over all the maximum ash content was received from *Cyprus rotendus* (4.62 %), *Chrysopogon fulvus* and *Chorchorus aletorisus* (4.31 %), while the minimum quantity of ash was estimated in *Pennisetum pedicellatum* (2.32 %). In legumes, maximum and minimum ash content was found 3.13 per cent and 2.33 per cent in *Alysicarpus bupleurifolius* and *Stylosanthes hamata*, respectively.

4.8.7 Calorific value

The combustible calorific energy received from the combustion of herbage species were measured by Bomb Calorie Meter (Table 4.18). In grass species, the maximum energy was found in *Heteropogon contortus* (3479.16 cal gm^{-1}) followed by *Pennisetum pedicellatum* (3396.26 cal gm^{-1}) and minimum was estimated in *Themeda quadrivalvis* (2926.19 cal gm^{-1}). The maximum energy in leguminous species was found in *Stylosanthes hamata* (3674.27 gm cal gm^{-1}) and minimum was recorded in *Hylandia latibrosa* (2518.20 cal gm^{-1}).

4.9 Nutritive value of pasture crop

Nutritive value of pasture crop was estimated for major three groups *i.e*. grasses, legumes and other than grass and legumes. The bulk samples were used to calculate weight per unit area, availability of N P K, crude protein, ash, crude fibre and calorific values in pasture species collected from five different treatments of tree + pasture crops.

4.9.1 Nitrogen

The weight per unit area of nitrogen quantity under five pasture growing conditions were found non significant for grasses, legumes and total pasture crops. In grasses, it was found maximum in *D. sissoo* plots (4.74 gm m^{-2}) followed by *P. pinnata* plots (4.59 gm m^{-2}) and *T. arjuna* plots (2.88 gm m^{-2}) respectively. The minimum nitrogen was available in grasses of control plots

(1.71 gm m^{-2}). In case of legumes, the maximum nitrogen was recorded in control plots (7.71 gm m^{-2}) followed by crop in *G. arborea* plots (5.0 gm m^{-2}) and *T. arjuna* plots (3.13 gm m^{-2}), while the minimum was found in *P. pinnata* plots (2.15 gm m^{-2}). Among major three herbage groups the maximum nitrogen was estimated from grasses and minimum from other species. The total nitrogen in pasture crops was harvested in order of control plots (9.00gm m^{-2}) > *D. sissoo* (7.62gm m-^{2}) > *P. pi*nnata (7.11 gm m^{-2}) > *G. arborea* (7.07gm m^{-2}) > *T. arjuna* (6.09 gm m^{-2}) respectively (Table 4.19).

4.9.2 Phosphorus

Phosphorous content in pasture crops harvested from different treatments showed statistically non-significant results for all three groups of pasture and presented in table 4.20. Perusal of table showed that in grasses, the maximum phosphorus content was found in *D. sissoo* plots (8.08 gm m^{-2}) and the minimum was found in Control plots (2.92 gm m^{-2}). The phosphorus content in legumes was found maximum in control plots (3.43 gm m^{-2}) and the minimum was found in *P. pinnata* plots (1.12 gm m^{-2}). The overall phosphorus was found maximum in *P. pinnata* plots (9.52 gm m^{-2}) and the minimum was found in control plots (6.60 gm m^{-2}).

4.9.3 Potassium

Estimation of potassium content per unit area in pasture crops harvested from different treatments is presented in table 4.21. In grasses, the maximum potassium content was found in *D. Sissoo* plots (6.90 gm m^{-2}) and the minimum was found in *G. arborea* plots (1.92 gm m^{-2}). The results were found statistically non significant for grasses, legumes and total pasture crop. The maximum potassium content in legumes was found in control plots (4.96 gm m^{-2}) followed by *G. arborea* plots (1.62 gm m^{-2}) and the minimum was found in *P. pinnata* plots (0.74 gm m^{-2}). The over all maximum potassium was found in *D. sissoo* plots (7.81 gm m^{-2}) followed by control plots (7.63 gm m^{-2}) and the minimum was found in *G. arborea* plots (3.58 gm m^{-2}). The potassium content in other than grass and legume species was found statistically significant with very least amount of potassium available in range of 0.03 to 0.32 gm m^{-2}.

4.9.4 Crude protein

The nutritive value of any pasture crop is primarily accounted by its proteins. In the present study where the pasture crop under different treatments interfered by local invaded species, showed insignificant results for grasses, legumes and total pasture crop (Table 4.22). The data on crude protein revealed that crude protein in grasses was recorded maximum in *D. sissoo* plots (29.49 gm m^{-2}) followed by *P. pinnata* plots (19.45 gm m^{-2}) *T. arjuna* plots (17.86 gm m^{-2}) and the minimum in control plots (10.75 gm m^{-2}). In case of legumes it was found maximum in control plots (44.75 gm m^{-2}) followed by *G. arborea* plots (35.70 gm m^{-2}), *T. arjuna* (19.61 gm m^{-2}) and the minimum in *P. pinnata* plots (13.33 gm m^{-2}). The contribution of other species in protein content was less than 1 gm m^{-2} except 6.61 gm m^{-2} in *P. pinnata* plot. In the total pasture crop, the maximum crude protein was found in control plots (55.72 gm m^{-2}) followed by *G. arborea* plots (47.18 gm m^{-2}) and the minimum total crude protein was found in *T. arjuna* plots (37.96 gm m^{-2}).

4.9.5 Total crude fibre

Crude fibre of pasture crop from different treatment is presented in (Table 4.23). Grasses showed maximum showed crude fibre in *D. sissoo* plots (353.40 gm m^{-2}) followed by *P. pinnata* plots (230.48 gm m^{-2}) and *T. arjuna* plots (149.30 gm m^{-2}) and the minimum crude fibre of grasses was recorded in *G. arborea* plots (98.93 gm m^{-2}). In case of legumes, maximum crude fibre was recorded in control plots (189.87 gm m^{-2}) followed by *G. arborea* plots (133.93 gm m^{-2}) and *D. Sissoo* plots (70.41 gm m^{-2}), while the minimum crude fibre was found in the plots of *P. pinnata* and *T. arjuna* plots (59.31 gm m^{-2}). The maximum total crude fibre was recorded in pasture crops from *D. sissoo* plots (427.37 gm m^{-2}), followed by control plots (315.36 gm m^{-2}), *P. pinnata* plots (304.46 gm m^{-2}) and *T. arjuna* plots (287.13 gm m^{-2}), while the minimum total crude fibre was recorded in *G. arborea* plots (235.84 gm m^{-2}). The results were found statistically significant only for other herbage components with very least share (3.07 to14.56 gm m^{-2}).

4.9.6 Ash content

Dry plant material was burnt in muffle furnace and residues of combustion were weighed. The ash of pasture with its major three groups are presented in table 4.24. Perusal of table showed that the maximum ash was produced by the grasses harvested from *D. sissoo* plots (32.49 gm m^{-2}) followed by *T. arjuna* plots (16.68 gm m^{-2}) and *P. pinnata* plots (14.65 gm m^{-2}), while the minimum ash was received in grasses of *G. arborea* plots (8.32 gm m^{-2}). In case of leguminous species the maximum ash was received when they harvested from control plots (14.15 gm m^{-2}) followed by *G. arborea* plots (10.18 gm m^{-2}) and *D. sissoo* plots (5.33 gm m^{-2}) and the minimum was received in *P. pinnata* plots (4.49 gm m^{-2}). When it was estimated for total pasture crops grown under different treatments, the result showed that the maximum quantity of ash was received in *D. sissoo* plots (38.04 gm m^{-2}) followed by control plots (25.39 gm m^{-2}), *T. arjuna* plots (23.94 gm m^{-2}), while the minimum quantity was recorded in *G. arborea* plots (18.94 gm m^{-2}). The result was found statistically non-significant for total pasture crop and its two major components. The significant results were seen in case of other species in range of 0.22 to 1.37 gm m^{-2}.

4.9.7 Calorific value

Calorific values of pasture crops are given in table 4.25. It is evident from the table that the combustible energy of pasture crop was found varied for grasses, legumes and other plants as well as in total pasture in different treatments. It was found statistically insignificant for all classes. Energy generated from grasses was found maximum in *D. sissoo* plots (29876.33 k cal m^{-2}) followed by *P. pinnata* plots (21757.96 k cal m^{-2}), *T. arjuna* plots (16427.44 k cal m^{-2}) and control plots (10235.41 k cal m^{-2}), while it was recorded minimum in *G. arborea* plots (9044.89 k cal m^{-2}). In leguminous plant species the maximum energy stored was released from control plots (19094.74 k cal m^{-2}) and the minimum from *G. arborea* plots (13583.87 k cal m^{-2}). The combustible energy received from total pasture crop was maximum in *D. sissoo* plots (37357.23 k cal m^{-2}) and minimum in *T. arjuna* plots (26447.64 k cal m^{-2}).

Pasture component other than grasses and legumes showed minimum level of combustible energy in range of 342 to 7928.7 k cal $m^{-2.}$.

4.10 Physico chemical properties of soil under silvipasture system

Soils of any plantations sites are forced to get changed over a period according to utilization and release of nutrients by the growing plant species through harvesting of crops and litter decomposing status. In the present study the soil of five pastoral treatments viz. *D. sissoo, G. arborea, P. pinnata, T. arjuna* and control (without tree) were analysed up to three soil depth viz. 0-5, 5-10 and 10-15 cm. Thus effect of treatments soil depth and their interactions were examined for two important soil properties i.e. pH and organic carbon (Table 4.26 to 4.27).

