STUDIES ON INFLUENCE OF DIFFERENT TREE SPECIES ON SOIL FERTILITY

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DEPARTMENT OF FORESTRY AND ENVIRONMENTAL SCIENCE

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Affectionately Dedicated to

My Family

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Bengaluru

August, 2018 ***(DEEPIKA, J. T.)***

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ABSTRACT

Study was conducted to examine the soil fertility status, tree productivity and carbon sequestration potential of four deciduous tree species viz. *Tectona grandis, Terminalia tomentosa, Terminalia arjuna* and *Terminalia bellarica* in tree arboretum at GKVK Bengaluru. To check the soil nutrient status, soil samples were collected from tree arboretum at two different depths (0-15cm and 15-30cm) and also collected from an agricultural land for Comparision. For the estimation of tree productivity and carbon sequestration potential of tree species, growth data (height and GBH) was collected from randomly selected 20 trees within each tree species. On the basis of results obtained, soil fertility was varied under different tree species and also at different depths. Agricultural land is showing maximum difference compared to plantation site, with respect to soil pH 5.41, soil total nitrogen 292.92 kg ha^{-1} and total phosphorous 97.49 kg ha^{-1} at 0-15cm. In case of 15-30cm agricultural land pH was 5.12, total nitrogen was 281.50 kg ha^{-1} and total phosphorous was 84.53 kg ha^{-1}. Plantation soil showing good results at soil organic carbon which is more under *Tectona grandis* 1.52%. *Tectona grandis* and *Terminalia arjuna* are having sufficient soil potassium concentration of 303.87 kg ha^{-1} and 354.69 kg ha^{-1} at 0-15 cm. It revealed that with increasing depth nutrient status get reduced. The productivity of *Tectona grandis* (0.23m^3 $tree^{-1}$) is maximum and *Terminalia tomentosa* (0.12 m^3 $tree^{-1}$) is having lowest productivity among four species considered. Average Carbon sequestration potential of *Terminalia bellarica* was 170.59 kg ha^{-1} which was highest among the four species and *Terminalia tomentosa* was 101.43 kg ha^{-1} with lowest value.

August, 2018 — **(C. NAGARAJAIAH)**

Dept. of Forestry and Environmental Science — Major Advisor

UAS, GKVK, Bengaluru-65

ಮಣ್ಣಿನ ಫಲವತ್ತತೆಯ ಮೇಲೆ ವಿವಿಧ ಮರ ಜಾತಿಗಳ ಪ್ರಭಾವದ ಬಗ್ಗೆ ಅಧ್ಯಯನ

ದೀಪಿಕಾ ಜೆ.ಟಿ.

