

EVALUATION OF DIFFERENT LAND USE SYSTEMS IN CARBON SEQUESTRATION

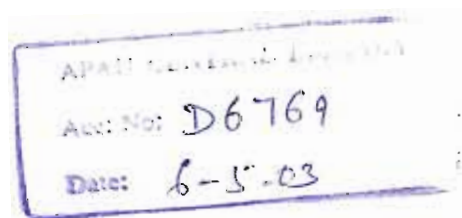
By

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B. Sc. (Ag.)



**THESIS SUBMITTED TO THE
ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE & AGRICULTURAL CHEMISTRY)**



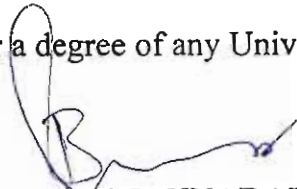
**DEPARTMENT OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY
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DECEMBER, 2002

CERTIFICATE

Mr. N. SANJEEVA REDDY, has satisfactorily prosecuted the course of research and that the thesis entitled **“EVALUATION OF DIFFERENT LAND USE SYSTEMS IN CARBON SEQUESTRATION”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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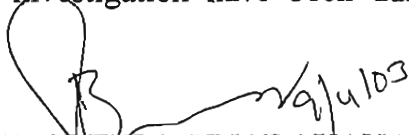


(B. SREEMANNARAYANA)
MAJOR ADVISOR

CERTIFICATE

This is to certify that the thesis entitled “**EVALUATION OF DIFFERENT LAND USE SYSTEMS IN CARBON SEQUESTRATION**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **Mr. N. SANJEEVA REDDY** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

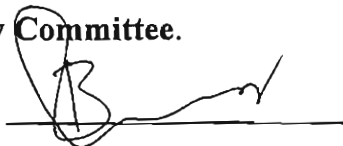
No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.


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LIST OF ABBREVIATIONS

@	:	At the rate of
CEC	:	Cation exchange capacity
cm	:	Centimeter
dS m ⁻¹	:	Deci siemen per meter
EC	:	Electrical conductivity
<i>et al.</i>	:	Others
mg kg ⁻¹	:	Milligram per kg
°C	:	Degree celsius
%	:	Per cent
P	:	Phosphorus
P ₂ O ₅	:	Phosphorus pentoxide
q ha ⁻¹	:	Quintal per hectare
SOC	:	Soil organic carbon
SAR	:	Sodium absorption ratio
t ha ⁻¹	:	Tonnes per hectare
t ha ⁻¹ yr ⁻¹	:	Tonnes per hectare per year
t km ⁻¹	:	Tonnes per kilometer
C	:	Carbon
Ca	:	Calcium
cmol (p ⁺) kg ⁻¹	:	Centimoles of cations per kilogram
K	:	Potassium
kg ha ⁻¹	:	kilogram per hectare
GHGs	:	Green house gasses
g kg ⁻¹	:	Grams per kilogram
m	:	meter
Mg	:	magnesium
ml	:	Milli litre
ml m ⁻³	:	milli litre per cubic meter
MSL	:	Mean sea level
m ha	:	Million hectares
N	:	Nitrogen
ppm	:	parts per million
µg	:	microgram
µLL ⁻¹ yr ⁻¹	:	Micro litre per litre per year

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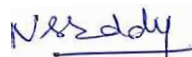
I am also thankful to the non-teaching staff of Soil Science and Agricultural Chemistry for their help and cooperation during the course of the study.

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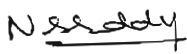
Last but not least, I express my sincere thanks to Mrs. and Mr. **D. Ravi Krishna**, Krishna Shashank Computers, Premavathipet, Rajendranagar for their immaculate execution of typing.

Finally, I wish to express my thanks and gratitude to everyone who has contributed even in a small way in completing this research work. To all of them whose names might not have appeared here, thank you very much and you are never forgotten.


(**N. SANJEEVA REDDY**)

DECLARATION

I, **N. SANJEEVA REDDY**, hereby declare that the thesis entitled **EVALUATION OF DIFFERENT LAND USE SYSTEMS IN CARBON SEQUESTRATION**” submitted to Acharya N.G. Ranga Agricultural University for the degree of **'MASTER OF SCIENCE IN AGRICULTURE'** is the result of original research work done by me. I further declare that the thesis or any part thereof has not been published earlier in any manner.


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ABSTRACT

An investigation entitled **"Evaluation of different land use systems in carbon sequestration"** was carried out at Agro-forestry research unit, ANGRAU, Rajendranagar during the year 2002. Soils under different land use systems were evaluated for Soil Organic Carbon (SOC) status, carbon mitigation potential besides investigating comparative performance of different land use systems in improving fertility status. Carbon sequestered per unit quantity of biomass in different tree species was also studied. An experiment was conducted on decomposition rates of different tree leaves which have a bearing on organic carbon status of soils. Relationship between organic carbon and different soil characteristics was studied.

Analysis of soils showed organic carbon status was higher in soils under Agri-silviculture system (0.89%) followed by Silvi-pasture (0.76%), Agri-silvi-horti system (0.72%). Fallow land (0.18%) showed lowest organic carbon status. The 'C' mitigation potential of Agri-silviculture (4.23) was maximum followed by Silvi-pasture (3.71), Agri-silvi-horti system (3.42), *L. leucocephala* (3.23) and remaining land use systems were lower than 3.00 when fallow land mitigation potential was assumed as 1.00. Since the biomass production was maximum with *L. leucocephala* (7 t ha⁻¹ yr⁻¹) and *E. camuldulensis* (5.35 t ha⁻¹ yr⁻¹),

the carbon sequestration was highest in these trees as compared to that of *A. lebbeck* ($2.98 \text{ t ha}^{-1} \text{ yr}^{-1}$) which was superior in sequestered carbon per unit quantity of biomass (0.458 kg/kg of biomass). Leaves of all the trees contained maximum carbon than that of twigs and wood portions. Agri-silviculture recorded higher silt (17.0%) & clay (25.1%) but lower sand content (58.7%) as compared to remaining land uses. Moisture status (10.2%) was high in Agri-silvi system. The available and total macronutrient status and exchangeable Ca and Mg status of soils were analysed in different land use systems. All the nutrients irrespective of land use systems were decreasing with increasing depth of soil i.e., 0-15 cm to 30-45 cm. Agri-silvi system was superior in accumulating higher quantity these available and total nutrients and exchangeable Ca and Mg.

Organic carbon showed significant positive correlation with silt, clay, moisture content, available and total N, P, K and exchangeable Ca and Mg, whereas sand content was negatively correlated with organic carbon. Decomposition rate (CO_2 release) was highest with respect to *A. lebbeck*, *L. leucocephala*, *A. albida* while lowest was associated with *E. camaldulensis* irrespective of periods of incubation and quantity of substrate addition. It was found that superior decomposition rate was associated when substrate incorporation was higher.

INTRODUCTION

CHAPTER I

INTRODUCTION

As long as carbondioxide concentration in the atmosphere remains at desirable level, it poses hardly any threat to environmental deterioration but becomes an impediment in maintaining clean atmosphere for the well being of mankind. If it goes beyond certain levels, an increase in its concentration combined with other greenhouse gasses that are associated with activities such as deforestation, burning of grasslands to stimulate regeneration of grasses, shifting cultivation etc. account for the major problem that leads to deterioration in quality of life in all spheres. The contribution of CO₂ to global warming is put approximately at 49 per cent. The level of CO₂ in atmosphere is now at alarmingly close to 370 ppm and is increasing at the rate of 1.5 μ LL⁻¹yr⁻¹ particularly in temperate regions (Lee and Dadson, 1996). According to estimates, if present trends continue, CO₂ levels may reach 600 ppm by 2100 and to 1300 ppm by 2200 and may level off at 1800 ppm in the year 2400 (Harvey and Danney, 2000). So, increase in CO₂ concentration in the atmosphere to an unmanageable proportions has far reaching consequences on the health of human and other living beings on the earth. Therefore, there is every need to combat the ill effects of CO₂ concentration by creating suitable sinks. Though, forest is the most important land use for mitigation of greenhouses gases, the best possibility lies with agro-

forestry where tree component plays an important role in sequestering carbon and lessen the ill effects significantly to a safe level. It was evidently proved that the carbon stored in forest land is highest followed by agricultural lands, pastures and barren lands etc. (Jha, 2002). Thus, it can be seen that intensive technology to strengthen forest conservation and conservation agriculture could lead to effective stabilization of greenhouse gasses (GHGs) in the atmosphere. Approximately, 260 mha land in India has biological potential of some use and quite suited to GHG stabilization because of large surface area, microbial diversity, moisture content and pH buffering. (In many regions, the diverse natural vegetation is replaced by a narrow range of annual plant species. Thus, carbon and nutrients are necessarily removed from plant-soil ecosystem as the harvest, affecting the resilience of soil. A means for reducing and/or reversing the land degradation i.e. soil fertility improvement is to provide a green cover and deposit surface litter on land cover. Tree vegetation as well as type of litter produced under different plant communities cause certain differences in the physical and chemical characteristics of soil and soil fertility is closely related to organic matter which is mainly contributed by vegetation and ground flora in various agroforestry systems and tree plantations. Litter has very strong effects on both hydrological and nutrient cycling characteristics of the ecosystem (Singh *et al.*, 1984). Different land use systems have varying potentials to hold leaf litter and other by-products which possess

differing decomposition rates and have a bearing on increasing the carbon store in the soil. Such information would help to evaluate different land use systems for mitigating GHGs of atmosphere and to ultimately arrive at one possible suitable system for adaptation in future. It is therefore, a felt need that is to be addressed immediately and the following objectives would to some extent can create possibilities of documenting the information in this direction. A study, therefore, has been formulated to evaluate different land use systems and their potential in sequestering carbon in soil with objectives underlined below.

1. To evaluate comparative efficiency of different land use systems in soil organic carbon storage.
2. To arrive at sequestered carbon content per unit quantity of biomass produced by trees.
3. To study the effect of different physico-chemical properties on carbon sequestration.
4. To evaluate the decomposition rates of different tree leaves.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

An investigation was carried out on “**Evaluation of different land use systems in carbon sequestration**” at Agroforestry research unit, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad during the year 2002. The literature collected on the topic is reviewed and presented under different heads:

2.1 INFLUENCE OF DIFFERENT LAND USE SYSTEMS ON PHYSICAL PROPERTIES OF SOILS

2.1.1 Mechanical composition

Tokey *et al.* (1986) reported that the soil texture varied from loamy sand to clay loam under miscellaneous tree cover, sandy loam to clay loam under *Eucalyptus* and loam to clay under teak plantations in Kotma range, Madhya Pradesh.

It was reported by Sharma and Gupta (1989) that the sand percentage was lower (91.8%) under tree vegetation in comparison to barren land (95.3%). Similarly, silt and clay contents also increased under vegetative cover.

2.1.2 Moisture content in different land use systems

Dhyani *et al.* (1990) reported an increase in soil moisture content in soil under tree cover.

Variations in moisture content were reported by Ravender Singh *et al.* (1990). It was observed that the soil moisture under eucalyptus was more, followed by subabul, teak, sal, chir, bamboo and agricultural land, might be because of quality of litter that has accumulated in the soil over the years, and changes brought about in structure or texture of soil.

Thomas Mathew *et al.* (1997) reported that the growth of different multipurpose tree species had significant influence on soil moisture status and varied under different tree canopies, however, it was significantly high under different tree canopies than control.

2.2 INFLUENCE OF DIFFERENT LAND USE SYSTEMS ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

2.2.1 pH

Ameliorating effect of 20 year old plantation on alkali soil was found to be in the order of *Prosopis* > *Acacia* > *Terminalia* > *Albizia* > *Eucalyptus*. Average pH of the soil decreased from 10.2 to 9.1 in *Eucalyptus*, to 9.03 in *Acacia*, to 8.67 in *Albizia*, to 8.15 in *Terminalia* and to 8.01 in *Prosopis* during 20 years of growth (Singh *et al.*, 1990). Rao and Gill (1988) noticed a marked decrease in pH and electrical conductivity in 30 months in high density plantation of *Sesbania spp.* in surface 30 cm layer. It was also reported that the soil pH reduced considerably after 9 years of plantations of *Azadirachta indica* and *Pongamia pinnata* when compared to pre plantation values of pH and the effect was more pronounced in *Azadirachta indica* stand (Jain *et al.*, 2002).

pH under different plantations showed varying trend depending on soil and climate. Chakraborty and Chakraborty (1989) reported that there was progressive increase in pH of soil from 5.9 (no plantation) to 7.6 (*Acacia auriculiformis*) with age of plantation, while Aparjitha *et al.* (1991) reported that pH in the original soil (before plantation) ranged from 5.3 to 7.1 which was comparatively higher than the pH range of 4.8 and 6.4 after plantation of *Eucalyptus territicornis*.

As per the studies conducted by Shukla and Misra (1993) there was a definite reduction in soil pH under different canopy covers, being more pronounced in the 0-15 cm depth surface layer. Maximum reduction in pH was brought about by *Prosopis* followed by *Dalbergia*, *Acacia* and *Eucalyptus* while least reduction was found in control plot. Mongia *et al.* (1998) also observed same trend of reduction in pH and EC by growing different tree species for more than three years and ameliorating effect on soil fertility was more under *Prosopis juliflora*.

2.2.2 Electrical conductivity

Aggarwal (1980) reported increase in salt concentration under tree cover as compared to bare soil.

The studies conducted by Kumar and Abrol (1986) showed that there was marked fall in soil pH and EC from the initial values of 10.3 and 2.2 dS m⁻¹ respectively. The soil pH and EC in the 0-15 cm soil

layer decreased to 8.9 and 0.36 dS m⁻¹ respectively within 74 months of *Leptochloa* plantations while Chakraborty and Chakraborty (1989) reported progressive increase in EC from 0.027 to 0.048 dS m⁻¹ with the age of the *Acacia auriculi formis* plantations.