4.10.1 pH value.

The pH value was measured for total 15 combustion of treatments x soil depth and results are presented in table 4.26. Perusal of table showed that the over all pH ranged between 5.50 to 7.06. It was found to be increased towards the neutral points from its acidic nature as the soil depth increased. The variation in pH was comparatively wide at upper layer of soil among the treatments but it was found narrowing at the deeper layer of soil. The variation in pH level was observed very sharp in case of *G. arborea* plots (5.50 to 6.90) and *P. pinnata* plots (5.70 to 7.06), while in the case of *D. sissoo* it ranged between 6.53 to 7.00.

4.10.2 Organic carbon

Organic carbon is considered a basic parameter for determining the soil quality. The availability of organic substances in its bio- degradable forms are found to be responsible to built a rich humus soil. For plants the availability of organic carbon content along with essential minerals are necessary. In the present, only organic carbon was analyzed in top fertile layers up to three depth layers i.e. 0 to 5, 5 to 10 and 10 to 15 cm.

Treatments:

Organic carbon was found maximum in control plots (1.71 %), followed by *T. arjuna* plots (1.39 %), *P. pinnata* plots (1.17 %) and *G. arborea* plots (1.12 %), while minimum was observed in *D. sissoo* plots (0.97 %). The role of treatments was found significant for their statistical variance ratio (Table 4.27).

Soil depth:

Impact of soil depth showed statistically significant results, where the maximum organic carbon (2.19 %) was found at 5-10 cm of soil depth and minimum (1.73 %) was found at 0-5 cm (Table 4.27).

Treatment x soil depth

The interaction of treatment x soil depth was also found statistically significant. The maximum organic carbon (0.61 %) was found in *T. arjuna* plots up to soil depth of 0-5 cm, followed by control plots at soil depth of 5-10 cm, and *P. pinnata* plots at soil depth of 10-15 cm, with 0.48 per cent. The minimum organic carbon (0.19 %) was found *in D. Sissoo* at soil depth of 0-5 cm. Over all organic carbon was observed maximum between 5 to 10 cm soil depths. Except in case of *T. arjuna* where it was highest in surface layer i.e. 0-5 cm depth and lowest at 10-15 cm depth.

CHAPTER-V

DISCUSSION

Biomass resources play a vital role in domestic and commercial energy sector. Population growth and increased exploitation of forest and rangelands have resulted in severe shortage of fuel wood, timber wood and animal feeds. Efforts to increase self-sufficiency of these mentioned natural resources require the development of degraded marginal land through silvipasture, farm forestry with short rotation plantation. A large tract of land in different parts of India suffering from one or other forms of degradation, are gradually responsible for severe ecological and economical imbalances. In Chhattisgarh state, red lateritic soil commonly known as Bhata land occupies 3,69,850 hectares of which mostly are lying as marginal wasteland.

The soil of these bhata lands is shallow sandy in nature with poor organic matter and low available nutrients. This leads to restrict its use for productive agriculture (Katre, 1989). The existing situations of such lands calls an immediate rehabilitation for restoring its productivity and mitigating the ecological and socio-cultural needs of the region. The planting in such degraded lands is an important biological reclamation technique, which could accompany the significant tangible and intangible benefits securing the interests of both local and global community (Houghton, 1996, Montagnini and Porras, 1998).

Besides, more than 36 per cent land under forest cover in central plains of Chhattisgarh there is an acute shortage of fuel, fodder, timber and other wood products. Because, surrounding marginal land of almost each village is lying as degraded barren lands. There are number of MPTs and pasture crops to match such edaphic and climatic conditions. In present research work, two species belongs to nitrogen fixing category and two species belongs to fast growing category. Among these two distinguished category, two species belongs to evergreen nature. Pasture species of grasses *Chrysopogon fulvus*; legumes *Stylosanthes hamata* were grown in the same intensity with the trees and without trees to study for quantitative and qualitative status after ten years of establishment under silvipasture system in red lateritic soil of Chhattisgarh. The results of study are discussed below.

The growth morphological characteristics of tree were recorded for total tree height, collar diameter, diameter at breast height and clean bole height, where growth of DBH was found statistically significant. Over all the growth performances was found better in *G. arborea*, followed by *D. sissoo*, *P. pinnata* and *T. arjuna.* It may be presumed that G. *arborea* and *D. sissoo* were more hardy and tolerant to stress conditions. A critical perusal of growth revealed that performance of all the species was influenced by their genetic potentialities as well as adaptabilities in such edaphic and climatic conditions (Sreemannarayana *et al.* 1994). Raizada and Padmach (1993) also reported that growth of height, collar diameter and DBH in a tree displayed the potential of tree species particularly in degraded red lateritic soil. Although many authors cleared that indigenous or local species showed better performance than introduced one (Toky *et al*. 1989, Naugraiya and Puri, 1994). Here the growth performance can be grouped on the basis of similar results into deciduous species *D. sissoo* and *G. arborea,* which were considerably fast growing than ever green *P. pinnata* and *T. arjuna.*

The results on dry matter accumulation revealed that above ground and below ground biomass were significantly varied in species to species. Biomass production of bole, branch and twigs in *D. sissoo* was more than other species. Rao and Gill (1993) also noticed in their study that average higher wood biomass in *Sesbania* species showed the potential of NFTs. Dry matter of all the components showed insignificant variation between *P. pinnata* and *T. arjuna*. This may be attributed to performance of tree species in this region. The contribution of bole wood production was found highest in *D. sissoo* (21.59 kg tree^{-1}) and is further related to the collar diameter, DBH and height of the tree species (Naugraiya and Puri, 2001). Dry matter production in all the tree components was found significant, but at least three tree species showed insignificant variation. This was ultimately reflected in total dry matter production, which was found statistically insignificant (Table 4.17).

A critical perusal of available stored N, P and K nutrients in leguminous and non-leguminous tree species showed that the nitrogen and phosphorous were highest in *D. sissoo,* followed by *P. pinnata.* The highest available of phosphorous occurred in *T. arjuna,* followed by *P. pinnata* and potassium was found highest in *P. pinnata,* followed by *G. arborea.* After C H and O, nitrogen is the major nutritional elements and lodged its presence in basic molecules of protein, RNA, DNA and enzymes, thus it gets deposited in the tissues through nitrogen assimilation process and profusely available in living and dead cells. Nutrient contribution in different plant parts exhibited maximum nitrogen in bole, followed by different woody parts of the tree i.e. branch, twigs and roots in all the cases. Similar results were observed in leguminous *Sesbania* species, by Rao and Gill (1993). But it was significantly higher in leguminous species as compared to non-leguminous species. NFT are found to be self sufficient in respect to fulfill their requirements of nitrogen in low fertility soils (Halliday and Nakao, 1982, Mac Dicken, 1990). The root system of leguminous species had two to six times higher nitrogen, which might be attributed to association of rhizobium and also higher mobilization of nitrogen, compound required for initiations and growth of nodules in leguminous (Singh and Singh, 1998).

Phosphorous available in growing tissues is involved in the synthesis of nucleoprotein and gets deposited in least concentration in all plant parts of every species as compared to nitrogen. Here in case of four MPTs, the phosphorous concentration was varied in species and their different components with statistically significant variation. However, occurrence of maximum content of phosphorous was not specific to species in respect to different plant parts *viz*; bole, branch, twigs, foliage and roots. The maximum content of phosphorous was harvested in *D. sissoo* which is comparatively fast growing species, hence required sufficient phosphorous for maintaining its sustainable growth and production performance.

Potassium is the only monovalent cation essential for plant growth and it does not take part in the composition of organic compounds in plants. It maintained the ionic concentration, cellular organization, permeability and hydration in tissues. The availability of potassium in the four MPTs showed that in majority of species, potassium content was maximum in bole wood (82.56 to 170.89 gm tree^{-1}) and minimum in foliage (1.84 to 12.79 gm tree^{-1}). Further the maximum content of the nutrient was found to occur in *G. arborea,* while minimum content in *T. arjuna.* Thus the concentration of nutrients in intra and inter species was differed to certain extent depending on this site quality and growth behaviour, which exert profound influence on the nutrient contents of the tree species (Rodin and Bazilevich, 1967).

It is evident from the results that bole wood and branch wood produced maximum energy, while leaves produced minimum. Similar results were also observed by (Singh and Gupta, 1990) in fodder tree species of western Himalayas. The energy productions from bole wood were 5196.23, 5169.29, 4869.29 and 4199.26 cal kg-1 for *T. arjuna*, *D. sissoo*, *P. pinnata* and *G. arborea*, respectively. The highest combustible energy in wood of *T. arjuna* might be attributed to its comparatively higher density of hard wood than rest three species. *D. sissoo* was most pronounced species for harvesting of total combustible energy at the age of eleven years (186473.38 k cal tree^{-1}). Per unit of combustible energy in MPTs might be depended on the growth rate and molecular composition of synthesized organic compound in components, but total status of combustible energy in a tree bole was associated with the dry weight production. In the present study, the total combustible energy was highest due to large amount of total dry matter accumulation in *D. sissoo,* while *T.*

arjuna generated higher calories on combustion (5196.23 cal kg^{-1}) in woody parts, because of its comparatively slow growth performance (Naugraiya and Puri, 2001).