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಮಣ್ಣಿನ ಫಲವತ್ತತೆ, ಮರದ ಉತ್ಪಾದಕತೆ ಮತ್ತು ಇಂಗಾಲದ ಸ್ವಾಧೀನ ಸಾಮರ್ಥ್ಯದ ಮೌಲ್ಯಮಾಪನದ ಅನ್ವೇಷಣೆಯನ್ನು ಬೆಂಗಳೂರಿನ ಜಿಕೆವಿಕೆಯ ಮರ ಆರ್ಬೋರೇಟಂ ನ ನಾಲ್ಕು ಪತನಶೀಲ ಮರಜಾತಿ (ತಾರೆ, ಕರಿಮತ್ತಿ, ಹೊಳೆಮತ್ತಿ ಮತ್ತು ತೇಗ)ಗಳಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಮಣ್ಣಿನ ಪೌಷ್ಠಿಕಾಂಶದ ಸ್ಥಿತಿಯನ್ನು ಪರೀಕ್ಷಿಸಲು ಮಣ್ಣಿನ ಮಾದರಿಗಳನ್ನು ಮರ ಆರ್ಬೋರೇಟಂ ಮತ್ತು ಕೃಷಿ ಭೂಮಿಯಿಂದ ಎರಡು ವಿಭಿನ್ನ ಆಳಗಳಿಂದ (೦–೧೫ ಸೆಂ.ಮೀ ಮತ್ತು ೧೫–೩೦ ಸೆಂ ಮೀ)ಸಂಗ್ರಹಿಸಲಾಯಿತು. ಪ್ರತಿ ಮರದ ಜಾತಿಯಲ್ಲಿ ಆಯ್ದ ಇಪ್ಪತ್ತು ಮರಗಳ ಬೆಳವಣಿಗೆ ಮಾಹಿತಿ (ಎತ್ತರ ಮತ್ತು ಅಗಲ) ಯ ಆಧಾರದ ಮೇಲೆ ಮರದ ಉತ್ಪಾದಕತೆ ಮತ್ತು ಇಂಗಾಲದ ಸ್ವಾಧೀನ ಸಾಮರ್ಥ್ಯವನ್ನು ಅಳೆಯಲಾಯಿತು. ಮಣ್ಣಿನ ಫಲವತ್ತತೆಯು ವಿಭಿನ್ನ ಆಳಗಳಲ್ಲಿ ಮತ್ತು ವಿಭಿನ್ನ ಮರ ತಳಿಗಳ ಅಡಿಯಲ್ಲಿ ಬದಲಾಗುತ್ತದೆ. ಭೂಮಿಯ ಆಳ ೦–೧೫ ಸೆಂ.ಮೀ ನಲ್ಲಿ ಕೃಷಿ ಭೂಮಿಯ ರಸಸಾರ ೫.೪೧, ಒಟ್ಟು ಸಾರಜನಕ ೨೯೨.೯೨ ಕೆಜಿ/ಹೆಕ್ಟೇರು, ಒಟ್ಟು ರಂಜಕ ೯೭.೪೯ಕೆ.ಜಿ/ಹೆಕ್ಟೇರು ಮತ್ತು ಆಳ ೧೫–೩೦ ಸೆಂ.ಮೀ ನಲ್ಲಿ ಕೃಷಿ ಭೂಮಿಯ ರಸಸಾರ ೫.೧೨, ಒಟ್ಟು ಸಾರಜನಕ ೨೮೧.೫೦ ಕೆ.ಜಿ/ಹೆಕ್ಟೇರು ಮತ್ತು ಒಟ್ಟು ರಂಜಕ ೮೪.೫೩ ಕೆ.ಜಿ/ಹೆಕ್ಟೇರು ಇದೆ. ಇದಕ್ಕೆ ಸಂಬಂಧಿಸಿದಂತೆ ಕೃಷಿ ಭೂಮಿಯು ಮರ ಆರ್ಬೋರೇಟಂ ಭೂಮಿಗಿಂತ ಗರಿಷ್ಟ ವ್ಯತ್ಯಾಸವನ್ನು ತೋರಿಸುತ್ತಿದೆ. ಮಣ್ಣಿನ ಸಾವಯವ ಇಂಗಾಲವು ಮರ ಆರ್ಬೋರೇಟಂನಲ್ಲಿ ಉತ್ತಮ ಫಲಿತಾಂಶವನ್ನು ತೋರಿಸುತ್ತಿದೆ. ಇದು ತೇಗ್ಗ ಮರಗಳಲ್ಲಿ ಹೆಚ್ಚಿದೆ (೧.೫೨%). ಮಣ್ಣಿನ ಒಟ್ಟು ಪೊಟ್ಯಾಷಿಯಂ ಸಾಂದ್ರತೆಯು ತೇಗ ಮತ್ತು ಹೊಳೆ ಮತ್ತಿಯಲ್ಲಿ ಕ್ರಮವಾಗಿ ೩೦೩.೮೭ ಮತ್ತು ೩೫೪.೬೯ ಕೆ.ಜಿ/ಹೆಕ್ಟೇರು ನಷ್ಟಿದೆ. ಇದು ಗರಿಷ್ಟ ಪ್ರಮಾಣವನ್ನು ಸೂಚಿಸುತ್ತಿದೆ. ಈ ಎಲ್ಲಾ ಫಲಿತಾಂಶವು ಬಹಿರಂಗಪಡಿಸುವುದೇನೆಂದರೆ ಮಣ್ಣಿನ ಆಳವು ಲಭಿಸಿದಂತೆ ಮಣ್ಣಿನ ಒಟ್ಟು ಪೌಷ್ಟಿಕಾಂಶವು ಕಡಿಮೆಗೊಳ್ಳುತ್ತದೆ. ಮರಗಳ ಉತ್ಪಾದನೆಗೆ ಸಂಬಂಧಿಸಿದಂತೆ ತೇಗವು ಹೆಚ್ಚು ಉತ್ಪಾದನೆ ಮತ್ತು ಕರಿ ಮತ್ತಿಯು ಕಡಿಮೆ ಉತ್ಪಾದನೆಯನ್ನು ಹೊಂದಿದೆ. ತಾರೆ ಮರದ ಸರಾಸರಿ ಇಂಗಾಲ ಸ್ವಾಧೀನ ಸಾಮರ್ಥ್ಯವು ಉಳಿದ ಮೂರು ಮರ ಜಾತಿಗಳಿಗೆ ಹೋಲಿಸಿದಾಗ ಗರಿಷ್ಟ ಪ್ರಮಾಣವನ್ನು ಹೊಂದಿದೆ ಮತ್ತು ಕರಿಮತ್ತಿಯು ಕಡಿಮೆ ಮೌಲ್ಯವನ್ನು ಹೊಂದಿದೆ.