Chhabra *et al.* (1987) also reported appreciable decrease in pH, EC and sodium absorption ratio (SAR) in the top 15 cm soil layer in an alkali soils when *Sesbania aegyptica* was grown for more than four years over initial values.

2.3 INFLUENCE OF DIFFERENT LAND USE SYSTEMS ON CHEMICAL CHARACTERISTICS OF SOIL

2.3.1 Nitrogen (Total and available)

The magnitude of increase in total nitrogen was maximum under the canopy of *Prosopis cineraria* followed by *Acacia nilotica* and it was minimum under the bare soils of open fields (Singh and Lal, 1969). Chakraborty and Chakraborty (1989) reported that *Acacia auriculiformis* increased total nitrogen content with age of the plantation from 0.364 to 0.564 per cent in the forest division of Tripura.

It was found that the sand dunes contained zero level of total nitrogen as compared to those soils under tree cover (Sharma and Gupta, 1989). Available nitrogen accretion in the soil was significantly higher when trees were associated with agricultural crops than sole trees, sole crops and control. The nitrogen content increased by 8-46 per cent (0-7.5cm soil depth): the increase being maximum in the case

of *Acacia* based system followed by *Populus* and *Eucalyptus* based systems (Kaur *et al.*, 2000).

Ravi Kumar *et al.* (1998) reported higher content of available nitrogen in soils under different plantations than in control and availability of nutrients was higher in surface horizons of all the profiles and it decreased gradually with depth. Nadagoudar (1990) evaluated the benefits of *Acacia ferruginea*, a promising tree of Vertisols in agro forestry system and reported that all the chemical properties improved under the tree as compared to open area. Total nitrogen increased from 0.028 per cent in open area to 0.031 per cent under the tree at 0-22.5 cm depth.

Jha *et al.* (2001) studied the effect of Agro forestry (*Populus deltoids* + wheat) and farming (wheat only) land uses on the soil properties in Yamunanagar (Haryana) and reported that total nitrogen content was higher in the soil under agro forestry than farming land use.

2.3.2 Phosphorus (Available and total)

Sreemannarayana *et al.* (1994) evaluated different multipurpose trees and their influence on soil fertility improvement and observed that available P_2O_5 was more under *Leucaena leucocephala* and *Albizia lebbeck* and minimum under *Acacia auriculiformis* after five years of plantations. Similarly Vamsi Krishna (2000) studied the nutrient profile of different land use systems in Alfisols under rainfed conditions and

reported that Silvi agriculture showed higher values of available phosphorus (14 kg ha^{-1}) when compared to fallow land (5.7 kg ha^{-1}) in 0-15 cm depth.

Solanki *et al.* (1999) compared the extent of enrichment of N, P and K under various agro forestry systems and showed that there was highest increase in available N, P and K contents under agri-horticultural systems in Bundelkhand region of Uttar Pradesh. Sharma and Gupta (1989) also observed that the available phosphorus increased markedly from 14.9 kg ha^{-1} to 33.7 kg ha^{-1} under *Prosopis cineraria* and the least under *Prosopis juliflora*. Kang and Ghuman (1991) showed that the alley cropped *Albizia lebbeck* maintained higher soil (organic matter) extractable phosphorus and exchangeable cations than under control (no tree).

2.3.3 Potassium (Available and total)

Adejuwon and Exanade (1988) reported that fallow land and soils under the tree covers were significantly different in total K content.

Chakraborty and Chakraborty (1989) studied changes in soil properties under *Acacia auriculiformis* plantations in Tripura and reported that total potassium was more under *Acacia* plantations when compared to control plot.

Srivastav (1993) conducted a study and observed changes in physical and chemical properties of soil in irrigated Eucalyptus plantations and reported that available K was higher in soils with

plantations than in control plots. It was reported that potassium content was 5 to 13 times more concentrated in the surface soil under penyon-pines than in soils from shrub dominated areas (Barth, 1980). Campbell *et al.* (1994) reported that the concentration of the cations (K, Ca and Mg) were lower in areas without trees.

The total K values of cultivated soils were greater than that of uncultivated soils. The increase in total K of the soil profiles from surface to subsurface in uncultivated soils were found to be non-significant. Exchangeable K showed a decreasing trend downward under the agro-forestry and horticulture. Highest amount was recorded under horticulture followed by agro-forestry and pasture ((Madhumita Das *et al.*, 1997).

It was reported that available potassium in all vegetative systems was low with relatively higher values observed in pure eucalyptus plot (Saha *et al.*, 1999). But Aparjita *et al.* (1991) observed that the exchangeable K_2O was more in the original soils (before plantation) as compared to the plantation areas of *Eucalyptus* trees.

2.3.4 Exchangeable calcium and magnesium

Ravender Singh *et al.* (1990) also reported that different tree plantations showed high status of calcium and magnesium than agricultural land.

The exchangeable calcium and magnesium status of soils with tree cover in A₁ horizon, were higher than under cultivated soil (control), but below this horizon the values of Ca⁺⁺ & Mg⁺⁺ were almost similar in all the soil profiles (Ravikumar *et al.*, 1998). Shukla and Misra (1993) conducted a study on improvement of sodic soil under different tree covers and reported that *Prosopis juliflora* was more effective in raising the Ca content in the soil [8.19-18.28 c mol (p⁺) kg⁻¹] followed by *Dalbergia sissoo* [6.43-15.29 c mol (p⁺) kg⁻¹], *Eucalyptus hybrid* [6.07-14.8 c mol (p⁺) kg⁻¹], *Acacia nilotica* [7.5-14.15 c mol (p⁺) kg⁻¹] and control [4.06-8.23 c mol (p⁺) kg⁻¹].

2.4 ORGANIC CARBON IN DIFFERENT LAND USE SYSTEMS

Radwanski and Wickens (1981) reported high organic carbon, cation exchange capacity and base saturation under *Leucaena leucocephala* tree canopies than in adjacent open land. The effect was more significant when planted at close spacing as was observed by Pathak and Gupta (1987). It was seen that 2 years old plantation of *Leucaena* added 5.6 t ha⁻¹ of organic matter and resulted in an increase in water retain ability and cation exchange capacity. Das and Bhaskar Rao (1992) showed an increase in organic matter content in soil with legume pasture (*Stylo*) after fourth year of experimentation, while Lal (1989) reported more of organic carbon in 0-5cm and 5-10cm layer of agro forestry treatments (*Leucaena* and *Gliricidia* based systems) than either the plow till or no till systems.

Chakraborty and Chakraborty (1989) noticed changes in soil properties under *Acacia auriculiformis* plantations in Tripura and reported that organic carbon content increased from 0.81 in barren land to 2.70 per cent in plots with four years old trees.

In *Prosopis cineraria* and *Balanites aegyptica* there was perceptible change in organic carbon status in sand dunes recording a significant improvement over no tree cover and showed rise in organic carbon from 0.03 in barren sand dunes to 0.47 per cent (Sharma & Gupta, 1989). Similar results were also reported by Sharma *et al.* (1990).

Long term experiments in Australia showed that soil under long term pasture (1918-1986) contained 11.5×10^9 g ha⁻¹ more organic carbon than unfertilized cropped plots (Ridley *et al.*, 1990).

These observations were well supported by Singh and Singh (1993), whose studies indicated that raising of trees on alkali soils of Karnal increased soil organic carbon (SOC) from 0.12 to a maximum of 0.58 per cent.

Cambardella and Elliot (1994) observed bare fallow soil had significantly less total organic C and N than stubble mulch and no till soils.

The work carried out at Indian Grassland and Fodder Research Institute (IGFRI), Jhansi showed that there was significant improvement

in soil physical properties and soil fertility in silvi-pastural agro-forestry system after three years of experimentation. The increase in organic carbon status was from 0.20 (initial) to 0.81 per cent (Hazra, 1994).

It was observed by Subrahmanyam *et al.* (1996) that the organic carbon content was found to increase by three folds in all the *sissoo* plots when compared to fallow plots after two years of plantation. However, sole *sissoo* plot recorded the highest organic carbon content when compared to intercropping situation. Similarly, the soil with sole trees recorded higher organic carbon than the control plots (Thomas Mathew *et al.*, 1997).

The studies conducted by Madhumita Das (1997) showed that organic carbon decreased gradually down along the profiles in agriculture with considerable acceleration at the surface as compared with natural fallow. They also stated that organic carbon accumulation was maximum in agro forestry followed by pasture and horticulture.

Significant improvement in organic carbon status of soil was reported by several workers. Rao *et al.* (1997) reported 50 per cent increase in soil organic carbon (SOC) after eight years of plantation as compared to agricultural land. In a three year study, three land use systems were compared for carbon storage efficiency. Agro-forestry and plantations could nearly store 26 and 22 per cent more carbon respectively than agriculture in Haryana plains (Jha *et al.*, 1997).

Jha *et al.* (2001) also reported that soil under *prosopis* was enriched by a good amount of organic carbon just after 3 years of afforestation (86.11% increase over control) followed by *Eucalyptus*, *Dalbergia*. Carbon enrichment was high under *prosopis* (193.05% & 790% over control after 6 and 9 years of plantations respectively) followed by *Dalbergia* and *Eucalyptus*.

Cadisch *et al.* (1998) reported that the introduction of improved pastures increase soil organic carbon @ 230 to 3300 kg c ha⁻¹ y⁻¹ in tropics. Solanki *et al.* (1999) also compared the extent of enrichment of carbon under various agro-forestry systems and reported highest enrichment of carbon (377%) under silvi-pastoral system.

Dutta and Dhiman (2001) noticed enrichment of organic carbon under various multipurpose tree species and of which *Michelia champaca* showed the maximum rise in organic carbon from 5 g kg⁻¹ (no tree) to 6.3 g kg⁻¹ followed by *Albizzia*, *Gliricidia*, *Dalbergia* and *Gmelina*.

2.5 RELATIONSHIP BETWEEN SOIL ORGANIC CARBON WITH SOIL PARAMETERS

The relationship between organic carbon and the soil parameters *viz.*, mechanical composition, pH, electrical conductivity, available N, P & K, total N, P & K, exchangeable Ca & Mg and moisture content was studied by several workers. Generally there was significant positive correlations except in some cases, depending on the soil and climatic conditions.

Sharma *et al.* (1981) studied the soil organic carbon as a common index of availability of both phosphorus and potassium to potatoes in acidic brown hill soils of Simla and revealed that there was high significant association of organic carbon with Bray-P in field soils while recording a positive association of organic carbon with Al-P and Fe-P. A positive association of organic carbon with available K was also reported. Similar positive significant correlation was obtained with studies conducted by Minhas and Bora (1982).

Ravender Singh *et al.* (1990) worked out correlations between organic carbon and total N, available N and CEC under different plant covers and reported a positive correlation between organic carbon, available and total N, whereas no significant correlation was observed in case of organic carbon and CEC. Though, Kanthaliya and Bhatt (1991) showed similar positive correlation between organic carbon and available N, the relation between organic carbon and available P and K was found to be non-significant.

Gupta *et al.* (1991) studied organic carbon in Silver Fir and Spruce forest soil under different silvi cultural systems and reported inter correlation between soil organic carbon and total and available N, P, K and C:N ratio. The results on soil organic carbon showed significant positive correlation with N, P, K (total and available) and C:N ratio.

2.6 CO₂ MITIGATION POTENTIAL OF DIFFERENT LAND USE SYSTEMS

Results of the 3-year Chicago urban forest climate project indicated that there were about 50.8 million trees in the Chicago area; 66 per cent of these trees were in good or excellent condition. It was estimated that the trees removed 6145 tons of air pollutants and sequestered 155000 tones of carbon per year (Mcpherson *et al.*, 1994). Silver *et al.* (2000) also reported that tropical reforestration has the potential to serve as a carbon offset mechanism both above and below ground for at least 40 to 80 years and possibly much longer.

It was seen that CO₂ assimilation was 2.2 times more in the agro forestry system (composed of mixed areas of 18.5% forest cover) than agricultural area alone and 1.6 times more in the same area before the mixed forestry/agricultural system was established. It was also showed that the average CO₂ concentration in the atmosphere in the agro forestry system was 5.5-9.2 mL/m³ which was lower than that in the single agricultural system (Guangming and Xiculing, 1995).

It was also seen by expanding the existing US conservation Reserve forest program (CRP) into a carbon sequestration program, there exists a substantial potential for sequestering atmospheric carbon by conversion of farm land to forest plantations (Hardie *et al.*, 1996).

Jo-Hyunkil *et al.* (1999) compared the effects of different densities of tree planting on direct and indirect uptake of atmospheric

CO₂ in two residential neighbour hoods of Chuncheon province in Korean Republic. Such average carbon storage (accumulation over years through photosynthesis) per each detached residence with (10%) tree cover was 72 kg and 244 kg with a tree cover of about 20 per cent. The carbon storage with the higher tree cover was 3 times greater than that with sparse tree population. The results implied that more tree plantations in residential lands could enhance the benefits in reducing atmospheric carbon levels significantly.

A sink for atmospheric carbon in soils generally derived from the application of conservation tillage and the re-growth of native vegetation on abandoned agricultural land. It was also noticed that accumulation of soil organic matter could offset emissions of CO₂ from fossil fuel combustion (Schlesinger, 2000).

Carbon storage of top one foot of soil under six land uses was compared by Jha *et al.* (2001), while assuming the mitigation potential of barren land as 1 and they concluded that forests had maximum mitigation potential followed by agro forestry, plantations, agriculture etc.

Negi and Chauhan (2002) also reported that the carbon storage in total biomass of Sal forests of Doon valley varied from 91.00 to 88.45 t ha⁻¹ and explained that the Sal forests of Doon valley were capable of obtaining the CO₂ flux in the atmosphere.

2.7 CARBON CONTENT IN TREE SPECIES AND SEQUESTRATION

Reduction of CO₂ concentration in the atmosphere is of prime concern and ways are to be found to dilute this problem. Among these avenues, tree growing is the cost effective means because it reduces CO₂ concentration as it goes on attaining higher biomass level with the age.