Ash content was received maximum in twigs of *P. pinnata* (8.89 %) and minimum in bole of *G. arborea* (2.22 %). This may be due to the varying chemical nature and anatomical structures of different species studied earlier (Zobel and Talbert, 1984). Bhatt and Todaria, 1992 and Kataki and Konwer, 2001 also noticed in their studies that heat energy of combusting material found to be decreased with increasing ash percentage. Similar results were observed in present study on the combustion of four tree species.

Leaves collected from four MPTs and were tested for its fodder values. Quantity of NPK nutrients, crude protein and crude fibre available in leaves determine the fodder value of species (Ranjhan, 1991). Crude protein includes the true protein and non-protein nitrogenous compounds, but it required fulfilling the diet of the animal. In present study results showed very less difference of available crude protein in leaves of *D. sissoo, G. arborea* and *P. pinnata.* This may be reflected due to seasonal variation, because the trees were harvested in month of February. Momin and Ray, 1942 also worked out the effect of seasonal variation a quality of fodder trees.

In case of crude fibre it was recorded maximum in *T. arjuna* (20.63 %) and minimum of *P. pinnata* leaves (18.27 %). The crude fibre increases in the leaves grown older on tree (Momin and Ray, 1943, Palani and Dastharin, 1996). The constituents of crude fibre in the least digestible part of the feed and the nutrient value of any feed are considerably determined by the availability of fibre content. Here it was more or less similar to *G. arborea* (18.98 %), *P. pinnata* (18.92 %) and *T. arjuna* (20.6 %) on the basis of digestible crude protein, crude fibre and other important parameter in International feed numbers were generated to classify the fodder vale of three species (Ranjhan, 1991).

In nature growing inherent woody species play important role to change climate conditions of surroundings as they proliferate; this gradual change in surrounding microclimate invites the invasion of suitable species and in process of succession, the existing initial suitable species might be either disappeared or suppressed in a given plant community (Misra, 1959). In the present study *Chrysopogon fulvus* and *Stylosanthes hamata* were introduced, but after a decade of establishment silvipasture system, these two pasture species was found to be dominated by other native species of the area.

It is evident from the results that among the herbaceous species *Aschinomon indica* acquired highest IVI (82.53 to 144.37) followed *Stylosanthes hamata* and *Pennisetum pedicellatum* in all the treatments. Thus *Aschinomon indica* was found as dominant local invaded legumes, while introduced legume *Stylosanthes hamata* was found as codominant. This result also showed that these two prominent legumes were found to be more productive species. Thus, all the pastoral community were recognized by some major herbaceous vegetation dominating over all, the results are conformity with the finding of Trivedi *et al.* (1998).

Results shows that index of dominance were found higher with lower index of diversity. The higher values of diversity index of vegetation indicate that vegetation community was to be unstable (Verma *et al*. 1998). The results on association index between with the introduced species *Stylosanthes hamata* and *Chrysopogon fulvus* was ranged 57.14 to 100% in all the cases. This reveals the positive co-existence of new species in man-made silvipasture system on red lateritic wasteland of Chhattisgarh. The change in association index between species in the community of under storey vegetation are directly related with three component, first of them is sun flacks filtered from top storey crowns, second is alleleopathic effect of tree species and third is species association (both positive and negative) which developed between species (Turkington and Cavers, 1979).

The dry matter production of grasses was found in *D. sissoo* plots (893.84 gm m^{-2}) followed by *P. pinnata* plots (643.72 gm m^{-2}) and minimum was recorded in *G. arborea* plots (273.90 gm m^{-2}), thus the dry matter production of grasses was apparently found to be influenced by the intangible benefits of leguminous trees (Kareemulla *et al*. 2002).

Evaluation of NPK in pasture crop showed nitrogenous organic substance was found to increase in pasture crop with the increasing the association between grass and legumes as well as the increasing of quantitative share of legumes Rai *et al*. (1998). Here NPK content were also reported maximum in pasture crop grown under NFTs.

It is evident from the results that the crude fibre in grass community was found maximum in *Chrysopogon fulvus* (42.9 %) and minimum in *Cynodon dactylon* (22.6%), because the crude fibre increases, as the leaves grow older on the tree (Momin and Ray, 1943) and anatomical structure of the crops.

Ash content in pastures was recorded maximum in *Chrysopogon fulvus* (4.32 %) and minimum in *Stylosanthes hamata* (2.33%). The combustible energy was recorded maximum in *Heteropogon contortus* (3476.16 cal gm^{-1}) and minimum was recorded in *Hylandia latibrosa* (2518.20 cal gm^{-1}). The production of heat energy and residues of ash depended on the growth behaviour and maturity stage of the crop in the available environments (Bawa and Singh, 1991). Misra and Misra (1982) have also reported for tropical grassland at Berhampur that biomass energy gradually increase with the growing age of pasture and reaches on peak at the time of harvesting of crop i.e. flowering to seedling age of plants.

The physico-chemical characteristics of the soil under different pastoral system i.e. with trees and with out trees showed that pH were increased with increasing soil depth. pH of the soil was found to be influenced by tree canopy but it ranged in a limit of 7.06 to 5.70 at *P. pinnata* under soil depth at 10-15 cm and soil depth at 0-5 cm, respectively. But reversed trend was noticed in case of organic carbon, which increased significantly as soil depth decreased. The results are in conformity with finding of Bisht *et al.* (1998) and Soni (1991).

Such man made silvipastoral systems where the physical environment of under storey crops was more or less governed by top storey woody species, the structural and functional relationship of herbage species in such community was expressed in species diversity. May (1973) has shown in his theoretical models that increasing diversity should destabilize inter active systems. Here the increasing diversity of the herbage species was not only reduced the dominance, but also regulated the productivity and relative basal cover of occurring species. Similar relationship of diversity, dominance, productivity and population density, have been observed by Naugraiya and Pathak (1993 & 2001) in man made *L. leucocephala* forest and silvipasture system.

The feature of the herbaceous community has shown that succession was accompanied by increased biological diversity and reduced dominance (Mc Naughton (1967). Further Millinger and Mc Naughton (1975) advocated after their study that increased diversity and reduced dominance has to be associated with increased stability of the system.

The process of stabilizing the species of herbage community under tree canopy has shown the response directly to availability of illumination and its intensity and alleleopathic effect received from residues of woody species. These two parallel physical and chemical components generate successional stage of different herbage species with relationship among their structures and functions *viz*; population density, biomass, dominance and diversity for making a stable ecosystem with woody species.

CHAPTER-VI

SUMMARY AND CONCLUSION

The study on **"Productivity status of ten years old silvipasture system in red lateritic soil**" was carried out at " Baronda Research Farm" IGAU, Raipur, (C.G) during 2003-2004.

Four tree species viz. *Dalbergia sissoo, Gmelina arborea, Pongamia pinnata, Terminalia arjuna* were planted at 5 x 5 m spacing in July 1992. Pasture crop comprised of *Chrysopogon fulvus* and *Stylosanthes hamata* were introduced after two years of tree plantations in July 1994.

The highlights of the finding are here with

1. Average collar diameter of four MPTs was found highest in *G. arborea* (15.03 cm) followed by *D. sissoo* (13.25 cm), *T. arjuna* (12.45 cm) and *P. pinnata* (12.01 cm).
2. Average diameter at breast height was observed highest in *D. sissoo* (13.1 cm) followed by *G. arborea* (11.50 cm), *T. arjuna* (9.43 cm) and *P. pinnata* (9.06 cm).
3. The performance of four MPTs for average clean bole growth was in the order of *D. sissoo* (2.61 m) > *G. arborea* (2.60 m) > *T. arjuna* (0.09 m) > *P. pinnata* (2.01m).
4. Average height growth of four MPTs was in order of *G. arborea* (7.2 m) > *D. sissoo* (6.1 m) >*P. pinnata* (5.3 m) > *T. arjuna* (5.4 m).

5. The maximum dry matter yield in AG part of trees was recorded in *D. sissoo* (45.18 kg tree^{-1}) followed by *G. arborea* (36.97 kg tree^{-1}) and minimum was found in *T. arjuna* (23.13 kg tree^{-1}).

6. Amount of nitrogen accumulated in four MPTs showed statistically significant results.

7. At harvest, maximum amount of N exported from both nitrogen fixing tree species viz., *D. sissoo* (754.91 gm tree^{-1}) and *P. pinnata* (43690 gm tree^{-1}), while the minimum amount of nitrogen was exported by *T. arjuna* (253.31 gm tree^{-1}).

8. The overall phosphorous deposited in four MPTs was found in order of *D. sissoo* (180.43 gm tree^{-1}), *T. arjuna* (105.83 gm tree^{-1}) > *P. pinnata* (99.68 gm tree^{-1}) > *G. arborea* (73.91 gm tree^{-1}).

9. The overall potassium content in four MPTs was found 338.62, 270.73, 220.44 and 201.87 gm tree^{-1} for *G. arborea, D. sissoo, P. pinnata* and *T. arjuna*, respectively.

10. The total crude protein content was found maximum in *D. sissoo* (4219.33 gm tree^{-1}), followed by *P. pinnata* (2414.66 gm tree^{-1}), *G. arborea* (2339.57 gm tree^{-1}) and minimum was found in *T. arjuna* (1413.27 gm tree^{-1}).