ಅಗಸ್ಟ್ ೨೦೧೮

ಅರಣ್ಯ ಮತ್ತು ಪರಿಸರ ವಿಜ್ಞಾನ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರು–೬೫.

(ಸಿ. ನಾಗರಾಜಯ್ಯ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Studies on carbon sequestration potential of different tree species

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Introduction

- ✓ Trees are the carbon sinks of terrestrial ecosystem. In nature, photosynthesis is the unique mechanism through which carbon flows in ecosystems.
- ✓ In the present context of climate change documenting the different ecosystem services such as carbon sequestration, improving soil fertility etc.
- ✓ Establishing plantations seems a good management strategy to improve carbon stock and to reduce the climate change.
- ✓ The carbon storage varies greatly among different tree species and it is highly dependent on specific traits of trees and understory vegetation.

Objective:

To assess the carbon sequestration potential of different tree species.

Material and Methods

- The field experiment was conducted at tree Arboretum at UAS, GKVK, Bengaluru in block C, established in 1987.
- Species selected for experiment are:
- *1.Tectona grandis* *2.Terminalia tomentosa*
- 3.*Terminalia arjuna* 4.*Terminalia bellarica*
- Carbon storage in different tree species is estimated by using the below formula With the available data of girth and height
- Carbon sequestration(C) = Total above ground biomass× wood density× 0.45
- Tree height was calculated with the help of altimeter from ground level to the tip of the tree and is expressed in terms of meter.
- Girth was measured at the dbh (diameter breast height) level by using the measuring tape and is expressed in terms of cm.
- ❖ 0.45 It represents the carbon content of the biomass varies between 0.45 to 0.50. It is expressed in terms of C kg per tree or per hactare.
- ❖ V= Basal area × height × farm factor