Brandle *et al.* (1992) estimated the amount of carbon that could be sequestered in the above ground biomass of shelterbelts. Their estimates for 20 year old, single row shelterbelts were 9.14 t km⁻¹ of carbon for Conifers, 5-41 t km⁻¹ for hardwoods and 0.6 t km⁻¹ for shrubs.

Kort and Turnock (1999) reported that the above ground carbon content of shelterbelts (Deciduous trees, Coniferous trees, shrubs) in Saskatchewan, Canada varied from 48.0 per cent to 50.1 per cent. From this perceptive, it was concluded that shelterbelts have the potential to contribute a modest but significant amount to the goal of limiting net carbon emissions.

Negi and Chauhan (2002) measured the total biomass and carbon storage capacity of Sal in Doonvalley and indicated that total biomass varies from 182-777 t ha⁻¹ and depends on the stand age and tree density. Similarly, the carbon storage in total biomass varies from 91.00-88.45 t ha⁻¹ and also reported that plantations (6.7 t ha⁻¹ yr⁻¹) and coppiced system (9.05 t ha⁻¹ yr⁻¹) appeared to be more efficient in carbon sequestration as compared to natural forest.

2.8 INFLUENCE OF DIFFERENT FACTORS ON DECOMPOSITION OF TREE LEAVES

2.8.1 Soil moisture

A study was conducted on decomposition of tree leaves in arid soils at different moisture levels and it was apparent that maximum CO₂ was evolved at 50 per cent water holding capacity (WHC) of the soil and the least activity was observed at 2 per cent WHC. It was also seen that with increase in moisture content from 2 to 50 per cent WHC, the CO₂ evolution increased but after 50 per cent WHC it started decreasing, indicating that moisture holds the key in decomposition of litter (Tarafdar and Rao, 1992). Senapathi and Behera (2000) studied the effect of moisture on evolution of CO₂ and microbial activity in soil amended with organic substrates and it was noticed that CO₂ evolution was more at 60 per cent water holding capacity than at standing water of 3cm height.

Room Singh and Joshi (1982) studied the decomposition of root and litter materials of sand dune regions at Narhar near Pilani, Rajasthan and found that the temperature and moisture were critical environmental factors that influence decomposition. The results also indicated that a high rate of decomposition was associated with rainfall. Further, studies showed that moisture, temperature and stage of decomposition of litter governed the microbial populations in different seasons (Wikramp, 1963).

2.8.2 Periods and levels of incubation

Maharudrappa *et al.* (2000) reported that the cumulative CO₂ release increased with increase in periods of incubation. The rate of decomposition was higher with large quantity of litter additions (10t ha⁻¹). Among the litters teak showed rapid decomposition while Casurina was slow in getting decomposed. The rate of decomposition of leaf litter was of the order of Teak > Acacia > Eucalyptus > Casurina. Similar results of increase in carbon dioxide per unit time with increase in organic matter inputs were reported (Swift *et al.*, 1979; Merekx and Mulonogy, 1994).

Omkar Singh *et al.* (1993) studied the leaf litter decomposition in Sal, Teak, Eucalyptus and poplar forests in Uttar Pradesh and reported fast rate of decomposition in Sal followed by Teak, Poplar and Eucalyptus. Bahuguna *et al.* (1990) studied the leaf litter decomposition and nutrient release in *Shorea robusta* and *Eucalyptus camaldulensis* plantations and concluded that the rate of decomposition was faster in Eucalyptus as compared to Sal.

Pande and Sharma (1993) studied the litter decomposition in Pine, Sal, Teak and Eucalyptus trees and reported that leaf litter decomposition was higher in Sal followed by Teak, Pine and Eucalyptus.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

An investigation entitled “**Evaluation of different land use systems in carbon sequestration**” was carried out during the year 2002 in Agro-forestry research unit, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad. The methods adopted and materials used for this investigation are given in this chapter.

3.1 LOCATION OF THE STUDY AREA

Different land use systems located in Agro-forestry Project, Rajendranagar were selected for the present study. The Agro-forestry Project is located at an altitude of 542.6 m above MSL and at 78°29'E longitude and 17°19'N latitude.

A total of eleven land use systems selected for the study are detailed below. All the land use systems from where the soil samples collected were planted in Randomized Block Design with 3 replications except in fallow and agriculture land. However, in these two systems, soil samples were collected at random so as to fit into the statistical design.

3.1.1 Fallow land

Fallow land was chosen from uncultivated field situated in Student's Farm, College of Agriculture, Rajendranagar, Hyderabad. The soils were sandy in nature.

3.1.2 Agricultural land

An area which was continuously under cultivation and was grown with cereals, pulses and millets in different cropping seasons was selected for investigation. The soils were of red sandy loam.

3.1.3 Agri-silvi system (*Albizia lebbbeck* based)

The *Albizia lebbbeck* based agri-silvi system was initiated during the year 1993 on a red sandy clay loam soil with sunflower as intercrop and replaced with cowpea after four years. These plots received N, P and K in the form of chemical fertilizers and as per the doses recommended for the crops mentioned above. The sources of N, P and K used were urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP) respectively. The trees were planted at a spacing of 8 x 4 m.

3.1.4 Silvi-pasture system (*Acacia nilotica* based)

The Silvi-pasture system chosen for the study was initiated during the year 1993 on an Alfisol with *Acacia nilotica* as tree and *Stylosanthes hamata* and *Cenchrus ciliaris* as fodder grasses. These grasses received chemical fertilizers in the form of urea, SSP and MOP respectively to supply N, P and K. The spacing adopted for trees is 4 x 4 m.

3.1.5 Agri-silvi-horti system (Tamarind based) (*Tamarindus indica*)

Tamarind was planted at a spacing of 4 x 4 m during the year 1989. Jowar, redgram and cluster bean were being grown. The soil was red sandy loam. These crops received N, P and K in the form of urea, SSP and MOP respectively as per the recommended doses.

3.1.6 Eucalyptus plantations (*Eucalyptus camaldulensis*)

Eucalyptus trees were planted during the year 1989 at 2 x 2 m spacing on red sandy loam soils.

3.1.7 Subabul plantations (*Leucaena leucocephala*)

Subabul plantations were initiated during the year 1989 at 2 x 2 m spacing on red sandy loam soils.

3.1.8 Bamboo plantations (*Dendrocalamus strictus*)

Bamboo trees were planted during the year 1989 at 2 x 2 m spacing on red sandy loam soils.

3.1.9 *Acacia albida*

Acacia albida trees were planted at 3 x 3 m spacing during the year 1989 on red sandy loam soils.

3.1.10 Neem (*Azadirachta indica*)

Neem trees were planted at 4 x 4 m spacing during the year 1989 on red sandy loam soils.

3.1.11 Teak (*Tectona grandis*)

Teak trees were planted at 3 x 3 m spacing during the year 1989 on red sandy loam soils.

3.2 COLLECTION OF SOIL SAMPLES

Soil samples were collected from three depths (0-15 cm, 15-30 cm and 30-45 cm), from each of the three profiles selected randomly at 3 places in different land use systems by following standard procedures.

These soil samples were shade dried and pounded with wooden pestle and mortar before passing through a 2 mm sieve. The soil, thus processed was stored in polythene bags after labelling and used for analysis of different parameters.

3.3 SOIL ANALYSIS

Various methods followed for analysis of soil samples are described below:

3.3.1 Mechanical composition

The mechanical composition of the soils was estimated by the Bouyoucos Hydrometer method (Bouyoucos, 1962) and the results were expressed in percentage.

3.3.2 Soil moisture (%)

Soil moisture content was determined by Gravimetric method (Gupta, 2000).

3.3.3 pH

pH of the soil samples was determined in 1:2.5 soil water suspension as described by Jackson, 1973 using a digital combined glass electrode pH meter.

3.3.4 Electrical conductivity

The electrical conductivity (dS m^{-1}) was determined in 1:2.5 soil water suspension using electrical digital conductivity meter (Jackson, 1973).

3.3.5 Organic carbon (%)

Organic carbon content of the soils was determined by wet digestion method (Walkley and Black, 1934).

3.3.6 Available primary nutrients

3.3.6.1 Nitrogen

Alkaline permanganate method as given by Subbaiah and Asija (1956) was used to estimate the available nitrogen content of soil and is expressed in kg ha^{-1} .

3.3.6.2 Phosphorus

Available phosphorus content was estimated calorimetrically by extracting with Olsen's reagent (0.5M NaHCO_3 , pH: 8.5) as given by Watanabe and Olsen (1965). The contents were expressed in $\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$.

3.3.6.3 Potassium

The available potassium was estimated with neutral normal ammonium acetate and the content was determined by using flame photometer as described by Muhr *et al.* (1965) and is expressed in $\text{kg K}_2\text{O ha}^{-1}$.

3.3.7 Total primary nutrients

3.3.7.1 Total nitrogen (%)

Total nitrogen was estimated by modified Kjeldal method using sulphuric salicylic acid mixture (Hesse, 1971).

Preparation of acid extract

One gram of dried soil was weighed into a 150 ml conical flask to which 20 ml of concentrated nitric acid was added and a small funnel was placed over the erlenmeyer flask to prevent rapid evaporation of acid. The contents were heated to oxidize the organic matter. Then 10 ml of 60 per cent perchloric acid was added and the digestion was continued until dense white fumes appeared. A little extra perchloric acid was used to wash down the sides of the conical flask and the heating was continued for another 15 minutes to dehydrate the silica. The contents were filtered through Whatman No. 42 filter paper and the residue was washed with 0.5 M hydrochloric acid and finally the volume was made upto 250 ml (Hesse, 1971).

3.3.7.2 Total phosphorus (mg kg^{-1})

Total phosphorus content was determined by perchloric acid digestion method as described by Jackson (1973).

3.3.7.3 Total potassium (mg kg^{-1})

Total potassium in the acid extract was estimated by aspirating the extract into flame photometer (Jackson, 1973).

3.3.8 Exchangeable calcium and magnesium

Exchangeable calcium and magnesium of soil were estimated by Versenate method (Kanwar and Chopra, 1976). The contents were expressed in $\text{cmol (p}^+\text{) kg}^{-1}$.

3.4 PLANT ANALYSIS

Plant samples (leaf, twig and wood along with bark) collected from tree species under nine land use systems (except Fallow and Agriculture land) selected for the study were dried in an electric oven at 60°C , powdered and used for estimation of carbon. Carbon status was determined in different parts such as leaf, twig and wood along with bark. The carbon content was determined by $\text{K}_2\text{Cr}_2\text{O}_7\text{-H}_2\text{SO}_4$ oxidation method (Jackson, 1973).

3.5 DECOMPOSITION STUDIES (Laboratory incubation)

A laboratory experiment was carried out to investigate decomposition of different tree leaves selected for this study. An indirect method of decomposition of leaves was used by quantifying the amount of CO_2 released at a given time and at specified moisture level. One hundred grams of soil was taken in 500 ml conical flask to which powdered tree leaf samples were added at the rate of 2500, 3750 mg kg^{-1} (5, 7.5 t ha^{-1}) on weight basis. After thorough mixing of leaf samples with soil, sufficient water was added to bring it to field capacity (60% maximum water holding capacity). Then flasks were sealed. A control

was maintained. The CO₂ released was trapped in 0.5 N KOH and was quantified at periodic intervals by acid titration in the presence of phenolphthalein indicator. The amount of CO₂ produced was calculated using the formula given by Wilde *et al.* (1972). Results were expressed in mg/100 g of soil.

3.6 BIOMASS

The above ground biomass of different tree species was estimated by felling trees during the year 2002. Biomass was separately quantified for leaves, twigs and wood portions and expressed in t ha⁻¹.

3.7 STATISTICAL ANALYSIS

The data obtained from experiment were subjected to standard methods of statistical analysis as given by Snedecor and Cochran (1967) using in house built software package at computer centre, ANGRAU, Rajendranagar, Hyderabad.

RESULTS

CHAPTER IV

RESULTS

An investigation was carried out on “**Evaluation of different land use systems in carbon sequestration**” at Agro-forestry research unit, ANGRAU. As per the objectives laid down for this study, various parameters were analysed and the results obtained on each of the parameter are presented in this chapter.

4.1 MECHANICAL COMPOSITION AND MOISTURE CONTENT OF SOILS UNDER DIFFERENT LAND USE SYSTEMS

4.1.1 Mechanical Composition

It could be observed from data (Table 1) that sand content increased with increasing depth but silt and clay content, in general, decreased with increasing depth. The lowest sand content and highest clay content were recorded in soils under Agri-silviculture at all three depths as compared to other land use systems. Agri-silviculture (17.0%), Agri-silvi-horti system & *E. camuldulensis* (15.8%) and *E. camuldulensis* (15.4%) showed highest silt content at 0-15, 15-30 and 30-45cm soil depth respectively. Fallow land showed highest sand content and lowest silt and clay contents at all the three depths.

4.1.2 Soil Moisture Content

Soil moisture status under different land use systems at three different depths is presented in Table 1.