11. The maximum crude fibre in foliage was found in *D. sissoo* (gm tree^{-1}) and minimum was found in *T. arjuna* (69.79 gm tree^{-1}).

12. The maximum ash content was recorded from the bole of *D. sissoo* *(*1344.38 gm tree^{-1}), followed by the bole of *T. arjuna* (848.38 gm tree^{-1}), while the minimum was recorded in *T. arjuna* (235.91 gm tree^{-1}).

13. The maximum ash content was found in twigs of *D. sissoo* (540.97 gm tree^{-1}), followed by *P. pinnata* (269.51 gm tree^{-1}), *T. arjuna* (174.71 gm tree^{-1}) and minimum was recorded in *G. arborea* (166.96 gm tree^{-1}).

14. The bole wood yielded maximum and foliage yielded the minimum energy on combustion in all the four tree species.

15. If branches were used for combustion, maximum combustible energy was generated from branch of *D. sissoo* (33776.52 cal tree^{-1}) and minimum was from *P. pinnata* (13623.67 cal tree^{-1}).

16. Population of herbage species in different treatments showed the heavy infestation of unwanted local/native species dominating over the introduced ones.

17. The important value index of all the species showed that population of *Aschinomon indica* (legume) and *Pennisetum pedicellatum* were found to be dominating in all the treatments of pastoral systems.

18. In all the five pastoral conditions, introduced grass species *Chrysopogon fulvus* was competed with other local perennial grasses *viz. Eremopogon faveolatus, Pennisetum pedicellatum* and *Heteropogon contortus.*

19. Dominance index of herbage species was higher in control open plots (0.2585) followed by *G. arborea* plots (0.2046), *T. arjuna* plots (0.1444) and lowest was found in *P. pinnata* plots (0.1237).

20. Diversity level among the herbage species was higher in *P. pinnata* plots (1.0674), followed by *T. arjuna* plots (0.8743), *G. arborea* plots (77.78), *P. pinnata* plots (66.67) and lowest value was recorded in control plots (57.14).

21. Association index between *Stylosanthes hamata* and *Chrysopogon fulvus* showed highest degree of association under *D. sissoo* plots (100 %), followed by *T. arjuna* plots (90 %), *G. arborea* plots (77.78 %), *P. pinnata* plots (66.67 %) and lowest value was recorded in control plots.

22. Similarity index showed that 61.64 per cent species were found common among the five habitats.

23. Production of pasture was found insignificant for grasses and legume component and over all the total pasture production was found maximum in *D. sissoo* plots (1107.02 gm m^{-2}), while the minimum was found in *G. arborea* plots (665.17gm m^{-2}). The share of different components of pasture crop were in order of grasses > legume > other species.

24. NPK nutrients available with harvested pasture crop from different tree + pasture crop systems, showed statistically insignificant outcome. Over all these were ranged 7.17 to 2.15 gm m^{-2} for nitrogen, 9.52 to 6.60 gm m^{-2} for phosphorous and 7.81 to 3.58 gm m^{-2} for potassium.

25. Pasture crop grown under *D. sissoo* contain highest NPK nutrients and it was shared maximum by grasses followed by legumes.

26. Crude protein and crude fibre was found maximum in pasture crop grown under *D. sissoo* plots (46.59 and 427.37 gm m^{-2}, respectively) with maximum shared of grasses in both cases.

27. After combustion the maximum residues of ash and release of energy was received from pasture crop grown under *D. sissoo* i.e. (38.04 gm m^{-2} and 37557.23 k cal m^{-2}, respectively), with insignificant results.

28. Combustible calorific value in pasture crop was recorded in order of grasses > legumes > other species.

29. The level pH was recorded low at 0 to 5 cm soil layer and it trends to increased towards neutral side as depth of soil increased. Over all pH ranged between 5.50 (*G. arborea)* to 7.06 (*P. pinnata*) for upper and lower layer of soil respectively.

30. Organic carbon in the soil was found to be increased as soil depth increased from 0 to 15 cm depth, while it was analysed higher in control plots (1.74 %) than tree plots with statistically significant results.

Conclusion

The study indicated that *Dalbergia sissoo* and *Gmelina arborea* species based silvipasture system was found comparatively more suitable for development and utilization of red lateritic wasteland. Introduction of pasture crops *viz*; *Chrysopogon fulvus* and *Stylosanthes hamata* also found responsible for quantity and quality production of pasture. Thus the combination of trees + *Chrysopogon fulvus* + *Stylosanthes hamata* were found suitable for restoring the organic matter in red lateritic wastelands. Systematic long-term studies should be initiated in various agro climatic regions to work out compatible tree-grass-legumes cultivation for optimum growth, biomass and live stock production as well as conservation of environment. But the invasion of local species is found to be causing the unavoidable competition to introduce grass and legumes, thus ultimately quality of pasture is influenced. Results of study further strengthened the

thoughts of previous workers in respect to the in inversely proportionate relations between Diversity and Dominance in a plot community.

The study revealed that the renovation of pasture is to be done for maintaining quantity and quality production of pasture crop. Similarly, the management of tree canopy is also needed to be studied for exposing under storey crop to get suitable climate for sustainable pasture production and cyclic production of fuel and fodder from lopping of trees. The interaction of rearing of cattle in a Tree + Pasture system should be studied so that plant-animal relationship should be worked out for sustainability of the silvipasture system with proper managements.

“ Productivity status of ten years old silvipasture system in red lateritic soil of Chhattisgarh”

by

RAJIV UMRAO

ABSTRACT

The study entitled “Productivity status of ten years old silvipasture system in red lateritic soil of Chhattisgarh” was conducted at Baronda Research Farm, Indira Gandhi Agricultural University (IGAU), Raipur (C.G.) during 2003-2004. The study was carried out in eleven years old MPTs plantation at 5 x 5 m spacing where the pasture crop (*Chrysopogon fulvus* and *Stylosanthes hamata*) was introduced after two-year growth of MPTs. The study was conducted to find out status of under storey vegetation for phytosociological structure, biomass production, nutritive value, ash and energy production.

In light of study the collar diameter, DBH and tree height for stands of *D. sissoo, G. arborea, P. pinnata* and *T. arjuna* were range from 12.01 to 15.03 cm, 9.06 to 13.1 cm and 5.40 to 7.19 m, respectively with statistically significant result ($P< 0.05$). The over all dry matter production was found in order of *D. sissoo* (45.18 kg $tree^{-1}$), *G. arborea* (36.97 kg $tree^{-1}$), *P. pinnata* (26.74 kg $tree^{-1}$) and *T. arjuna* (23.12 kg $tree^{-1}$). The maximum amount of nutrients viz. nitrogen (754.91 gm $tree^{-1}$), phosphorous (180.43 gm $tree^{-1}$), crude protein (4219.33 gm $tree^{-1}$) and combustible energy (186473.88 k cal $tree^{-1}$) were recorded in *D. sissoo,* but the maximum amount of potassium (338.62 gm $tree^{-1}$) was recorded in *G. arborea.* The minimum amount of nutrients *viz.* nitrogen (253.31 gm $tree^{-1}$), potassium (120.97 gm $tree^{-1}$) and crude protein (1413.27 gm $tree^{-1}$) was recorded in *T. arjuna* while, minimum amount of phosphorous (73.91 gm $tree^{-1}$) and combustible energy (79355.49 k cal $tree^{-1}$) was recorded in *G. arborea* and *P. pinnata*, respectively.

The *Aschinomon indica* was dominant species in all plots. The IVI values *A. indica* was recorded 144.32, 121.36, 109.61, 86.72 and 82.53 for control, *G. arborea, T. arjuna, D. sissoo* and *P. pinnata* plots, respectively. The index of similarity was found 61.64 per cent. The highest dominance level of species was found in control plots (0.2585), followed by *G. arborea* plots (0.2046) and lowest was found in *P. pinnata* plots (0.1273). Level of species diversity was found maximum in *P. pinnata* plots (1.0674), followed *T. arjuna* plots (0.8752) and minimum in control plots (0.84). Association level between *Stylosanthes hamata* and *Chrysopogon fulvus* was recorded highest under closed canopy of *D. sissoo* plots (100 %) and lowest in open plot (57.1 4 %).

In grasses the maximum amount of nitrogen (4.74gm m^{-2}), phosphorous (8.08 gm m^{-2}), potassium (6.90 gm m^{-2}), crude protein (29.49 gm m^{-2}), crude fibre (353.40 gm m^{-2}), ash (32.49 gm m^{-2}) and energy content (37357.23 k cal m^{-2}) were recorded in pasture crop under leguminous trees *D. sissoo,* while minimum amount of nitrogen (2.02 gm m^{-2}), phosphorous (2.92 gm m^{-2}) and crude protein (10.75 gm m^{-2}) was recorded under control plot. The potassium (1.92 gm m^{-2}), crude fibre (98.93 gm m^{-2}) and ash (8.32 gm m^{-2}) was recorded in pasture crop under *G. arborea,* where is minimum combustible energy was received from vegetation under *T. arjuna* (26447.64 k cal m^{-2}). The role of leguminous component in total pasture production in respect to quality and quantity was accounted, but it was in order of grass > legumes > others.