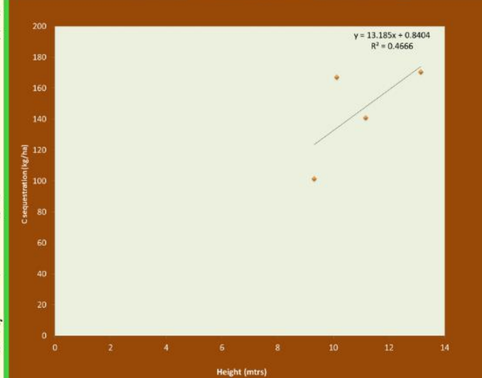
  Basal area = $g^2/4\Pi$
- Wood density represents the dry biomass of the tree. WD of the above trees is as fallows...
- ✓ *Tectona grandis* (Teak):- 0.55
- ✓ *Terminalia tomentosa* (Kari matti):-0.74
- ✓ *Terminalia arjuna* (Hole matti):- 0.68
- ✓ *Terminalia bellarica* (Thare):- 0.72
- Total above ground biomass = volume × wood density.
- ✓ Volume is the wet biomass of the tree

Experimental Results

Table 1. Carbon sequestration potential of different tree species

Treatment	Height (m)	Girth (m)	Volume (m^3)	C S kg/m^3
Tectona grandis	11.15^b	0.58^a	0.22^a	0.056^{ab}
Terminalia bellarica	13.14^a	0.52^{bc}	0.22^a	0.071^a
Terminalia tomentosa	9.31^c	0.47^c	0.12^b	0.040^b
Terminalia arjuna	10.12^{bc}	0.60^a	0.21^a	0.06^a
MSE	1.51	0.10	0.09	0.028
F value(0.05)	0.0001^s	0.0056^s	0.0091^s	0.020^s
R^2	0.49	0.19	0.18	0.15
Mean	10.93	0.54	0.197	0.058
Cv	13.83	18.57	48.15	48.029

❖ Correlation between carbon sequestration and height



❖ Table 2 carbon sequestration and biomass of trees

Trees	Carbon sequestration (CS) kg/m^3	Biomass (kg/m^3)
Tectona grandis	0.056	0.125
Terminalia bellarica	0.071	0.159
Terminalia tomentosa	0.040	0.09
Terminalia arjuna	0.06	0.148

Ravi altimeter

Discussion

- Table represents the above ground carbon stock in different tree species.
- In general, above ground biomass contributed 82 per cent of the total biomass and below ground (root biomass) contributed only 18 per cent.
- *T. bellarica* is showing highest values of height compared to other tree species considered in the research. And also it is showing more volume.
- Significantly higher carbon stock was recorded in *Terminalia bellarica* fallowed by *Terminalia arjuana*, *Tectona grandies* and the least in *Terminalia tomentosa*.
- This could be attributed from higher values of height, girth and total volume of tree species.
- Due to increase in the height and girth it results in the increase of total volume and total biomass, which is the major carbon sinks thus increases the carbon sequestration.

Summary

- All four tree species like Teak, *T. tomentosa, T. bellarica* and *T. arjuna* have significant carbon sequestration potential of 140.48, 101.40, 179.58 and 167.05 kg/ha respectively.
- *T. bellarica* was found to be dominant that sequestered 179.58kg/ha carbon compared to other three tree species.
- The research can be useful for estimating carbon sequestration capacity of the tree species in GKVK.
- Plantations of these species are beneficial to mitigate the global warming problem.
- It will also add additional income through timber.

Advisory committee::
Chairperson: Dr. C, Nagarajaiah
Members : Dr. B. C. Mallesha
Dr. C. T. Subbarayappa
Dr. S. Raghavendra

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I INTRODUCTION

Forest plantations are predominantly established through afforestation or reforestation process. It includes planting, seeding and coppicing (previously planted trees) of both native and non-native species. Over exploitation of forest for fuel, woods, charcoal etc. leads to diminishing of forest resources. The global forest loss in the year 1990– 2000 was 0.22 %year^{-1} and in 2000–2005 was 0.18 % year^{-1}.