Table 1: Mechanical composition and moisture status in soils under different land use systems

S No	Land use systems	Sand (%)			Silt (%)			Clay (%)			Moisture content (%)		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
1	Fallow land	85.6	87.2	88.0	9.1	7.9	7.3	5.3	4.9	4.7	3.2	2.8	2.2
2	Agricultural land	76.2	77.8	78.3	12.5	11.9	11.8	11.3	10.3	9.9	4.1	3.3	2.8
3	Agri-silviculture	58.7	59.8	62.3	17.0	15.1	14.6	24.3	25.1	23.1	10.2	8.9	6.2
4	Silvi-pasture	61.4	63.2	64.1	14.6	14.2	13.8	24.0	22.6	22.1	9.8	7.7	5.9
5	Agri-Silvi-Horti System	62.3	63.8	65.4	16.1	15.8	15.1	21.6	20.4	19.5	8.7	7.4	5.7
6	<i>Eucalyptus camaldulensis</i>	66.2	66.9	68.2	15.2	15.8	15.4	18.6	17.3	16.4	8.6	8.1	5.8
7	<i>Leucaena leucocephala</i>	65.2	66.2	67.8	14.5	14.5	14.1	20.3	19.3	18.1	7.4	6	4.9
8	<i>Dendrocalamus strictus</i>	72.1	73.7	74.4	12.7	11.7	10.9	15.2	14.6	14.7	6.2	5.4	4.1
9	<i>Acacia albida</i>	66.4	67.9	68.7	15.6	14.8	14.5	18.0	17.3	16.8	6.8	5.7	3.9
10	<i>Azadirachta indica</i>	73.2	74.6	75.8	12	11.2	10	14.8	14.2	14.2	6.3	5.8	4.1
11	<i>Tectona grandis</i>	70.1	71.8	73.2	13.7	12.3	12.3	16.2	15.9	14.5	6.9	6.2	4.3
CD (P=0.05)		-	-	-	-	-	-	-	-	-	0.8	0.6	0.7

The data revealed that moisture content in soils under Agri-silviculture (10.2%) and Silvi-pasture (9.8%) was significantly higher than the remaining land use systems. Moisture content in fallow land (3.2%) was significantly lower when compared to other systems under study.

In 15-30cm soil layer, the highest (8.9%) and lowest (2.8%) moisture content were recorded under Agri-silviculture and fallow land. The soils under Agri-silviculture contained significantly higher moisture status than those of under remaining land use systems. However, the fallow land (2.8%) showed significantly lower moisture status compared to systems with vegetation of different nature.

In 30-45cm layer also moisture content was highest in soils under Agri-silviculture (6.2%) which was on par with status under Silvi-pasture (5.9%), *E. camuldulensis* (5.8%) and Agri-silvi-horti system (5.7%) and Soil moisture status was significantly lowest in fallow land (2.2%) which was on par with Agriculture land (2.8%).

4.2 pH AND ELECTRICAL CONDUCTIVITY OF SOILS UNDER DIFFERENT LAND USE SYSTEMS

4.2.1 pH

pH of soil recorded under various land use systems and at three different depths are presented in Table 2. The results indicated that at 0-15 cm depth, the values of pH recorded under Agri-silviculture (7.15) was

Table 2: pH and EC of soils under different land use systems

S.No.	Land use systems	pH			EC (dSm ⁻¹)		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
1	Fallow land	6.41	6.20	6.14	0.058	0.057	0.052
2	Agricultural land	6.53	6.44	6.30	0.062	0.060	0.058
3	Agri-silviculture	7.15	7.00	6.89	0.196	0.180	0.154
4	Silvi-pasture	6.90	6.73	6.68	0.179	0.162	0.149
5	Agri-Silvi-Horti System	7.01	6.95	6.74	0.186	0.168	0.151
6	<i>Eucalyptus camaldulensis</i>	6.63	6.52	6.43	0.174	0.166	0.150
7	<i>Leucaena leucocephala</i>	7.09	6.89	6.84	0.108	0.101	0.097
8	<i>Dendrocalamus strictus</i>	6.78	6.64	6.53	0.087	0.084	0.079
9	<i>Acacia albida</i>	6.83	6.76	6.65	0.121	0.109	0.097
10	<i>Azadirachta indica</i>	6.90	6.83	6.74	0.152	0.141	0.126
11	<i>Tectona grandis</i>	6.73	6.68	6.62	0.163	0.152	0.143
	CD (P=0.05)	0.29	0.31	0.26	0.027	0.024	0.026

highest, which was on par with values of pH in soils under *L. leucocephala* (7.09), Agri-silvi-horti system (7.01), Silvi-pasture (6.90), and *A. indica* (6.90). Fallow land (6.41) contained lowest pH which was significantly lower to other land use systems except *E. camuldulensis* (6.63) and Agricultural land (6.53) whose values were on par with fallow land.

At 15-30 cm soil layer, fallow land (6.20) contained lowest pH which was on par with Agricultural land (6.44). The pH of soils under Agri-silviculture (7.00) was highest which was on par with Agri-silvi-horti system (6.95), *L. leucocephala* (6.89), *A. indica* (6.83), *A. albida* (6.76) and Silvi-pasture (6.73). However, at 30-45 cm soil layer, the pH of soil under Agri-silviculture (6.89) recorded highest value which was on par with *L. leucocephala* (6.84), Agri-silvi-horti system (6.74), *A. indica* (6.74), Silvi-pasture (6.68), *A. albida* (6.65) and Fallow land (6.14) contained significantly lowest soil pH than other land use systems except Agricultural land (6.30) which was on par with fallow land.

4.2.2 Electrical Conductivity (dS m^{-1})

Data presented in Table 2 revealed that at 0-15 cm depth, the EC of soils under Agri-silviculture (0.196 dS m^{-1}) recorded significantly highest EC over the remaining land uses except Agri-silvi-horti system (0.186 dS m^{-1}), Silvi-pasture (0.179 dS m^{-1}), and *E. camuldulensis* (0.174 dS m^{-1}) whose values were on par with Agri-silviculture. The Electrical conductivity in fallow land (0.058 dS m^{-1}) was significantly lowest than remaining land use systems except Agricultural land (0.062 dS m^{-1})

where EC was on par with fallow land. An increase in EC by 0.138, 0.128, 0.121, 0.116, 0.105, 0.094, 0.063, 0.050 and 0.029 dS m⁻¹ were recorded under Agri-silviculture, Agri-silvi-horti system, Silvi-pasture, *E. camuldulensis*, *T. grandis*, *A. indica*, *A. albida*, *L. leucocephala* and *D. strictus* respectively over the fallow land.

At 15-30 cm depth, the EC of soils under Agri-silviculture (0.180 dS m⁻¹) showed significantly higher value compared to remaining land uses. Agri-silvi-horti system (0.168 dS m⁻¹), *E. camuldulensis* (0.166 dS m⁻¹) and Silvi-pasture (0.162 dS m⁻¹) were on par with Agri-silviculture. The EC in fallow land (0.057 dS m⁻¹) was significantly lower than remaining land uses except Agricultural land (0.060 dS m⁻¹) where it was on par with fallow land. The increase in soil EC by 0.123, 0.111, 0.109, 0.105, 0.095, 0.084, 0.052, 0.044 and 0.027 dS m⁻¹ under Agri-silviculture, Agri-silvi-horti system, *E. camuldulensis*, Silvi-pasture, *T. grandis*, *A. indica*, *A. albida*, *L. leucocephala* and *D. strictus* respectively, over the fallow land was recorded. Similarly at 30-45 cm depth of soil, the EC of soils under Agri-silviculture (0.154 dS m⁻¹) was significantly highest over the remaining land uses except in Agri-silvi-horti system (0.151 dS m⁻¹), *E. camuldulensis* (0.150 dS m⁻¹), Silvi-pasture (0.149 dS m⁻¹) and *T. grandis* (0.143 dS m⁻¹) where the EC was on par with values recorded under Agri-silviculture. The EC in fallow land (0.052 dS m⁻¹) was significantly lowest than remaining land use systems except in Agricultural land (0.058 dS m⁻¹) where it was on par with that of fallow

land. The EC recorded in different land use systems varied significantly and they were higher than under fallow land and were in the following order: Agri-silviculture (0.102 dS m^{-1}) > Agri-silvi-horti system (0.099 dS m^{-1}) > *E. camuldulensis* (0.098 dS m^{-1}) > Silvi-pasture (0.097 dS m^{-1}) > *T. grandis* (0.091 dS m^{-1}) > *A. indica* (0.074 dS m^{-1}) > *L. leucocephala* (0.045 dS m^{-1}) > *A. albida* (0.045 dS m^{-1}) > *D. strictus* (0.027 dS m^{-1}). In general, it was observed that the EC under different land use systems decreased with increase in depth.

4.3 ORGANIC CARBON STATUS, ORGANIC CARBON/UNIT AREA AND MITIGATION POTENTIAL IN SOILS UNDER DIFFERENT LAND USE SYSTEMS

Mean values of Soil Organic Carbon (SOC) are presented in Table 3 and Fig.1. The results revealed that, in general, the SOC decreased with increase in depth in all the systems. Further, it was seen that at 0-15 cm soil depth, SOC was high in all the systems except those of Agricultural land (0.42%) and fallow land (0.21%). Among different land use systems higher status of SOC was recorded under Agri-silviculture (0.89%) followed by Silvi-pasture (0.76%), Agri-silvi-horti system (0.72%), *L. leucocephala* (0.68%), *A. albida* (0.68%), *E. camuldulensis* (0.59%), *T. grandis* (0.56%), *D. strictus* (0.52%), *A. indica* (0.51%) and Agricultural land (0.42%). Fallow land, however, recorded minimum value for soil organic carbon (0.21%).

Table 3: Organic carbon (%), soil organic carbon/unit area and mitigation potential of different land use systems

S.No.	Land use systems	Soil organic carbon (%)				Soil organic carbon (t ha ⁻¹)		Carbon mitigation potential
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	0-15 cm	0-15 cm	
1	Fallow land	0.21	0.20	0.18	4.70		1	
2	Agricultural land	0.42	0.38	0.34	9.40		2	
3	Agri-silviculture	0.89	0.76	0.68	19.93		4.23	
4	Silvi-pasture	0.76	0.71	0.63	17.47		3.71	
5	Agri-Silvi-Horti System	0.72	0.70	0.64	17.02		3.42	
6	<i>Eucalyptus camaldulensis</i>	0.59	0.49	0.42	13.22		2.80	
7	<i>Leucaena leucocephala</i>	0.68	0.66	0.59	15.68		3.23	
8	<i>Dendrocalamus strictus</i>	0.52	0.49	0.42	11.65		2.47	
9	<i>Acacia albida</i>	0.68	0.58	0.52	15.23		3.23	
10	<i>Azadirachta indica</i>	0.51	0.46	0.41	11.43		2.42	
11	<i>Tectona grandis</i>	0.56	0.50	0.44	12.54		2.66	
	CD (P=0.05)	0.10	0.09	0.08	-		-	

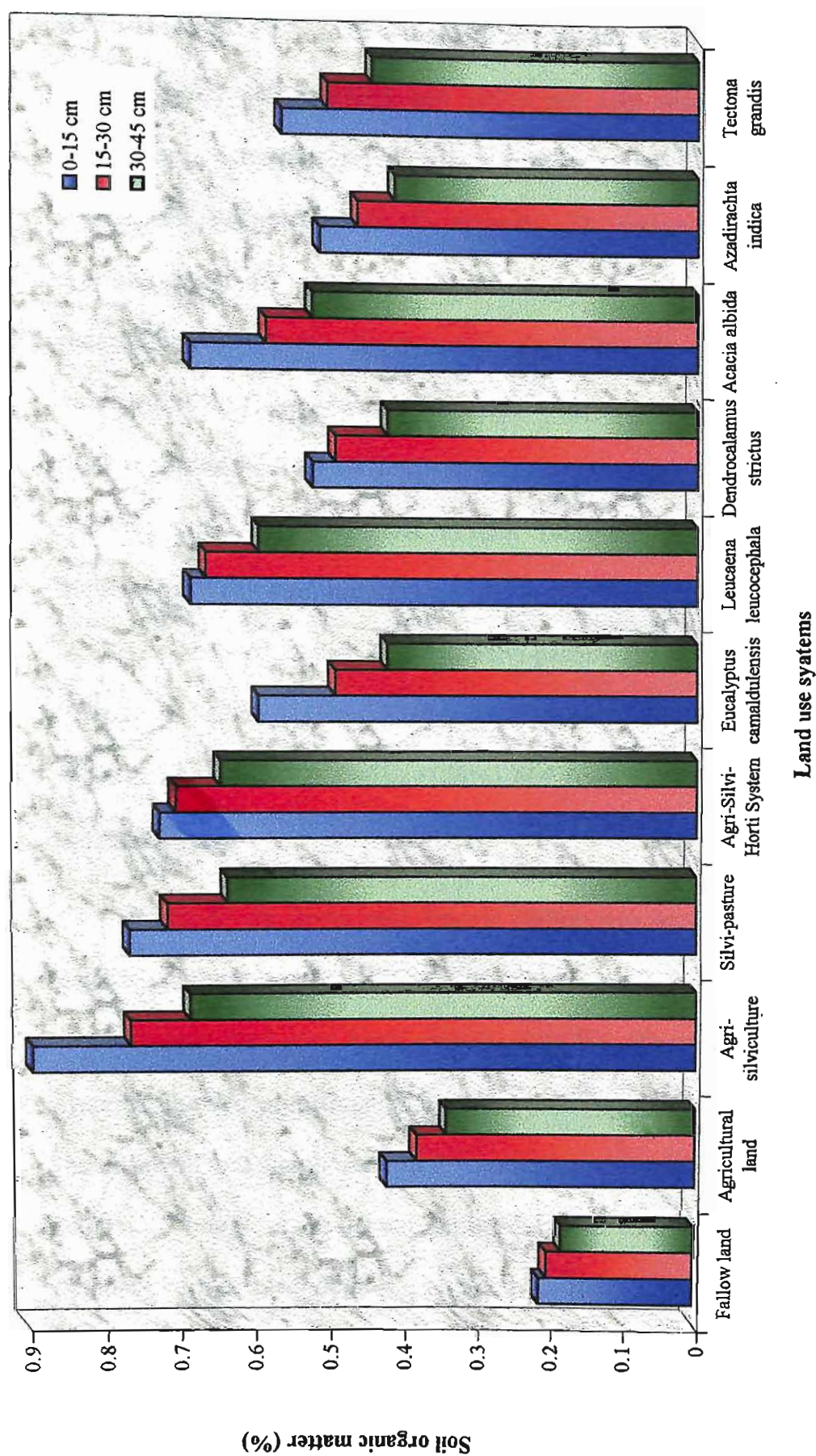


Fig. 1 Organic carbon status of different land use systems

The results presented in the Table 3 further showed that there was an increase of SOC to the tune of 323.8, 261.9, 242.0, 223.8, 223.8, 180.9, 166.6, 147.6, 142.8 and 100.0 per cent respectively in Agri-silviculture, Silvi-pasture, Agri-silvi-horti system, *L. leucocephala*, *A. albida*, *E. camuldulensis*, *T. grandis*, *D. strictus*, *A. indica* and Agricultural land over the fallow land. Similar results were also recorded at 15-30 cm depth, while Agri-silviculture showed highest value (0.76%), lowest was associated with fallow land (0.20%). The SOC recorded in Agri-silviculture was on par with that of Silvi-pasture (0.71%) and Agri-silvi-horti system (0.70%). It was noticed that increase in SOC was maximum with Agri-silviculture (280%) followed by Agri-silvi-horti system (255%), Silvi-pasture (250%), *L. leucocephala* (230%), *A. albida* (190%), *T. grandis* (150%), *E. camuldulensis* (145%), *D. strictus* (145%), *A. indica* (130%) and Agricultural land (90%) over the fallow land.