Soil profile of study area was measured with availability of organic carbon and pH status in different treatment organic carbon in related to organic matter it was significantly recorded high in open without tree plot, it was found in order of control > *T. arjuna* > *P. pinnata* > *G. arborea* > *D. sissoo*. The under storey pasture crop of *Chrysopogon fulvus* > *Stylosanthes hamata* get established during initial growing stage of silvipasture system. As soon as the tree canopy developed the invasion of local native / flora gets interacted with the growing species and started to influence the quality and quantity production of established pasture crops. The phytosociological structure, biomass production and nutritive value of pasture crop and invaded flora were studied under four tree species and compared with control fields.

Date :

Department of Forestry **Dr. M. N. Naugraiya**
College of Agriculture **Chairman**
IGAU, Raipur (C.G.) **Advisory committee**

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Table 4.1: Morphological characteristics of trees under silvipasture system

Tree species	CD (cm)	DBH (cm)	Clean bole height (m)	Total height (m)
Dalbergia sissoo	13.25	13.1	2.61	6.08
	± 6.21	±1.64	±1.06	±2.83
Gmelina arborea	15.03	11.50	2.60	7.19
	± 3.14	± 2.15	± 0.61	± .55
Pongamia pinnata	12.01	9.06	2.01	5.53
	± 2.03	±1.99	± 0.27	± 0.99
Terminalia arjuna	12.45	9.43	2.09	5.40
	± 1.66	± 0.88	± 0.49	± 0.65
SEm ±	1.93	0.95	0.36	2.11
SEd ±	2.73	1.35	0.51	2.99
CD (at 5%)	NS	2.94	NS	NS

Table 4.2: Biomass of trees (fresh wt. kg tree^{-1}) under silvipasture system

Tree species	Fresh Weight (kg tree^{-1})						
	Bole	**Branch**	**Twigs**	**Foliage**	**AG**	**Root**	**Total**
D. sissoo	43.70	17.88	18.95	3.30	83.83	8.25	92.08
	±13.62	± 2.62	± 5.32	±1.84	± 22.57	± 3.26	± 25.77
G. arborea	39.30	14.76	7.16	3.40	61.28	11.61	72.89
	±11.80	± 9.62	±3.03	±0.87	±21.42	±2.60	± 23.95
P. pinnata	16.93	11.80	5.83	1.73	36.33	15.88	52.21
	± 8.45	±10.48	± 4.97	± 0.73	±23.22	± 7.06	±29.35
T. arjuna	23.56	8.18	3.76	0.66	36.18	7.23	43.41
	±10.20	± 6.38	± 2.12	± 0.35	±18.21	± 1.65	±9.11
SEm ±	5.81	4.11	2.17	0.56	10.87	2.46	12.97
SEd ±	8.22	5.82	3.07	0.79	15.37	3.48	18.34
CD (at 5%)	17.92	NS	6.69	1.72	33.50	7.59	39.96

Table 4.3 : Dry matter production of trees under silvipasture system

Tree species	Dry Matter (kg tree^{-1})						
	Bole	**Branch**	**Twigs**	**Foliage**	**AG**	**Root**	**Total**
D. sissoo	21.59	9.11	8.90	1.61	41.23	4.61	45.18
	± 6.73	± 1.30	± 2.50	± 0.90	± 11.05	± 1.82	±13.43
G. arborea	18.78	8.63	3.29	1.63	30.70	6.26	36.97
	±5.64	±5.63	±1.39	±0.41	±11.13	±1.40	±12.49
P. pinnata	8.19	5.24	3.03	0.96	17.43	9.30	26.74
	±4.09	±4.66	±2.58	±0.41	±11.03	±4.19	±14.94
T. arjuna	12.79	3.80	2.40	0.33	19.34	3.79	23.13
	±5.53	±2.97	±1.35	±0.18	±9.50	±0.06	±10.03
SEm ±	2.90	2.10	1.09	0.28	5.42	1.38	6.62
SEd ±	4.10	2.97	1.54	0.39	7.67	1.95	9.37
CD (at 5%)	8.94	NS	3.36	0.86	16.72	4.26	NS

Table 4.4 : Nutrient status in different components of trees under silvipasture system

Tree species	Nutrient (%)					
		Bole	Branch	Twigs	Foliage	Roots
Dalbergia sissoo	N	1.73	1.69	1.55	1.38	1.45
	P	0.43	0.05	0.85	0.05	0.06
	K	0.44	0.78	0.92	0.55	0.84
	Ash	6.22	3.03	6.07	5.79	3.14
	CP	10.81	10.56	9.68	8.62	9.06
	CF	-	-	-	19.61	-
Gmelina arborea	N	0.99	0.96	0.94	1.28	1.17
	P	0.32	0.06	0.06	0.05	0.06
	K	0.91	0.95	0.98	0.78	0.93
	Ash	2.22	2.91	5.07	4.86	2.91
	CP	6.18	6.00	5.87	8.00	7.31
	CF	-	-	-	18.98	-
Pongamia Pinnata	N	1.65	1.54	1.52	1.31	1.60
	P	0.48	0.55	0.65	0.53	0.06
	K	1.00	0.63	0.81	0.53	1.02
	Ash	2.88	3.00	8.89	6.08	3.94
	CP	10.31	9.62	9.5	8.18	10.0
	CF	-	-	-	18.27	-
Terminalia arjuna	N	1.05	1.15	1.07	1.07	1.21
	P	0.55	0.37	0.65	0.53	0.07
	K	1.03	0.95	0.93	0.54	0.89
	Ash	6.67	2.88	7.26	6.85	3.01
	CP	6.56	7.18	6.68	6.68	7.56
	CF	-	-	-	20.63	-

Where, CP = Crude protein, CF = Crude fibre

Table 4.5: Crude protein in different components of trees under silvipasture system

Tree species	Crude protein (gm trees^{-1})							
	Bole	Branch	Twigs	Total wood	Foliage	AG	Root	Total
D. sissoo	2334.59 ±727.84	962.71 ±138.19	862.00 ±242.16	4159.31 ±1075.15	144.06 ±74.05	3801.07 ±1963.16	418.26 ±165.43	4219.33 ±2118.38
G. arborea	1160.60 ±348.71	524.56 ±350.72	193.31 ±81.79	1878.48 ±686.88	130.40 ±33.53	1881.37 ±952.59	458.21 ±102.90	2339.58 ±1053.94
P. pinnata	844.55 ±421.92	504.56 ±448.68	287.85 ±245.92	1636.97 ±1080.28	79.20 ±33.84	1483.99 ±1262.84	930.66 ±419.55	2414.66 ±1610.53
T. arjuna	839.23 ±363.38	317.95 ±210.32	160.76 ±90.80	1317.95 ±627.71	22.59 ±12.39	1126.70 ±809.40	286.56 ±65.96	1413.27 ±838.88
SEm ±	261.31	168.07	98.25	467.77	22.58	541.42	132.83	649.46
SEd ±	369.49	237.65	138.93	661.43	31.93	765.56	187.82	918.34
CD (at 5%)	805.13	517.85	302.73	1441.27	69.57	166817	409.27	2001.07

Table 4.6: Accumulation of nitrogen in different components of trees under silvipasture system

Tree species	Nitrogen (gm tree^{-1})							
	Bole	Branch	Twigs	Total wood	Foliage	AG	Root	Total
D. sissoo	373.61 ±116.48	154.06 ±22.11	138.02 ±38.77	665.71 ±172.08	22.26 ±12.48	687.97 ±183.52	66.93 ±26.47	754.91 ±209.50
G. arborea	185.91 ±55.86	82.86 ±54.08	30.95 ±13.09	299.73 ±108.14	20.86 ±5.36	320.59 ±112.46	73.33 ±16.47	293.92 ±128.44
P. pinnata	148.49 ±67.25	80.77 ±71.82	46.05 ±39.34	275.31 ±166.55	12.68 ±5.42	287.99 ±167.15	148.90 ±67.12	436.90 ±231.51
T. arjuna	134.32 ±58.16	43.71 ±34.16	25.74 ±14.54	203.78 ±102.28	3.61 ±1.98	207.40 ±103.58	45.12 ±10.48	253.31 ±109.37
SEm ±	43.27	25.65	15.72	73.85	3.79	76.32	21.24	94.71
SEd ±	61.18	36.27	22.24	104.43	5.35	107.92	30.03	133.92
CD (at 5%)	33.32	79.04	48.46	227.56	11.67	235.17	65.45	291.81

Table 4.7: Accumulation of phosphorus in different components of tree under silvipasture system

Tree species	Phosphorus (gm tree^{-1})							
	Bole	Branch	Twigs	Total wood	Foliage	AG	Root	Total
D. sissoo	94.80	5.10	76.48	176.39	0.94	177.34	3.08	180.43
	±29.55	±0.73	±21.48	±50.98	±0.53	±51.46	±1.22	±52.66
G. arborea	61.59	5.52	2.20	69.31	0.84	70.15	3.75	73.91
	±18.50	±3.60	±0.93	±21.35	±0.22	±21.55	±0.84	±22.91
P. pinnata	39.97	29.26	19.72	88.95	5.15	94.10	5.58	99.68
	±19.97	±26.02	±16.85	±60.74	±2.20	±61.04	±2.51	±63.34
T. arjuna	71.23	14.29	15.71	101.24	1.79	103.03	2.80	105.83
	±30.94	±11.16	±8.87	±48.36	±0.98	±48.99	±0.64	±49.33
SEm ±	13.38	7.34	7.89	24.83	0.71	25.01	0.85	25.71
SEd ±	18.92	10.38	11.16	35.11	1.00	35.36	1.21	36.36
CD (at 5%)	41.22	22.62	24.33	76.50	2.19	77.06	NS	79.23

Table 4.8: Accumulation of potassium in different components of trees under silvipasture system

Tree species	Potassium (gm tree^{-1})							
	Bole	Branch	Twigs	Total wood	Foliage	AG	Root	Total
D. sissoo	98.26	71.83	82.63	252.73	8.87	231.91	38.82	270.73
	±30.63	±10.31	±23.21	±61.93	±4.97	±115.93	±5.35	±130.27
G. arborea	170.89	82.68	32.30	285.88	12.79	280.27	58.35	338.62
	±51.34	±53.96	±13.67	±104.64	±3.29	±141.58	±13.10	±154.47
P. pinnata	82.56	33.30	24.62	140.49	5.18	125.52	94.92	220.44
	±41.25	±29.61	±21.04	±88.93	± 2.21	±104.27	±42.79	±140.30
T. arjuna	132.69	36.15	22.45	191.29	1.84	168.10	33.77	201.87
	±56.27	±28.25	±12.68	±92.92	± 1.01	±117.62	±7.71	±120.97
SEm ±	23.94	17.96	9.73	44.85	1.60	45.17	13.66	56.29
SEd ±	33.86	25.40	13.76	63.41	2.26	63.87	19.32	79.60
CD (at 5%)	73.78	NS	29.99	NS	4.93	NS	42.11	NS

Table 4.9: Calorific values in different components of trees under silvipasture system

Tree species	Calorific values (cal kg^{-1})				
	Bole	Branch	Twigs	Foliage	Root
D. sissoo	5169.82	3704.92	2863.46	1546.96	2826.96
G. arborea	4199.26	2694.29	2046.86	1686.23	2929.87
P. pinnata	4869.29	2597.46	1948.97	1495.16	1986.86
T. arjuna	5196.23	3944.75	1886.63	1546.26	2697.76

Table 4.10 : Export of calorific values in different components from harvesting trees

Tree species	Calorific values (k cal tree^{-1})							
	Bole	Branch	Twigs	Total wood	Foliage	AG	Root	Total
D. sissoo	111650.8	33776.5	25499.10	170926.50	2495.75	173422.25	13051.12	186473.38
	±34808.8	±4847.4	±7163.41	±45630.90	±1398.99	±46894.34	±5162.01	±51955.22
G. arborea	78862.1	23256.2	6740.98	108859.29	2748.54	111607.84	18365.39	129973.24
	±23694.4	±15178.4	±2852.26	±36869.25	±706.87	±37475.88	±4124.61	±41507.46
P. pinnata	39887.5	13623.6	5905.37	59416.64	1147.80	60864.45	18491.03	79355.49
	±19927.0	±12114.8	±5045.17	±36031.22	±618.54	±36109.50	±8336.00	±43895.24
T. arjuna	66035.4	14996.6	4540.48	85572.52	523.14	86095.66	10237.99	96333.66
	±29205.1	±11718.7	±2564.56	±42260.53	±286.84	±42427.22	±2337.09	±43596.19
SEm ±	14428.64	5921.17	2568.19	20575.09	434.48	20842.72	3068.42	23365.36
SEd ±	20402.10	8372.54	3631.42	29093.18	614.35	29471.60	4338.74	33038.62
CD (at 5%)	44454.18	18243.78	7912.86	63394.05	1338.68	6418.65	NS	71991.16

Table 4.11: Phytosociological structure of under storey herbage crop

Attributers	T_1	T_2	T_3	T_4	T_0
Total density (m^{-2})	582.60	268.80	362.80	382.20	396.60
Total basal area (m^{-2})	4303.88	2977.72	2708.32	3618.72	4550.80
Total abundance (m^{-2})	381.44	198.00	234.92	205.53	287.82
Total A.G. biomass (gm^{-2})	1107.02	665.17	856.82	781.89	864.74
Total species	14.00	14.00	17.00	12.00	15.00
a. Grasses	5.00	7.00	7.00	5.00	6.00
b. Legumes	5.00	5.00	4.00	4.00	4.00
c. Others	4.00	2.00	6.00	3.00	5.00
Dominance	0.1444	0.2046	0.1237	0.1950	0.2585
Diversity	0.8608	0.8743	1.0674	0.8752	0.85
Association index (%) *Stylosanthes hamata* v/s *Chrysopogon fulvus*	100	77.78	66.67	90.00	57.14

Table 4.12 : Population structure of herbage species under *Dalbergia sissoo* based silvipasture system

Herbage species	Frequency (%)	Density (m^{-2})	Abundance (m^{-2})	Basal area ($cm^2 m^{-2}$)	Relative frequency	Relative density	Relative basal area	IVI
Grasses								
Cenchrus ciliaris. Linn	-	-	-	-	-	-	-	-
Chrysopogon fulvus. Spreng	45.00	110.0	66.11	262.72	8.49	20.42	6.10	35.01
Cynodon dactylon. Pers	15.00	7.4	12.33	5.6	2.83	1.27	0.13	4.23
Eremopogon faveolatus. Stapf	40.0	59.2	35.75	232.36	7.54	10.16	5.39	23.09
Heteropogon contortus. Beauve. R.S.	30.0	55.4	46.16	176.12	5.66	9.50	4.09	19.25
Iseliema laxum. Hock								
Pennisetum pedicellatum. Trin	70.0	61.2	21.85	1025.28	13.2	10.50	23.82	47.52
Themeda quadrivalvis (L)	-	-	-	-	-	-	-	-
Legumes								
Alysicarpus bupleurifolius (L) DC	50.0	24.2	12.1	20.0	9.43	4.15	0.46	12.1
Alysicarpus monilifer (L) DC	25.00	9.20	9.2	7.64	4.71	1.57	0.17	6.45
A. tetragonolabus (L) DC	20.00	16.8	21.00	4.44	3.77	2.88	0.10	6.7
Aschinomon indica (L)	95.00	124.00	32.63	2045.32	17.92	21.28	47.52	86.72
Cassia pumila. Lamk	-	-	-	-	-	-	-	-
Hylandia latibrosa. DC	-	-	-	-	-	-	-	-
Stylosanthes hamata (L)	45.00	19.8	11.0	326.56	3.39	8.49	7.58	19.46
Others								
Celosia argentia. Linn	25.00	4.20	4.2	37.08	0.72	4.71	0.86	6.29
Chorchorus aletorius. Linn	-	-	-	-	-	-	-	-
Cyprus rotendus. Linn	10.00	2.00	5.00	17.64	0.34	1.88	0.40	2.62
Fembristylis schoenoides (Retz)	-	-	-	-	-	-	-	-
Fembristylis tenera Schult.	15.00	53.6	89.33	25.76	2.83	9.20	0.59	12.6
Sida carpinifolia Linn	45.00	26.60	14.78	117.28	8.49	4.56	2.72	15.77
Total	530.0	582.6	381.44	4303.88	99.95	99.94	99.93	299.82

Table 4.13: Population structure of herbage species under *Gmelina arborea* based silvipasture system

Herbage species	Frequency (%)	Density (m^{-2})	Abundance (m^{-2})	Basal area (cm^2m^{-2})	Relative frequency	Relative density	Relative basal area	IVI
Grasses								
Cenchrus ciliaris. Linn	-	-	-	-	-	-	-	-
Chrysopogon fulvus. Spreng	35.00	12.4	8.86	27.36	7.86	4.61	0.92	13.39
Cynodon dactylon. Pers	-	-	-	-	-	-	-	-
Eremopogon faveolatus. Stapf	20.00	20.00	23.75	74.56	4.49	7.07	2.50	14.06
Heteropogon contortus. Beauve. R.S.	35.00	26.4	18.86	27.36	7.86	4.61	0.82	20.5
Iseliema laxum. Hock	15.00	3.20	5.33	32.16	3.37	1.19	1.08	5.64
Pennisetum pedicellatum. Trin	55.0	33.8	15.36	566.24	12.36	12.57	19.01	43.94
Themeda quadrivalvis (L)	10	2	5	8.8	2.25	0.74	0.29	3.28
Legumes								
Alysicarpus bupleurifolius (L) DC	45.00	31.4	17.44	26.08	10.11	11.68	0.87	22.66
Alysicarpus monilifer (L) DC	20.00	3.4	4.25	34.8	4.49	1.23	1.17	6.92
A. tetragonolabus (L) DC	-	-	-	-	-	-	-	-
Aschinomon indica (L)	100.00	106.8	26.7	1761.74	22.47	39.73	59.16	121.36
Cassia pumila. Lamk	25.00	3.8	3.8	31.36	5.62	1.41	1.05	8.08
Hylandia latibrosa. *DC*	5.00	2.40	12.00	11.8	1.12	0.89	0.4	2.41
Stylosanthes hamata (L)	45.00	19.00	10.55	313.4	10.11	7.07	10.52	27.7
Others								
Celosia argentia. Linn	10.00	0.60	1.5	1.08	2.24	0.22	0.03	2.49
Chorchorus aletorius. Linn	25.00	4.6	4.6	4.52	5.62	1.71	0.15	7.48
Cyprus rotendus. Linn	-	-	-	-	-	-	-	-
Fembristylis schoenoides (Retz)	-	-	-	-	-	-	-	-
Fembristylis tenera Schult.	-	-	-	-	-	-	-	-
Sida carpinifolia Linn	-	-	-	-	-	-	-	-
Total	445.00	268.80	158.0	2977.72	99.97	99.97	99.97	299.11