In 30-45 cm layer, soil organic carbon was highest in soils under Agri-silviculture system (0.68%) which was on par with Silvi-pasture (0.63%) and Agri-silvi-horti system (0.64%). However, all land use systems showed significantly superior soil organic carbon status over the fallow land which recorded lowest value for soil organic carbon (0.20%). Though at 30-45 cm depth, the SOC recorded was lowest as compared to surface depths, the trend noticed at 0-15 and 15-30 cm

depth was maintained with regard to superiority of Agri-silviculture system over other systems.

The magnitude of increase of SOC over fallow land recorded with different land use systems was of the order: Agri-silviculture (277.7%) > Agri-silvi-horti system (255.5%) > Silvi-pasture (250.0%) > *L. leucocephala* (227.7%) > *A. albida* (188.8%) > *T. grandis* (144.4%) > *E. camuldulensis* (133.3%) > *D. strictus* (133.33%) > *A. indica* (127.0%) > Agricultural land (88.8%).

Soil organic carbon status (t ha^{-1}) and CO_2 mitigation potential of different land uses were evaluated and are presented in Table 3. Soil organic carbon status was highest in Agri-silviculture system (19.93 t ha^{-1}) which was followed by Silvi-pasture (17.47 t ha^{-1}), Agri-silvi-horti system (17.02 t ha^{-1}), *L. leucocephala* (15.68 t ha^{-1}), *A. albida* (15.23 t ha^{-1}), *E. camuldulensis* (13.22 t ha^{-1}), *T. grandis* (12.54 t ha^{-1}), *D. strictus* (11.65 t ha^{-1}), *A. indica* (11.43 t ha^{-1}), Agricultural land (9.40 t ha^{-1}) and least was in fallow land (4.70 t ha^{-1}). The carbon mitigation potential of fallow land was assumed as 1. At 0-15 depth Agri-silviculture (4.23) showed best mitigation potential which was followed by Silvi-pasture (3.71), Agri-silvi-horti system (3.42), *L. leucocephala* (3.27), *A. albida* (3.23), *E. camuldulensis* (2.80), *T. grandis* (2.66), *D. strictus* (2.47), *A. indica* (2.42) and Agricultural land (2.00).

4.4 CHEMICAL PROPERTIES OF SOILS UNDER DIFFERENT LAND USE SYSTEMS

4.4.1 Total Nitrogen (%)

The total nitrogen (%) of soils under different land use systems was assessed and the results obtained are presented in Table 4. As seen from the data, the total nitrogen contents ranged from 0.021 to 0.076 per cent, lowest and highest being recorded under fallow and Agri-silviculture systems respectively at 0-15 cm depth. So also at 15-30 and 30-45 cm depths, the total nitrogen contents were high in soil with Agri-silviculture system and lowest in fallow land. At 15-30 cm depth the content was 0.07 in Agri-silviculture and the lowest being in fallow land (0.017%).

It was also observed that the total nitrogen content of soils was superior by 261.9, 219.0, 209.5, 195.2, 176.1, 157.1, 142.8, 123.8, 109.5 and 85.7 per cent under Agri-silviculture, Silvi-pasture system, Agri-silvi-horti system, *L. leucocephala*, *D. strictus*, *A. albida*, *E. camuldulensis*, *T. grandis*, *A. indica* and Agricultural land, respectively over the fallow land.

The trend of total nitrogen contents at lower depths (15-30 cm) was akin to surface layers as it showed that fallow land contained lower value of 0.017 per cent while maximum was in Agri-silviculture system (0.071%). The improvement in total nitrogen status over fallow land was to an extent of 317.6, 276.4, 264.7, 229.4, 211.7, 188.2, 147.0, 141.0,

Table 4: Total (%) and available nitrogen (kg ha⁻¹) content of soils under different land use systems

S.No.	Land use systems	Total nitrogen (%)			Available nitrogen (kg ha ⁻¹)		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
1	Fallow land	0.021	0.017	0.016	109.7	106.6	98.3
2	Agricultural land	0.039	0.036	0.032	138	125.4	116
3	Agri-silviculture	0.076	0.071	0.064	272.8	248.1	222.4
4	Silvi-pasture	0.067	0.064	0.061	231.4	215.3	206.1
5	Agri-Silvi-Horti System	0.065	0.062	0.057	256.7	236.5	207.4
6	<i>Eucalyptus camaldulensis</i>	0.051	0.042	0.037	191.1	183.8	168.6
7	<i>Leucaena leucocephala</i>	0.062	0.056	0.052	248.2	239.6	220.3
8	<i>Dendrocalamus strictus</i>	0.058	0.053	0.048	178.3	169.9	139.3
9	<i>Acacia albida</i>	0.054	0.049	0.044	189.2	175.6	156.8
10	<i>Azadirachta indica</i>	0.044	0.04	0.035	165.2	152.8	142.5
11	<i>Tectona grandis</i>	0.047	0.041	0.039	173.1	165	150.2
	CD (P=0.05)	0.008	0.010	0.012	12.3	9.1	8.6

135.2 and 111.7 per cent under Agri-silviculture, Silvi-pasture system, Agri-silvi-horti system, *L. leucocephala*, *D. strictus*, *A. albida*, *E. camuldulensis*, *T. grandis*, *A. indica*, and Agricultural land respectively over the fallow land.

At 30-45 cm depth also, total nitrogen content was highest in soils under Agri-silviculture (0.064%) which was significantly superior to other land use systems except Silvi-pasture (0.061%), Agri-silvi-horti system (0.057%) and *L. leucocephala* (0.052%) which recorded values on par with Agri-silviculture and there was an improvement of total nitrogen by 300.0, 281.2, 256.2, 225.0, 200.0, 175.0, 143.7, 131.2, 118.7 and 100.0 per cent in soils under Agri-silviculture, Silvi-pasture, Agri-silvi-horti system, *L. leucocephala*, *D. strictus*, *A. albida*, *T. grandis*, *E. camuldulensis*, *A. indica* and Agricultural land respectively over the fallow land. In general, total nitrogen content decreased with increase in depth of soil.

4.4.2 Available Nitrogen (kg ha^{-1})

Results presented in Table 4 indicated decrease in available nitrogen status with the increase in depth in all the land use systems. At 0-15 cm depth, Agri-silviculture recorded highest value for available nitrogen (272.8 kg ha^{-1}) which was significantly superior to other systems while fallow land showed the minimum value for available nitrogen i.e. 109.7 kg ha^{-1} . The increase in available nitrogen status was

148.6, 134.0, 126.2, 110.9, 74.2, 72.4, 62.5, 57.7, 50.5 and 25.7 per cent in soils under Agri-silviculture, Agri-silvi-horti system, *L. leucocephala*, Silvi-pasture, *E. camuldulensis*, *A. albida*, *D. strictus*, *T. grandis*, *A. indica* and Agricultural land systems respectively over fallow land.

At 15-30cm layer, Agri-silviculture showed highest value for available nitrogen (248.1 kg ha⁻¹) which was on par with the values under *L. leucocephala* plantation (239.6 kg ha⁻¹). In the other land use systems, there was significant improvement in available nitrogen over the fallow land which showed lowest available nitrogen content (106.6 kg ha⁻¹). The improvement in content of available nitrogen was by 132.7, 124.7, 121.8, 101.9, 72.4, 64.7, 59.3, 55.3, 43.3 and 17.6 per cent in soils under Agri-silviculture, *L. leucocephala*, Agri-silvi-horti system, Silvi-pasture, *E. camuldulensis*, *A. albida*, Bamboo, *T. grandis*, *A. indica* and Agricultural land respectively over the fallow land.

At the lower depth i.e. at 30-45 cm of soil, all the land use systems were significantly superior over fallow land (98.3 kg ha⁻¹) for available nitrogen. Agri-silviculture showed highest value for available nitrogen (222.4 kg ha⁻¹) which was on par with the values of available nitrogen of soils under *L. leucocephala* plantation (220.3 kg ha⁻¹). However, Agri-silviculture was significantly superior over all the land use systems except *L. leucocephala*. There was an increase in available nitrogen status by 126.7, 124.1, 110.9, 109.6, 71.5, 59.5, 52.7, 45.1, 41.7

and 18.0 per cent in soils under Agri-silviculture, *L. leucocephala*, Agri-silvi-horti system, Silvi-pasture, *E. camuldulensis*, *A. albida*, *T. grandis*, *A. indica*, *D. strictus* and agricultural land respectively over fallow land.

4.4.3 Total phosphorus (mg kg^{-1})

Total phosphorus of soils under different land use systems at three different depths are presented in Table 5.

In 0-15 cm soil layer, total phosphorus was significantly higher in Agri-silviculture system (356 mg kg^{-1}) *vis-à-vis* other systems and it was also seen that Fallow land recorded lowest total phosphorus content (186 mg kg^{-1}) which was significantly lower to the remaining land use systems. An increase in total phosphorus was noticed in Agri-silviculture (91.4%), Silvi-pasture (59.1%), Agri-silvi-horti system (54.3%), *L. leucocephala* (37.6%) *A. albida* (32.7%), *T. indica* (24.7%), Agricultural land (19.8%), *E. camuldulensis* (18.8%) *A. indica* (17.2%), *D. strictus* (16.1%) respectively over the fallow land.

In 15-30 cm layer, Agri-silviculture (323 mg kg^{-1}) was significantly superior for soil phosphorus content when compared to the remaining land uses. Of the different land uses, fallow land showed lowest total phosphorus content of 162 mg kg^{-1} which was significantly lower to the remaining land use systems. Total phosphorus showed an increase of 87.7 per cent, 56.3, 44.1, 31.9, 30.2, 25.5, 22.18, 13.9 and 9.8 per cent under Agri-silviculture, Silvi-pasture, Agri-silvi-horti

Table 5: Total (mg kg^{-1}) and available phosphorus (kg ha^{-1}) content of soils under different land use systems

S.No.	Land use systems	Total phosphorus (mg kg^{-1})			Available phosphorus (kg ha^{-1})		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
1	Fallow land	186	162	158	8.9	7.8	7.1
2	Agricultural land	223	210	179	12	11.4	10.7
3	Agri-silviculture	356	323	292	25.3	22.7	19.2
4	Silvi-pasture	296	269	214	18.5	15.6	12.6
5	Agri-Silvi-Horti System	287	248	231	21.5	18.2	15.9
6	<i>Eucalyptus camaldulensis</i>	221	203	189	14.4	13.3	12.3
7	<i>Leucaena leucocephala</i>	256	227	212	23.3	21	17.3
8	<i>Dendrocalamus strictus</i>	216	189	173	11.7	9.7	8.9
9	<i>Acacia albida</i>	245	224	204	20.8	17.9	15.1
10	<i>Azadirachta indica</i>	218	196	178	13.8	12.3	10.5
11	<i>Tectona grandis</i>	232	216	196	10.1	9.3	8.8
	CD ($P=0.05$)	23	16	14	3.7	3.2	2.7

systems, *L. leucocephala*, *A. albida*, *T. indica*, Agricultural land, *E. camuldulensis*, *A. indica*, *D. strictus* respectively over the fallow land.

Similarly, at 30-45 cm soil depth, when different land use systems were evaluated for phosphorus status, Agri-silviculture (292 mg kg⁻¹) showed significant superiority over the remaining land use systems. An improvement of total phosphorus over the fallow land was of the order of: Agri-silviculture (84.8%) > Agri-silvi-horti system (46.2%) > Silvi-pasture (35.4%) > *L. leucocephala* (34.1%) > *A. albida* (29.1%) > *T. indica* (24.0%) > *E. camuldulensis* (19.6%) > Agricultural land (13.2 %) > *A. indica* (12.6%). *D. strictus* (9.4%) respectively.

4.4.4 Available phosphorus (kg ha⁻¹)

Similar to the status of total phosphorus, with respect to available P₂O₅ also, it was noticed from the data (Table 5) that the available phosphorus status was in general decreasing with depth of soil. Different land use systems when evaluated for available P₂O₅ status, Agri-silviculture showed significant superiority at all three depths (0-15, 15-30 and 30-45cm) recording 25.3, 22.7 and 19.2 kg P₂O₅ ha⁻¹ respectively. It was followed by *L. leucocephala*, Agri-silvi-horti system, *A. albida*, Silvi-pasture, *E. camuldulensis*, *A. indica*, Agricultural land, *D. strictus*, and *T. grandis*. Fallow land showed significantly inferior status over all the land uses recording values of 8.9, 7.8 and 7.1 kg P₂O₅ respectively at

0-15cm, 15-30cm and 30-45cm depth of soil. The results also revealed that at all three depths, Agri-silviculture and *L. leucocephala* showed significantly equal values for available P_2O_5 . Similarly, the values recorded by Agricultural land (11.7 kg ha^{-1}), *D. strictus* (11.7 kg ha^{-1}) and *T. grandis* (10.1 kg ha^{-1}) were on par with fallow land (8.9 kg ha^{-1}) at 0-15cm depth and so also at 15-30 cm depth of soil.

At 0-15cm depth, the improvement of available phosphorus content over the fallow land was found to be in the order: Agri-silviculture (184.2%), *L. leucocephala* (23.3%), Agri-silvi-horti system (141.5%), *A. albida* (133.7%), Silvi-pasture (107.8%), *E. camuldulensis* (61.7%) and *A. indica* (13.8%).

At 15-30cm soil depth, it was observed that there was an improvement of available phosphorus by 191, 169.2, 133.3, 129.4, 100.0, 70.5, 57.6, and 46.1 per cent in soils under Agri-silviculture, *L. leucocephala*, Agri-silvi-horti system, *A. albida*, *E. camuldulensis*, *A. indica* and agricultural land over the fallow land.

At 30-45cm soil depth, it was evident from data that there was an improvement of available phosphorus content by 170.4, 143.6, 123.9, 112.6, 77.4, 73.4, 50.7 and 47.8 per cent in soils under Agri-silviculture, *L. leucocephala*, Agri-silvi-horti system, *A. albida*, Silvi-pasture, *E. camuldulensis*, Agricultural land and *A. indica* respectively over the fallow land.

4.4.5 Total Potassium (mg kg^{-1})

Results indicated that the total potassium content (Table 6) in soils under different land use systems, in general, was decreasing with increase in depth. It was evident from the data that for total potassium status, Agri-silviculture showed significant superiority at all the three depths (0-15, 15-30 and 30-45 cm) recording 4653, 4420 and 4139 mg kg^{-1} , respectively. It was followed by Agri-silvi-horti system, Silvi-pasture, *L. leucocephala*, *A. albida*, *E. camuldulensis*, *T. grandis*, *D. strictus*, *A. indica* and Agricultural land. Fallow land showed significantly inferior status over all the three land uses recording values of 1812, 1729 and 1648 mg kg^{-1} , respectively at 0-15, 15-30 and 30-45 cm depths of soil.

At 0-15cm soil depth, Agri-silviculture, Agri-silvi-horti system, Silvi-pasture, *L. leucocephala*, *A. albida*, *E. camuldulensis*, *T. grandis*, *D. strictus*, *A. indica* and Agricultural land showed significantly higher total potassium content i.e. 156.7, 143.0, 137.3, 101.3, 53.4, 46.4, 42.3, 25.8 and 15.7 per cent, respectively than the fallow land.

At 15-30cm soil depth, the percentage of improvement for total potassium over the fallow land was of the order of Agri-silviculture (155.6), Agri-silvi-horti system (143.4), Silvi-pasture (136.6), *L. leucocephala* (97.8), *A. albida* (41.4), *E. camuldulensis* (36.7), *T. grandis* (23.3), *D. strictus* (18.4), *A. indica* (11.7) and Agricultural land (10.6).

Table 6: Total (mg kg^{-1}) and available potassium (kg ha^{-1}) content of soils under different land use systems

S.No.	Land use systems	Total potassium (mg kg^{-1})				Available potassium (kg ha^{-1})		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	
1	Fallow land	1812	1729	1648	116.2	98.2	87.4	
2	Agricultural land	2281	2048	1913	139.2	102.4	118.8	
3	Agri-silviculture	4653	4420	4139	276.8	238.5	196	
4	Silvi-pasture	4300	4092	3896	245.6	215.7	180.5	
5	Agri-Silvi-Horti System	4404	4209	3936	259.8	221.3	187.9	
6	<i>Eucalyptus camaldulensis</i>	2746	1932	1826	242	206.3	172.3	
7	<i>Leucaena leucocephala</i>	3644	3421	3210	245.2	212.8	176.1	
8	<i>Dendrocalamus strictus</i>	2653	2132	1932	218.2	176.9	123.2	
9	<i>Acacia albida</i>	2781	2365	2067	247	210.8	168.4	
10	<i>Azadirachta indica</i>	2097	1913	1861	179.2	162.4	128.8	
11	<i>Tectona grandis</i>	2579	2446	2162	204.5	168.2	136.8	
	CD (P=0.05)	174	142	163	14.5	8.9	12.3	

The improvement in total potassium over the fallow land, at 30-45cm soil depth, followed the trend of Agri-silviculture (151.1%), Agri-silvi-horti system (138.8%), Silvi-pasture (136.4%), *L. leucocephala* (94.7%), *A. albida* (31.1%), *E. camuldulensis* (25.4%), *T. grandis* (17.2%), *D. strictus* (140.9%), *A. indica* (12.9%) and Agricultural land (10.8%).

4.4.6 Available Potassium (kg ha^{-1})

It was evident from the data presented in Table 6 that available potassium status was in general, decreasing with depth of soil. Different land use systems when evaluated for available potassium status, Agri-silvi culture showed significant superiority at 0-15 and 15-30cm soil depth recording 276.8, and 238.5 kg ha^{-1} , respectively but at 30-45cm soil depth Agri-silviculture (196.0 kg ha^{-1}) showed on par results with Agri-silvi-horti system (187.9 kg ha^{-1}). Fallow land showed significantly inferior status for available potassium over other land use systems recording values of 116.2, and 87.4 kg ha^{-1} respectively at 0-15 and 30-45cm soil depths but at 15-30cm soil depth fallow land (98.2 kg ha^{-1}) showed values on par with agricultural land (102.4 kg ha^{-1}). At 0-15cm soil depth, the improvement over the fallow land for available potassium followed the order of: Agri-silviculture (138.2%), Agri-silvi-horti system (123.5%), *A. albida* (112.5%), Silvi-pasture (111.3%), *L. leucocephala* (111%),

E. camuldulensis (108.2%), *D. strictus* (87.7%), *T. grandis* (75.9%), *A. indica* (54.2%) and Agricultural land (19.7%).

At 15-30cm soil depth, there was increase in available potassium status over the fallow land amounting to 142.8, 125.3, 119.6, 116.7, 114.6, 110.0, 80.1, 71.2 and 65.3 per cent, respectively under Agri-silviculture, Agri-silvi-horti system, Silvi-pasture, *L. leucocephala*, *A. albida*, *E. camuldulensis*, *D. strictus*, *T. grandis* and *A. indica*.

The percentage increase in available potassium at 30-45cm soil depth was 124.2, 114.1, 106.5, 101.4, 97.1, 92.6, 56.5, 47.3, 40.9 and 35.9 per cent respectively under Agri-silviculture, Agri-silvi-horti system, Silvi pasture, *L. leucocephala*, *E. camuldulensis*, *A. albida*, *T. grandis*, *A. indica*, *D. strictus* and Agricultural land over the fallow land.

4.4.7 Exchangeable Calcium [$\text{c mol (p}^+) \text{ kg}^{-1}$]

Results showed that exchangeable calcium status (Table 7) was, in general, decreased with increasing depth except in Agri-silvi-horti system which showed increasing trend of exchangeable Mg with increasing depth. Different land use systems, when evaluated for exchangeable calcium status, Agri-silviculture showed significant superiority at all three depths (0-15, 15-30 and 30-45cm) recording 7.49, 7.46 and 7.23 $\text{c mol (p}^+) \text{ kg calcium ha}^{-1}$ respectively. It was followed by Silvi-pasture, *T. grandis*, Agri-silvi-horti system, *L. leucocephala*,

E. camuldulensis, *A. indica*, *A. albida*, *D. strictus* and Agricultural land. Fallow land contained significantly inferior status of exchangeable calcium over all the land use systems recording values of 1.92, 1.80, 1.70 c mol (p^+) kg at 0-15, 15-30 and 30-45cm depths of soil. At 0-15cm depth per cent improvement of exchangeable calcium over the fallow land was by 290.1, 215.6, 211.4, 181.2, 169.7, 157.2, 123.9, 97.9, 97.9 and 46.8 respectively in soils under Agri-silviculture, Silvi-pasture, *T. grandis*, Agri-silvi-horti system, *L. leucocephala*, *E. camuldulensis*, *A. indica*, *A. albida*, *D. strictus* and Agricultural land.

At 15-30 cm soil depth, Agri-silviculture, Silvi-pasture, *T. grandis*, Agri-silvi-horti system, *L. leucocephala*, *E. camuldulensis*, *A. indica*, *A. albida*, *D. strictus* and Agricultural land showed an increase of exchangeable calcium by 314.4, 228.3, 223.3, 211.1, 183.3, 161.1, 130.5, 102.2, 95.5 and 44.4 per cent respectively over the fallow land.

At 30-45cm soil depth, the increase in exchangeable calcium was by 325.2, 242.3, 221.1, 194.1, 155.8, 144.7, 131.1, 111.1, 90.0 and 23.5 per cent in soils under Agri-silviculture, Silvi-pasture, *T. grandis*, Agri-silvi-horti system, *L. leucocephala*, *E. camuldulensis*, *A. indica*, *A. albida*, *D. strictus* and Agricultural land, respectively over fallow land.

Table 7 Exchangeable Ca and Mg [c mol (p⁺) kg⁻¹] content of soils under different land use systems

S.No.	Land use systems	Exchangeable Ca			Exchangeable Mg		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
1	Fallow land	1.92	1.80	1.70	1.10	1.01	0.90
2	Agricultural land	2.82	2.60	2.10	1.20	1.10	0.91
3	Agri-silviculture	7.49	7.46	7.23	4.52	4.21	4.20
4	Silvi-pasture	6.06	5.91	5.46	3.20	2.80	2.32
5	Agri-Silvi-Horti System	5.40	5.60	5.82	2.90	2.10	2.04
6	<i>Eucalyptus camaldulensis</i>	4.94	4.70	3.93	2.03	1.93	1.90
7	<i>Leucaena leucocephala</i>	5.18	5.10	4.35	2.72	2.10	2.00
8	<i>Dendrocalamus strictus</i>	3.80	3.52	3.23	1.98	1.72	1.46
9	<i>Acacia albida</i>	3.80	3.64	3.59	1.22	1.10	1.10
10	<i>Azadirachta indica</i>	4.30	4.15	4.16	1.80	2.00	2.20
11	<i>Tectona grandis</i>	5.98	5.82	5.00	1.74	1.72	1.20
	CD (P=0.05)	0.52	0.43	0.39	0.22	0.20	0.18

4.4.8 Exchangeable Magnesium [$\text{c mol (p}^+) \text{ kg}^{-1}$]

Exchangeable magnesium in soils under different land use systems at all the three depths are presented in Table 7. In 0-15cm soil layer, exchangeable magnesium in fallow land was found to be significantly less i.e. $1.10 \text{ c mol (p}^+) \text{ kg}^{-1}$. Agri-silviculture [$4.52 \text{ c mol (p}^+) \text{ kg}^{-1}$] was found to be superior over the remaining land uses for exchangeable magnesium.

In 15-30cm soil layer, exchangeable magnesium was found to be lowest in fallow land [$1.01 \text{ c mol (p}^+) \text{ kg}^{-1}$] which was on par with results of Agricultural land [$1.10 \text{ c mol (p}^+) \text{ kg}^{-1}$] and *A. albida* [$1.10 \text{ c mol (p}^+) \text{ kg}^{-1}$]. Exchangeable magnesium was found to be significantly higher in Agri-silviculture [$4.21 \text{ c mol (p}^+) \text{ kg}^{-1}$] compared to the remaining land use systems.

In 30-45cm soil layer, exchangeable magnesium was highest in Agri-silviculture [$4.20 \text{ c mol (p}^+) \text{ kg}^{-1}$] which was found to be superior over the remaining land uses. However, fallow land [$0.90 \text{ c mol (p}^+) \text{ kg}^{-1}$] and agricultural land [$0.91 \text{ c mol (p}^+) \text{ kg}^{-1}$] was found to contain significantly lower values of exchangeable magnesium when compared to remaining land use systems. Exchangeable magnesium was decreasing with depth of soil under different land use systems.

4.5 CARBON CONTENT, BIOMASS AND QUANTITY OF SEQUESTERED CARBON CONTENT IN TREE SPECIES OF DIFFERENT LAND USE SYSTEMS

Carbon content in leaves, twigs and wood + bark individually and composite sample of different tree species and quantity of sequestered carbon content are presented in the Table 8.

4.5.1 Leaves

A. lebbeck (47.7%) contained significantly higher carbon which was on par with *L. leucocephala* (46.23%) and *A. albida* (46.16%) and it was followed by *E. camuldulensis* (45.06%), *T. grandis* (44.69%), *D. strictus* (43.18%), *A. indica* (43.16%), *A. nilotica* (42.54%) and minimum being present in *T. indica* (40.65%).

4.5.2 Twigs

Similarly in twigs of tree species, *A. lebbeck* (46.58%) contained significantly superior carbon content than remaining tree species and lowest carbon was present in *T. indica* (39.02%) which was on par with carbon content of *A. nilotica* twigs (40.12%).

4.5.3 Wood + bark

As in the case of leaves and twigs, in wood also, *A. lebbeck* (43.25%) contained significantly higher carbon which was on par with *L. leucocephala* (43.09%), *E. camuldulensis* (42.12%), *T. grandis* (41.52%), *A. albida* (41.43%). Significantly lower value of carbon was present in *T. indica* (38.21%) which was on par with that of *A. nilotica* (39.92%).