Table 4.14: Population structure of herbage species under *Pongamia pinnata* based silvipasture system

Herbage species	Frequency (%)	Density (m^{-2})	Abundance (m^{-2})	Basal area (cm^2m^{-2})	Relative frequency	Relative density	Relative basal area	IVI
Grasses								
Cenchrus ciliaris. Linn	35.0	7.6	5.43	47.36	5.64	2.09	1.75	9.48
Chrysopogon fulvus. Spreng	30.0	14.8	12.33	32.36	4.83	4.08	1.21	10.12
Cynodon dactylon. Pers	15.0	2.6	4.33	1.96	2.42	0.71	0.07	3.20
Eremopogon faveolatus. Stapf	25.0	17.8	17.8	69.88	4.03	4.91	2.58	11.52
Heteropogon contortus. Beauve. R.S.	45.0	48.6	27.0	154.52	7.26	13.39	5.71	26.36
Iseliema laxum. Hock	-	-	-	-	-	-	-	-
Pennisetum pedicellatum. Trin	-	-	-	-	-	-	-	-
Themeda quadrivalvis (L)	25.0	21.8	21.80	96.12	4.03	6.00	3.55	13.58
Legumes								
Alysicarpus bupleurifolius (L) DC	50.0	12.4	6.2	10.28	8.06	3.42	0.38	11.86
Alysicarpus monilifer (L) DC	65.0	30.2	11.61	25.08	10.48	8.32	0.93	19.73
A. tetragonolabus (L) DC								
Aschinomon indica (L)	85.0	77.8	22.88	1283.28	13.71	21.44	47.38	82.53
Cassia pumila. Lamk	-	-	-	-	-	-	-	-
Hylandia latibrosa. *DC*	-	-	-	-	-	-	-	-
Stylosanthes hamata (L)	45.0	10.8	6.0	178.12	7.26	2.98	6.58	16.83
Others								
Celosia argentia. Linn	25.00	8.00	8.0	70.64	4.03	2.20	2.61	8.84
Chorchorus aletorius. Linn	15.0	6.00		5.88	2.42	1.65	0.22	4.29
Cyprus rotendus. Linn	20.0	11.8	14.75	104.2	3.22	3.25	3.85	10.32
Fembristylis schoenoides (Retz)	5.0	2.2	11.00	1.04	0.81	0.60	0.04	1.45
Fembristylis tenera Schult.	35.0	39.2	28.00	18.84	5.64	10.80	0.69	17.13
Sida carpinifolia Linn	60.00	20.2	8.42	89.08	9.67	5.57	3.29	18.53
Total	620.00	362.8	234.92	2708.32	99.95	99.96	100.02	299.93

Table 4.15 : Population structure of herbage species under *Terminalia arjuna* based silvipasture system

Herbage species	**Frequency (%)**	**Density (m^{-2})**	**Abundance (m^{-2})**	**Basal area (cm^{2}m^{-2})**	**Relative frequency**	**Relative density**	**Relative basal area**	**IVI**
Grasses								
Cenchrus ciliaris. Linn	-	-	-	-	-	-	-	
Chrysopogon fulvus. Spreng	45.0	92.6	51.44	204.44	9.78	24.22	5.64	39.64
Cynodon dactylon. Pers	20.0	3.4	4.25	2.56	4.32	0.88	.07	5.29
Eremopogon faveolatus. Stapf	25.0	25.2	25.2	98.88	5.43	6.59	2.73	14.75
Heteropogon contortus. Beauve. R.S.	15.0	10.6	17.6	33.52	3.26	2.77	0.93	6.96
Iseliema laxum. Hock	-	-	-	-	-	-	-	-
Pennisetum pedicellatum. Trin	45.00	26.2	14.55	415.6	9.78	6.85	11.48	28.11
Themeda quadrivalvis (L)	-	-	-	-	-	-	-	-
Legumes								
Alysicarpus bupleurifolius (L) DC	50.00	32.4	16.2	26.88	10.86	8.47	0.74	20.07
Alysicarpus monilifer (L) DC	30.0	10.6	8.83	8.8	6.52	2.77	0.24	9.53
A. tetragonolabus (L) DC								
Aschinomon indica (L)	95.00	124.00	32.63	2045.32	20.65	32.44	56.44	109.61
Cassia pumila. Lamk	-	-	-	-	-	-	-	-
Hylandia latibrosa. *DC*	-	-	-	-	-	-	-	-
Stylosanthes hamata (L)	50.00	43.8	21.9	722.44	10.86	11.45	19.96	21.9
Others								
Celosia argentia. Linn	20.00	3.8	4.75	33.52	4.34	0.99	0.92	6.25
Chorchorus aletorius. Linn	-	-	-	-	-	-	-	-
Cyprus rotendus. Linn	-	-	-	-	-	-	-	-
Fembristylis schoenoides (Retz)	-	-	-	-	-	-	-	-
Fembristylis tenera Schult.	20.00	4.00	5.00	1.92	4.34	1.04	.05	5.43
Sida carpinifolia Linn	45.00	5.60	3.11	24.68	9.78	1.46	0.68	11.92
Total	460.00	382.2	205.53	3618.72	99.93	99.94	99.96	299.83

Table 4.16: Population structure of herbage species under pasture system (Control plot without trees)

Herbage species	Frequency (%)	Density (m^{-2})	Abundance (m^{-2})	Basal area (cm^2m^{-2})	Relative frequency	Relative density	Relative basal area	IVI
Grasses								
Cenchrus ciliaris. Linn	5.00	9.8	49.0	61.04	1.13	2.47	1.34	4.94
Chrysopogon fulvus. Spreng	20.00	30.4	38.0	67.08	4.54	7.66	1.47	13.67
Cynodon dactylon. Pers	15.00	2.4	4.00	1.8	3.40	0.60	.03	4.03
Eremopogon faveolatus. Stapf	20.0	24.6	30.75	96.52	4.54	6.20	2.12	12.86
Heteropogon contortus. Beauve. R.S.	50.00	34.8	17.4	110.6	11.36	8.77	2.43	22.56
Iseliema laxum. Hock	-	-	-	-	-	-	-	-
Pennisetum pedicellatum. Trin	40.00	28.2	17.62	472.44	9.09	7.11	10.38	26.58
Themeda quadrivalvis (L)								
Legumes								
Alysicarpus bupleurifolius (L) DC	30.00	10.4	8.67	8.6	9.81	2.62	0.18	9.54
Alysicarpus monilifer (L) DC	40.00	13.4	8.37	11.12	9.09	3.37	0.24	12.70
A. tetragonolabus (L) DC								
Aschinomon indica (L)	95.00	199.8	52.58	3295.64	21.59	50.37	72.41	144.37
Cassia pumila. Lamk	-	-	-	-	-	-	-	-
Hylandia latibrosa. *DC*	-	-	-	-	-	-	-	-
Stylosanthes hamata (L)	35.00	17.6	12.57	290.28	7.95	4.43	6.37	18.75
Others								
Celosia argentia. Linn	35.00	9.6	6.86	84.76	7.95	2.42	1.86	12.23
Chorchorus aletorius. Linn	8.4	30.00	7.00	8.24	6.81	2.11	0.18	9.10
Cyprus rotendus. Linn	10.00	4.00	10.0	35.32	2.27	1.00	0.77	4.04
Fembristylis schoenoides (Retz)	-	-	-	-	-	-	-	-
Fembristylis tenera Schult.	5.00	4.4	22.00	2.08	1.13	1.10	0.04	2.27
Sida carpinifolia Linn	10.00	1.2	3.0	5.28	2.27	0.30	0.11	2.68
Total	440.00	396.6	207.82	4550.8	100.53	99.93	99.93	300.39

Table 4.17: Dry matter production of pasture (gm m^{-2}) under silvipasture system

Tree species with pasture	**Grasses**	**Legumes**	**Others**	**Total**
D. sissoo	893.84	201.78	11.40	1107.02
	±657.52	±188.63	±12.58	±679.49
G. arborea	273.90	381.73	9.54	665.17
	±126.97	±44.02	±8.70	±136.71
P. pinnata	643.72	171.73	41.37	856.82
	±262.73	±113.78	±12.35	±200.46
T. arjuna	493.51	276.30	12.08	781.89
	±220.21	±165.56	±15.92	±178.01
Control without tree	305.69	538.07	21.05	864.74
	±223.81	±404.98	±12.87	±361.94
SEm ±	181.19	125.97	6.99	192.16
SEd ±	256.21	178.12	9.89	271.72
CD (at 5%)	NS	NS	21.54	NS