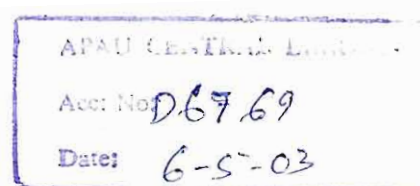


Table 8: Carbon content, biomass and quantity of sequestered carbon in different land use systems

SNo	Land use system	Age	Carbon content (%)			C Sequestered for unit quantity of biomass (kg/kg of biomass)	Biomass (t ha ⁻¹)	Net primary productivity (t ha ⁻¹ yr ⁻¹)	Carbon sequestration (t ha ⁻¹ yr ⁻¹)	
			Leaf	Twig	Wood + bark					Mean
1	<i>Albizia lebbeck</i> (Agri-silviculture)	9	47.70	46.58	43.25	45.84	0.458	58.75	6.52	2.98
2	<i>Acacia nilotica</i> (Silvi-pasture)	9	42.54	40.12	39.92	40.86	0.409	15.40	1.71	0.69
3	<i>Tamarindus indica</i> (Agri-silvi-horti system)	13	40.65	39.02	38.21	39.29	0.393	14.80	1.14	0.44
4	<i>Lueceana leucocephala</i>	13	46.23	44.14	43.09	44.48	0.445	204.60	15.74	7.00
5	<i>Acacia albida</i>	13	46.16	43.82	41.43	43.80	0.438	25.40	1.95	0.85
6	<i>Eucalyptus camaldulensis</i>	13	45.06	43.28	42.12	43.48	0.435	160.20	12.32	5.35
7	<i>Azadirachta indica</i>	13	43.16	41.43	40.94	41.84	0.418	24.90	1.92	0.80
8	<i>Tectona grandis</i>	13	44.69	43.22	41.52	43.14	0.431	21.60	1.66	0.71
9	<i>Dendrocalamus strictus</i>	13	43.18	42.66	40.36	42.06	0.421	22.30	1.72	0.72
CD (P=0.05)			2.26	2.14	1.93	-	-	-	-	-

Composite sample carbon content was highest in *A. lebbeck* (45.84%) which was followed by *L. leucocephala* (44.48%), *A. albida* (43.80%), *E. camuldulensis* (43.48%), *T. grandis* (43.14%), *D. strictus* (42.06%), *A. indica* (41.84%), *A. nilotica* (40.86%), and minimum being in *T. indica* (39.29%).

4.5.4 Biomass

Total biomass of above ground biomass of different tress species are presented in Table 8. The results showed that higher biomass was associated with *L. leucocephala* (204.60 t ha⁻¹) which was followed by *E. camuldulensis* (160.20 t ha⁻¹), *A. lebbeck* (58.75 t ha⁻¹).

4.5.5 Carbon sequestered per kg of biomass

Sequestered carbon content was highest in *A. lebbeck* (0.458 kg/kg of biomass) which was followed by *L. leucocephala* (0.445 kg/kg of biomass), *A. albida* (0.438 kg/kg of biomass), *E. camuldulensis* (0.435 kg/kg of biomass), *T. grandis* (0.431 kg/kg of biomass), *D. strictus* (0.421 kg/kg of biomass), *A. indica* (0.418 kg/kg of biomass), *A. nilotica* (0.409 kg/kg of biomass) and minimum being in *T. indica* (0.393 kg/kg of biomass).

4.5.6 Net primary productivity and carbon sequestration

Net-primary productivity (NPP) and carbon sequestration by different trees are presented in Table 8. NPP was derived by dividing biomass and age of respective tree species and carbon sequestration was

calculated from NPP. It was found that highest NPP was associated with *L. leucocephala* ($15.74 \text{ t ha}^{-1} \text{ yr}^{-1}$) which was followed by *E. camuldulensis* ($12.32 \text{ t ha}^{-1} \text{ yr}^{-1}$), *A. lebbeck* ($6.52 \text{ t ha}^{-1} \text{ yr}^{-1}$) etc. and least was in *T. indica* ($1.14 \text{ t ha}^{-1} \text{ yr}^{-1}$). Similarly carbon sequestration was found to be highest in *L. leucocephala* ($7.00 \text{ t ha}^{-1} \text{ yr}^{-1}$) which was followed by *E. camuldulensis* ($5.35 \text{ t ha}^{-1} \text{ yr}^{-1}$), *A. lebbeck* ($2.98 \text{ t ha}^{-1} \text{ yr}^{-1}$) and remaining tree species showed less carbon sequestration i.e. less than $1.00 \text{ t ha}^{-1} \text{ yr}^{-1}$.

4.6 INCUBATION STUDIES

The results obtained from the incubation studies conducted to assess the rate of decomposition of tree leaves by indirectly measuring CO_2 release are presented in Table 9.

The results revealed that release of CO_2 from control soil without tree leaves was significantly lower at all periods of incubation. Among different tree leaves incubated, the cumulative CO_2 release from *A. lebbeck* at 7.5 t ha^{-1} was significantly higher at 5, 10, 30, 45 and 60 days of incubation recording the values of 16.9, 36.8, 78.4, 99.4 and 115.4 mg/100 g of soil, respectively. But at 5, 10 and 30 days of incubation *A. lebbeck* at 7.5 t ha^{-1} showed on par results with *L. leucocephala* at 7.5 t ha^{-1} , *A. albida* at 7.5 t ha^{-1} and also with *A. lebbeck* 7.5 t ha^{-1} at 45 and 60 days of incubation. Among different tree leaves, *E. camuldulensis* at 5 t ha^{-1} recorded lowest value for cumulative CO_2 release at 5, 10, 30, 45 and 60 days of incubation

Table 9: CO₂ release (mg kg⁻¹) from different tree leaves at various periods of incubation

Tree species	5 days	10 days	30 days	45 days	60 days
<i>Albizzia lebbeck</i> (5 t ha ⁻¹)	15.7	30.2	69.6	90.9	109.2
<i>Albizzia lebbeck</i> (7.5 t ha ⁻¹)	16.9	36.8	78.4	99.4	115.4
<i>Acacia nilotica</i> (5 t ha ⁻¹)	14.4	27.7	63.3	78.3	94.2
<i>Acacia nilotica</i> (7.5 t ha ⁻¹)	15.7	32.8	72.3	85.3	100.8
<i>Tamarindus indica</i> (5 t ha ⁻¹)	11.2	21.1	46.2	55.8	66.0
<i>Tamarindus indica</i> (7.5 t ha ⁻¹)	12.1	24.9	50.3	59.8	71.6
<i>Lueceana leucocephala</i> (5 t ha ⁻¹)	15.1	29.1	67.2	86.4	104.4
<i>Lueceana leucocephala</i> (7.5 t ha ⁻¹)	16.4	35.2	77.4	95.8	110.3
<i>Acacia albida</i> (5 t ha ⁻¹)	14.9	28.9	66.0	83.2	100.2
<i>Acacia albida</i> (7.5 t ha ⁻¹)	16.2	34.5	74.6	87.4	106.2
<i>Eucalyptus</i> (5 t ha ⁻¹)	10.8	20.6	45.9	54.9	64.2
<i>Eucalyptus</i> (7.5 t ha ⁻¹)	11.7	24.2	49.3	58.3	70.2
<i>Azadirachta indica</i> (5 t ha ⁻¹)	13.6	26.3	56.7	74.2	87.5
<i>Azadirachta indica</i> (7.5 t ha ⁻¹)	14.5	30.9	61.2	81.9	93.6
<i>Tectona grandis</i> (5 t ha ⁻¹)	11.5	21.9	49.5	59.4	68.4
<i>Tectona grandis</i> (7.5 t ha ⁻¹)	12.4	26.0	57.9	65.1	74.7
<i>Dendrocalamus strictus</i> (5 t ha ⁻¹)	13.2	25.2	52.2	64.3	76.5
<i>Dendrocalamus strictus</i> (7.5 t ha ⁻¹)	14.2	29.4	60.2	70.5	81.3
Control	8.5	13.2	30.6	40.5	49.8
CD (P=0.05)	1.1	3.1	4.1	4.8	5.5

recording the values of 11.7, 24.2, 49.3, 58.3, 70.2 mg/100 g of soil respectively. But *E. camuldulensis* at 5 t ha⁻¹ showed cumulative CO₂ release values on par with *T. indica*, *T. grandis* at 5 t ha⁻¹ and *E. camuldulensis* at 7.5 t ha⁻¹ at 5, 30 and 45 days of incubation. But at 10 and 60 days of incubation, *E. camuldulensis* at 5 t ha⁻¹ had on par results with *T. indica* and *T. grandis* (5 t ha⁻¹).

Data revealed that there was significant improvement of decomposition with 7.5 t ha⁻¹ of leaf addition as compared to 5 t ha⁻¹ leaf addition in most of tree leaves except in *E. camuldulensis*, *T. indica* at 5 and 45 days of incubation period and in *D. strictus* at 60 days of incubation. It was also revealed that the cumulative CO₂ release *i.e.* decomposition increased with increase in incubation period. However, decomposition rate was higher at 5 days of incubation and is gradually decreased as time progressed.

4.7 CORRELATIONS BETWEEN SOIL ORGANIC CARBON AND DIFFERENT SOIL ATTRIBUTES

Different soil parameters analysed were correlated with carbon status of soils. The results showed that the organic carbon gave significant positive correlation with pH (0.89**), Electrical Conductivity (0.75**), Total Nitrogen (0.97**), Available Nitrogen (0.95**), Total Phosphorus (0.87**), Available Phosphorus (0.87**), Total Potassium (0.88**), Available Potassium (0.91**), Exchangeable Calcium (0.85**), Exchangeable Magnesium (0.77**) and Moisture content

Table 10: Correlation coefficients ('r' value) between soil organic carbon status and different soil parameters

Soil parameter	'r' value
pH	0.89**
EC	0.75**
Total Nitrogen	0.97**
Total Phosphorus	0.87**
Total Potassium	0.88**
Available Nitrogen	0.95**
Available Phosphorus	0.87**
Available Potassium	0.91**
Exchangeable Calcium	0.85**
Exchangeable Magnesium	0.77**
Moisture content	0.86**
Sand	-0.96**
Silt	0.85**
Clay	0.96**

** Significant at 1% level.

(0.86**). Among the soil separates sand content (-0.96**) showed significant negative correlation with organic carbon while silt (0.85**) and clay (0.96**) contents recorded significant positive correlation. These correlations were worked out for all the land use systems put together.

DISCUSSION

CHAPTER V

DISCUSSION

The soils under different land use systems were analysed for various parameters along with organic carbon, which is very closely related to the soil properties such as texture, moisture status, total and available nutrients, exchangeable Ca and Mg. The results of this study indicated that different soil separates such as silt and clay were maximum with Agri-silviculture systems followed by other systems studied. It was also observed that lower sand and higher clay were associated with Agri-silviculture system at all the three depths. Such observation was made earlier by Sharma and Gupta (1989) who found that there was high content of silt and clay under vegetative cover as compared to fallow land. Results also indicated that there was increase in sand content and decrease in silt and clay with depth. Probable reason for such a trend can be, with tree cover, the leaching of finer separates occur partially during rainy season and accumulated at lower depths. These results corroborate the findings of Singh and Lal (1969).

Moisture status of soil significantly influence the decomposition of litter which in turn helps for enriching the soil with nutrients. The higher moisture status associated with Agri-silvi system clearly indicates healthy soil as this system contributes litter both from underneath crop and of leaves and other materials from trees. The Agri-silvi system i.e., *Albizia*

lebbeck as tree possesses wider crown width that facilitates maximum interception of rain and hence the higher moisture status in soils. Fallow land however, was inferior in moisture storage relative to other land use systems with tree cover. This could be obviously due to variability in litter accumulation under each of these trees. The litter so accumulated on surface also acts as sink for moisture and looks spongy in nature. This particular property promotes better retention of moisture by soil (Thomas Mathew *et al.*, 1997; Jha *et al.*, 2001).

Accumulation of leaf litter over a period of time, influence the soil pH. Nair (1987) reported that trees tend to moderate the effects of leaching through the addition of bases to the soil surface. This particular reason was in evidence in this study wherein it was found that the fallow land and agricultural land had lower pH values as compared to land use systems with tree cover. This observation was supported by Chakraborty and Chakraborty (1989), who observed increase in pH from 5.9 (land without tree) to 7.6 (with trees). Similarly, the buildup of salts which lead to increase of EC was also highest with Agri-silviculture, Silvi-pasture and also in other systems. The reason for buildup of salts in tree system could be the consequence of total soluble salt concentration in the top soil (Thomas Mathew *et al.*, 1997; Agarwal, 1980).

Carbon lockup in soils and trees

While evaluating different systems for their potential for carbon sequestration, importance was given to quantify the soil organic carbon (SOC) store based on the organic carbon content of soil and of carbon in plant systems. Agro-forestry system carrying multiple components were predicted as potential sinks for carbon lockup in the direction of assimilating higher atmosphere carbon levels. Organic matter though, was seen as store house of nutrients and accompanying major source of supply to plants always remain a scarce commodity in arid regions where temperature plays an important role in organic carbon oxidation reducing its content to low level. This is partially true in areas where vegetative cover is low. In such situations, Agro-forestry or any system abounding with tree plays a crucial role in continuously adding litter and sustaining the level of organic matter in soil. Attempts to keep atmospheric carbon at manageable level for the advantage of plants and other living beings on earth are very much needed. The investigations conducted on different land use systems both in respect of soils and plants for their carbon store unearthed certain interesting observations. In this study, different systems were compared for soil organic carbon (SOC). Fallow land naturally showed lowest of the soil organic carbon because of long periods of exposure to climatic changes without tree cover. Investigations also revealed that soil organic carbon at 0-15cm soil depth was highest in Agri-silviculture (19.93 t ha^{-1}) followed by Silvi-pasture (17.47 t ha^{-1})

and other systems. Fallow land however, showed lowest carbon pool. Though, Silvi-pasture and Agri-silvi-horti system had multiple components, their SOC store was significantly lower than Agri-silvi system. Thus, it evidently proved that tree species also plays an important role in organic carbon build up in soil. In these studies, Agri-silviculture with *A. lebbeck* as tree component, Silvi-pasture and Agri-silvi-horti systems with *A. nilotica* and *T. indica* silvi components proved to be inferior in their respect to Agri-silvi system. This might be because of higher leaf fall associated with faster rate of decomposition of *A. lebbeck* leaves as compared to *A. nilotica*, *T. indica*. The incubation studies conducted alongside this investigation amply proved that *A. lebbeck* leaves decomposed at faster rate vis-à-vis other tree leaves. The higher organic carbon levels in Agri-silvi system comprising of *A. lebbeck* also might be due to its wider crown associated with higher leaf fall (Hazra, 1986). This was also well supported by studies of Balakrishna and Toky (1993) who were of the opinion that due to constant additions of organic matter to soil through dead and decaying roots lead to improvement in organic carbon status of soil. It was also observed that surface soils contained higher organic carbon levels than of lower depths which corroborate the findings of Madhudmita Das *et al.* (1997). Most important factor that attracts the attention is the potential of these systems to mitigate the higher carbon levels. The results showed that Agri-silvi culture had maximum mitigation potential (4.23) followed by Silvi-pasture (3.71), Agri-silvi-

horti system (3.42), *L. leucocephala* (3.23), *A. albida* (3.23), *E. camuldulensis* (2.80), *T. grandis* (2.66), *D. strictus* (2.47), *A. indica* (2.42) and Agricultural land (2.0). These studies were in conformity with the findings of Jha *et al.* (2001) who reported forest cover showed higher carbon mitigation potential followed by Agro forests, plantations, agriculture etc.