Table 4.18 : Nutritive status of pasture species under silvipasture system

Pasture species	**N %**	**P %**	**K %**	**Crude protein %**	**Crude fibre %**	**Ash %**	**Calorific value (cal gm^{-1})**
Grasses							
Cenchrus ciliaris. Linn	0.63	0.93	0.89	3.93	41.2	2.34	3196.29
Chrysopogon fulvus. Spreng	0.42	0.84	0.84	2.62	42.9	4.32	3308.17
Cynodon dactylon. Pers	1.09	0.94	0.84	6.81	22.6	3.52	3018.29
Eremopogon faveolatus. Stapf	0.63	0.63	0.57	3.93	32.6	2.36	3378.26
Heteropogon contortus. Beauve. R.S.	0.44	0.73	0.63	2.75	35.6	3.60	3479.16
Iseliema laxum. Hock	0.32	0.84	0.85	2.0	36.3	3.32	3016.18
Pennisetum pedicellatum. Trin	0.86	0.53	0.79	5.27	35.3	2.32	3396.26
Themeda quadrivalvis (L)	0.23	0.64	0.75	1.43	36.2	3.82	2926.19
Legumes							
Alysicarpus bupleurifolius (L) DC	1.31	0.66	0.36	8.18	30.2	3.13	3289.62
Alysicarpus monilifer (L) DC	0.76	0.72	0.83	4.75	31.2	2.34	3273.92
A. tetragonolabus (L) DC	1.00	0.73	0.64	6.25	32.6	2.41	2816.16
Aschinomon indica (L)	1.37	0.63	0.43	8.56	35.6	2.65	3546.26
Cassia pumila. Lamk	0.89	0.73	0.63	5.56	33.6	2.42	2818.19
Hylandia latibrosa. *DC*	0.14	0.64	0.69	0.87	29.2	2.62	2518.20
Stylosanthes hamata (L)	0.65	0.84	0.33	4.06	30.3	2.33	3674.27
Others							
Celosia argentia. Linn	0.56	0.23	0.64	3.5	31.6	2.61	3164.86
Chorchorus aletorius. Linn	1.09	0.74	0.76	6.81	29.6	4.31	2918.73
Cyprus rotendus. Linn	0.16	0.63	0.85	1.0	28.6	4.62	3027.86
Fembristylis schoenoides (Retz)	0.36	0.65	0.73	2.25	31.6	2.42	2818.26
Fembristylis tenera Schult.	0.33	0.63	0.89	2.06	39.6	2.62	2806.79
Sida carpinifolia Linn	1.28	0.26	0.36	8.00	29.2	2.35	3046.90

Table 4.19: Nitrogen in pasture components (gm m^{-2}) harvested from silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	4.74	2.73	0.16	7.62
	±2.46	±2.74	±0.12	±3.51
G. arborea	2.02	5.00	0.05	7.07
	±0.70	±0.42	±0.07	±0.93
P. pinnata	4.59	2.15	0.36	7.11
	±2.88	±1.40	±0.02	±2.24
T. arjuna	2.88	3.13	0.09	6.09
	±1.64	±2.33	±0.08	±1.49
Control (without tree)	1.71	7.17	0.013	9.00
	±0.86	±5.59	±0.09	±5.17
SEm ±	1.05	1.72	0.04	1.7
SEd ±	1.49	2.44	0.06	2.40
CD (at 5%)	NS	NS	0.14	NS

Table 4.20 : Phosphorus in pasture components (gm m^{-2}) harvested from silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	8.08	1.29	0.14	9.51
	±5.19	±1.17	±0.14	±5.03
G. arborea	4.29	2.48	0.09	6.86
	±2.19	±0.34	±0.09	±2.42
P. pinnata	7.98	1.12	0.42	9.52
	±5.19	±0.75	±0.20	±4.83
T. arjuna	4.90	1.91	0.14	6.95
	±3.02	±1.08	±0.19	±2.44
Control (without tree)	2.92	3.43	0.24	6.60
	±1.91	±2.54	±0.15	±1.94
SEm ±	2.07	0.80	0.08	1.96
SEd ±	2.93	1.12	0.11	2.76
CD (at 5%)	NS	NS	NS	NS

Table 4.21: Potassium in pasture components (gm m^{-2}) harvested from silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	6.90	0.84	0.07	7.81
	±5.53	±0.80	±0.07	±5.41
G. arborea	1.92	1.62	0.03	3.58
	±0.86	±0.19	±0.05	±0.91
P. pinnata	3.77	0.74	0.32	4.83
	±2.74	±0.50	±0.14	±2.40
T. arjuna	3.86	1.07	0.07	4.99
	±1.97	±0.73	±0.10	±1.62
Control (without tree)	2.53	4.96	0.14	7.63
	±1.83	±4.40	±0.08	±6.01
SEm ±	1.54	1.08	0.05	1.82
SEd ±	2.17	1.52	0.06	2.57
CD (at 5%)	NS	NS	0.14	NS

Table 4.22 : Crude protein (gm m^{-2}) in pasture components harvested from silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	29.49	16.35	0.70	46.59
	±15.28	±16.35	±0.75	±20.90
G. arborea	11.02	35.70	0.46	47.18
	±4.13	±11.75	±0.42	±10.27
P. pinnata	19.45	13.33	6.61	39.40
	±19.82	±8.72	±6.53	±14.51
T. arjuna	17.86	19.61	0.48	37.96
	±10.13	±14.53	±0.55	±9.34
Control (without tree)	10.75	44.75	0.19	55.72
	±5.46	±34.91	±0.18	±31.81
SEm ±	6.72	11.10	1.51	11.02
SEd ±	9.51	15.70	2.14	15.60
CD (at 5%)	NS	NS	4.66	NS

Table 4.23: Crude fibre received (gm m^{-2}) from posture crop under silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	353.40	70.41	3.56	427.37
	±285.79	±67.35	±2.39	±279.77
G. arborea	98.93	133.93	3.07	235.84
	±45.07	±13.93	±2.88	±47.42
P. pinnata	230.48	59.31	14.56	304.46
	±90.17	±39.31	±6.24	±74.26
T. arjuna	149.30	59.42	3.80	287.13
	±126.54	±39.31	±5.03	±75.46
Control (without tree)	118.75	189.87	6.74	315.36
	±99.54	±144.43	±4.11	±133.71
SEm ±	82.17	44.73	2.10	77.58
SEd ±	116.19	63.24	2.98	109.70
CD (at 5%)	NS	NS	6.5	NS

Table 4.24 : Ash residue (gm m^{-2}) of pasture component under silvipasture system

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	32.49	5.33	0.22	38.04
	±29.82	±5.08	±0.15	±29.13
G. arborea	8.32	10.18	0.44	18.94
	±4.17	±1.11	±0.51	±4.79
P. pinnata	14.65	4.49	1.37	20.51
	±7.63	±2.95	±0.66	±6.86
T. arjuna	16.68	6.94	0.32	23.94
	±9.35	±4.43	±0.39	±8.52
Control (without tree)	10.64	14.15	0.61	25.39
	±10.50	±10.71	±0.37	±11.49
SEm ±	7.08	3.33	0.23	7.24
SEd ±	10.01	4.71	0.32	10.24
CD (at 5%)	NS	NS	0.71	NS

Table 4.25: Energy released (k cal m^{-2}) on combustion of pasture components in silvipasture systems

Tree species with pasture	Grasses	Legumes	Others	Total
D. sissoo	29876.33	7138.92	341.99	37357.23
	±21828.55	±6685.85	±372.02	±21720.59
G. arborea	9044.89	13583.87	4753.85	27382.60
	±4535.44	±1570.47	±7928.68	±7746.89
P. pinnata	21757.96	6079.88	1321.02	29158.86
	±12912.70	±4035.53	±604.60	±11310.44
T. arjuna	16427.44	9641.55	378.65	26447.64
	±7550.30	±6230.48	±541.46	±6180.79
Control (without tree)	10235.41	19094.74	696.37	30026.52
	±7386.55	±14349.51	±342.00	±12750.83
SEm ±	6277.39	4502.45	1883.87	6992.64
SEd ±	8876.23	6366.46	2663.79	9887.60
CD (at 5%)	NS	NS	NS	NS

Table 4.26 : Soil pH at different depth of silvipasture system

Treatments	Soil depth (cm)		
	D1 (0-5cm)	D2 (5-10 cm)	D3 (10-15)
D. sissoo	6.53	6.57	6.90
G. arborea	5.50	6.10	6.90
P. pinnata	5.70	6.25	7.06
T. arjuna	6.70	6.97	7.00
Control	6.56	6.70	6.85

Table 4.27 :Available organic carbon (%) at different depth of silvipasture system

Tree species with pasture	Soil depth cm			
	(D_1) 0 to 5cm	(D_2) 5 to 10 cm	(D_3) 10 to15 cm	Mean
D. sissoo	0.19 ± 0.01	0.45 ±0.02	0.33 ±0.02	0.97
G. arborea	0.30 ± 0.01	0.45 ±0.02	0.37 ±0.02	1.12
P. pinnata	0.31 ± 0.01	0.38 ±0.01	0.48 ±0.008	1.17
T. arjuna	0.61 ± 0.01	0.42 ±0.01	0.36 ±0.005	1.39
Control (without tree)	0.032 ±0.008	0.48 ±0.02	0.37 ±0.008	1.7
Mean	1.73	2.19	1.91	
	SEm±	**SEd ±**	**CD (at 5%)**	
Treatment	0.013	0.018	0.038	
Soil depth	0.010	0.014	0.029	
T x S	0.006	0.008	0.017	