Carbon sequestration by above ground biomass

Trees generally vary in their capacity to store carbon which depends on factors such as atmospheric temperature, soil, precipitation, site conditions and growth rate of trees. The results showed that though Agri-silviculture and Silvi-pasture systems comprised multiple components because of the age and slow growth rate, the carbon sequestration was much less by *A. lebbeck* based Agri-silvi system (2.98 t ha⁻¹), *A. nilotica* based Silvi-pasture systems (0.69 t ha⁻¹) as compared to *L. leucocephala* land use system (7.0 t ha⁻¹ yr⁻¹) and *E. camuldulensis* (5.35 t ha⁻¹ yr⁻¹), where growth rate generally is greater than other plantations included in this investigation. Though soil organic carbon was highest with Agri-silvi system and its superiority in carbon mitigation potential and higher carbon in biomass, because of the difference in age (9 years), in the final analysis, it proved to be inferior to *L. leucocephala* and *E. camuldulensis* in green house gas mitigation potential. Such observations were recorded earlier by Negi and Chauhan (2002). The results also further suggested that carbon sequestered by

A. lebbeck for each kg of biomass produced was significantly high in case of *A. lebbeck* (0.433 kg/kg of biomass). So also was the trend with individual tree components. Among different tree components leaves accumulated maximum carbon in all the trees followed by twigs and wood portion. The reason could be major activities of photosynthesis being associated with greenish portion i.e., leaf and is least to nil with twig and wood portion. The net primary productivity calculated from different trees evidently proved that trees by utilizing CO₂ of atmosphere for synthesis of photosynthates to put up faster growth and maximum biomass production thus creating convenient sink for carbon storage. This was amply proved by the findings of Seigenhalen and Sanhuezza (1991).

Nutrient dynamics in soil

As a part of this study nutrient dynamics in soil was also investigated. The results obtained revealed that total and available status of soil was higher with *A. lebbeck* based Agri-silvi system. The mean total N was 0.076 per cent at 0-15cm depth and it decreased with depth recording 0.071 per cent at 15-30cm and 0.064 at 30-45 cm. Similar was the trend with respect to available nitrogen also. Lower value of nitrogen was recorded with fallow land. This particular trend was true with other systems also. Superiority of this system over other systems might be ascribed to litter accumulation from trees and crop component at the surface layer. The decrease in total and available nitrogen with

depth can also be attributed to washing of organic acid layer from surface layer. At low pH, the activity of nutrient is generally low. Similar to available and total nitrogen contents of soil, the available and total phosphorus also was highest for *A. lebbeck* based Agri-silvi system (356 mg kg^{-1} and $25.3 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) followed by Silvi pasture with respect to total phosphorus and *L. leucocephala* for available phosphorus ($23.3 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) at the surface layer. Similar was the trend at other depths also. Lowest value of total and available phosphorus was noticed with fallow land only. The superiority of Agri-silvi and Silvi-pastural systems might be due to conversion of fixed phosphorus to soluble form and also due to addition of phosphorus through inorganic sources during the crop season. The add on advantage of tree cover was evident as the tree roots might have contributed rock weathering at lower depths. In general, there was decrease in total and available P_2O_5 status of soil with depths. Such observations were recorded by Shankarnarayana (1984) and Sreemannarayana *et al.* (1994). It was also seen that total and available phosphorus status of soils was higher in systems wherever leguminous trees such as *A. lebbeck*, *L. leucocephala*, *A. albida* and *A. nilotica* etc., were incorporated. This type of soil enrichment could be due to gradual accumulation of mineral elements by woody legumes and incorporation of these into an enlarged plant-litter soil nutrient cycle mechanism that leads to significant contribution of available phosphorus to soil pool over a period of time

(Vediraj and Rudrappa, 1990). This observation holds good for N and K status also.

Due to accumulation of leaf litter in different land use systems having tree cover possessed higher potassium status as compared to Agriculture and fallow land. Among different systems, associated with crop components contained maximum total and available potassium contents. This might be due addition of K through inorganic fertilizer sources. At the surface i.e. 0-15cm depth, high status total K was found in Agri-silvi culture (4653 mg kg^{-1}), Agri-silvi-horti system (4404 mg kg^{-1}) and silvi-pasture systems (4200 mg kg^{-1}) followed by *L. leucocephala* (3644 mg kg^{-1}) and least was found with fallow land (1812 mg kg^{-1}).

Accumulation of organic matter at the surface due to litter provided by trees and the resultant favourable CEC might have contributed for higher K status in Agri-silvi systems as compared to other land use systems under study (Kapoor and Singh, 1992).

The exchangeable Ca and Mg contents of soils under different systems varied significantly. The results showed highest Ca and Mg in case of Agro forestry systems in general as compared to those of pure plantations, fallow and Agricultural lands. With respect to exchangeable Ca, there was reduction in content with increase in depth of soil. This was conspicuous particularly in Agri-silvi and Silvi-pasture systems.

Such observations were recorded earlier by Ravikumar *et al.* (1994). They also observed that cultivated soils with trees contained more of Ca than uncultivated fields which was true in this investigation also. Contrary to these observations, soils with Agriculture contained much lesser values as observed in this study when compared to those of systems with tree over. The reason might be utilisation of calcium up by agricultural crop for the growth or might have leached out of upper layer of soils due to rainfall. pH of the soil, which was around neutrality also could be the reason for increased availability of Ca in different systems (Young, 1997).

Interaction between organic carbon and soil characteristics

In order to assess the relationship between different nutrients and soil textural properties with organic carbon, 'r' values were worked out. It was noticed that organic carbon showed significant positive correlation with pH, EC, silt, clay content and also with available and total nutrient content and exchangeable Ca and Mg, besides moisture status of soils. These observations augur well with the trend noticed with each individual nutrient and soil parameter and then behaving in soils of different systems; thus it gave a clear indication that organic carbon/matter was the critical input, which controls the nutrient dynamics and textural properties of soils significantly in various systems under investigation. The only negative correlation observed was with sand. Such trends were also reported earlier by Gupta *et al.* (1991).

Positive correlations were also indicative of retentive capacity of soils through organic matter improvement and subsequent mineralization for plant availability. The positive correlation between organic carbon and soil separates (silt + clay) was also indicative of improvement in physical properties.

Incubation studies

In order to ascertain the rate of decomposition of tree leaves, the process by which soil enrichment takes place, a laboratory study was conducted with different levels of substrate i.e. leaves. The rate of decomposition was arrived at by calculating the CO₂ release at different periods of incubation which was an indirect method of ascertaining decomposition process. The results showed that when leaves of *A. lebbeck* were incorporated at 7.5 t ha⁻¹, CO₂ release was highest at all the periods of incubation; which was found to be on par with *L. leucocephala* and *A. albida* at 7.5 t ha⁻¹. These results signify the faster rate of decomposition with respect to leaves of these tree leaves and it also summarizes that the soil enrichment can be achieved at a faster rate with these trees as compared to other trees under study and the results presented earlier chapters also confirmed these findings. Among all the tree leaves studied, lower decomposition rates were with *E. camuldulensis* at 5 t ha⁻¹ at all periods of incubation, might due to higher lignin content in leaves. Similar observations were recorded earlier by Maharuddrappa *et al.* (2000). Faster rate of decomposition in case of *A. lebbeck*,

L. leucocephala and *A. albida* obviously might be due to narrow C:N ratio of leaves and the presence of easily decomposable and water soluble materials in leaves.

It was clearly noticed that with higher rates of leaf incorporation i.e. 7.5 t ha^{-1} , the release of CO_2 was maximum as compared to that of 5 t ha^{-1} . These observations corroborated the findings of Maharuddrappa *et al.* (2000). Tabatabai (1982) also reported that due to increase substrate in concentration, biological activities such as, decomposition, mineralization etc. increased significantly.

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY

The present investigation entitled "Evaluation of different land use systems in carbon sequestration" was carried out at Agro-forestry research unit, ANGRAU, Rajendranagar during the year 2002. Different land use systems such as Fallow land, Agricultural land, Agri-silviculture, Silvi-pasture, Agri-silvi-horti system, *E. camuldulensis*, *L. leucocephala*, *D. strictus*, *A. albida*, *A. indica* and *T. grandis* were evaluated for soil organic carbon (SOC) in soils. Similarly, carbon sequestration and CO₂ mitigation potential of different systems were also evaluated besides investigation of decomposition rates of various tree leaves which has a bearing on organic carbon status soils. In addition, soil fertility status/nutrient dynamics under different land use systems was also compared with reference to fallow land besides working out relation ship between organic carbon and different soil characteristics. The salient findings obtained from the study are briefly under lined below.

- ☛ Soils under Agri-silviculture showed higher silt (17.0%) & clay contents (25.1%) and less of sand content (58.7%) as compared to remaining land use systems. The land use system with tree cover and Agricultural land showed lower sand and higher silt and clay content as compared to fallow land. Moisture status was high in Agri-

silviculture system. Fallow land showed lowest moisture status. Results conclusively showed that soils with vegetative cover were advantageous in augmenting sustaining fertility status of soils.

- ☛ Organic carbon status of soils was higher in *A. lebbeck* based Agri-silviculture (0.89%) which was followed by Silvi-pasture, Agri-silvi-horti system and other land use systems. Fallow land showed lowest organic carbon of all the land use systems. Similarly, highest organic carbon storage, carbon mitigation potential at surface layer (0-15 cm) were also associated with Agri-silviculture system followed by Silvi-pasture, Agri-silvi-horti system etc.
- ☛ Though soil organic carbon was highest with Agri-silviculture and was superior in carbon mitigation potential, with respect to carbon storage in above ground biomass of tree component, Agri-silviculture proved to be inferior to *L. leucocephala* and *E. camaldulensis camaldulensis* probably due to age of stand. However, carbon sequestered for each kg of biomass produced was highest in *A. lebbeck*. Among different tree components, leaves accumulated maximum carbon in leaves followed by twigs and wood portions of all the trees.
- ☛ Soils under Agri-silviculture recorded higher amount of total and available major nutrients than other land use systems. The land use systems comprising of tree components recorded highest status of nutrients over fallow land.

- ☛ Higher exchangeable Ca and Mg were associated with soils under Agri-silviculture system. The land use system with tree and Agricultural land showed improvement in exchangeable Ca and Mg contents over the fallow land.
- ☛ Significant positive correlations were obtained with organic carbon vs silt, clay, moisture status, available and total major nutrients and exchangeable Ca and Mg contents of soil while it showed significant negative correlation with sand content.
- ☛ It was seen that CO₂ release was higher with leaves of *A. lebbeck* when incubated at different periods of incubation. Rate of decomposition was also found to be higher in *L. leucocephala*, *A. albida* tree leaves compared to other tree leaves. *E. camuldulensis* leaves underwent slow decomposition process. It was also seen that high decomposition rate was associated with higher tree leaf addition.

These studies indicated that systems approach as that of Agri-silviculture, Silvi-pasture and Agri-silvi-horti systems possesses significantly higher potential to store organic carbon in soil and to sequester maximum quantity of carbon.

The maximum CO₂ mitigation potential associated with *A. lebbeck* based Agri-silviculture was an indication that trees with wider crown and with underneath crop can store better levels of 'C' as compared to pure tree systems. It was also indicated that leguminous

trees such as *L. leucocephala* could be potential sinks for atmospheric CO₂, since these trees generate maximum amount of biomass in a short period of time. Maximum ground cover with vegetation as observed under Agri-silviculture and Silvi-pasture also contributes in enhancing the SOC store.

Soil fertility buildup was maximum with multi-component systems than of sole tree systems which was indicative advantage of adopting Agro forestry system with two or more than two components.

For improving soil fertility status, tree leaves such as *A. lebbeck* and *L. leucocephala* were advantageous as they showed fast rate of decomposition when incubated at 60% maximum water holding capacity. From this findings, it can also be concluded that further studies in the direction of documenting on variations in SOC and carbon sequestration with climatic changes is very much needed in the light of fast deteriorating environment and changing human habitats. There is also a need to go for such studies with larger number of tree species without getting restricted to limited number of trees and drawing conclusions.

By quantifying the amount of carbon sequestered for unit quantity of biomass produced, it is feasible to recommend such of those species with fast growth for accumulating higher quantity of biomass which would indirectly help in cleansing the atmosphere of greenhouse gases including that of CO₂.

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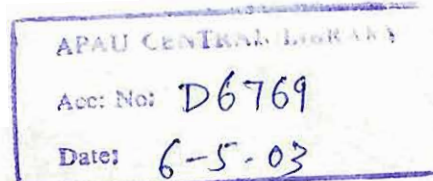
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