Maximum loss occurring in the tropics. Much of this land was converted to agriculture land and have been cultivated for only a short period and are now abandoned or under-utilised (Fox and Vogler 2005; Mayaux *et al*. 2005) then it is allowing for reforestation by secondary forest. With all this view several national tree planting campaigns came into existence. Followed by various afforestation projects funded by state and central government, foreign agents and private sectors. As a result of this, today many plantations of indigenous and exotic species have been established. In the early 1990 the secondary forest area was estimated at 87.5, 90 and 165 million ha in Asia, Africa and Latin America respectively.

This influence on soil fertility status, the nutrient demand also varies with the age of the stand as reported by Farley and Kelly (2004). During the early stage of development, plantation trees grow quickly thus nutrients demand is high at this stage. Turner and Kelly (1985) indicated that the most significant changes in the nutrient status of the soil are likely to occur in plantations that are 10–20 years old.

Trees can improve the nutrient balance of soil by reducing unproductive nutrient losses from erosion, leaching and by increasing nutrient inputs through nitrogen fixation and increase biological activities by providing biomass and suitable microclimate (Schroth and Sinclair 2003). During tree plantations or regeneration of secondary forest, it is necessary to consider tree species with nitrogen (N)-fixing capability which have stronger effects on soils than non-fixing trees because the input of biologically fixed nitrogen (N) can improve the levels of soil N and soil organic carbon(OC) (Voigtlaender *et al*. 2012), thus increase soil fertility and reduce negative impacts on soil nutrient status.

Litter quality of tropical plantations and secondary forests influences soil properties (Vitousek and Sanford 1986).

Tree roots contribute about 20-25% of the total living biomass of the tree and it is continuously add organic matter to the soil through dead and decaying roots. Along with nutrient enrichment trees provide both short and long- term benefits to the local people and they involves in carbon storage for the environmental stability. Deforestation and forest degradation has mostly occurred in tropical forests and 1.4 ± 0.5 billion tonnes carbon per year came from deforestation and forest degradation in the tropics (Houghton 2012). REDD (Reducing Emissions from Deforestation and Forest Degradation) activities need to be carried out in arid and semiarid tropical regions to enhance the carbon sequestration. It can provide the economic benefits to the local people to reduce poverty.

In the atmosphere natural balance in carbon dioxide and other greenhouse gases has increased considerably. This has resulted from burning of fossil fuels and the conversion of forest land to agricultural land. Since 1750, concentration of atmospheric CO_2 raised by 30 % with steep increase observed all through the last 50 years. About 0.5 % or 3.6% annual increase. Which has become one of the the most important global challenges. This has created awareness among people about the adverse effects of greenhouse gas emissions and climate change. The most affordable alternative to mitigate climate change is through carbon sequeastration by improving vegetation or by planting trees which are one of the major sinks of carbon.

The quantity of carbon storage mainly depends on the tree species. Information about carbon sequestration of tree species is limited in both tropical and temperate region. Exploring carbon storage potential of tree species is needed to regulate the climate change. On the other hand the tree growths and the carbon storage potentials are strongly correlated. Species-specific carbon sequestration potential studies provided totally different estimates. It depends on various factors like location, weather conditions and management practice etc.

Soil organic carbon (SOC) plays a very important role in global carbon cycle as it is the largest terrestrial carbon pool. Soil acts as sink (CO_2 and CH_4) and source (CO_2, CH_4 and N_2O) of greenhouse gases depending on management and land use.

In the tropics natural forests are not able to withstand increasing demands for wood and wood products at the local and international level. Thus tropical countries must fallow sustainable wood production systems by plantation forest. Plantations are necessary on limited and defined land areas to meet increasing demand of wood products including firewood, pulpwood and sawlogs.

Continuous scope for stand management of plantations and economic return from investments on market-oriented goods. These considerations and global demand for wood have promoted rapid expansion of plantation forestry in the subtropics and tropics (Brown 1997). Plantation forestry must also develop without adverse impact on the environment and must be economically viable. Productivity of plantations needs to be high and sustainable as large initial investments required. Short rotations and intensive harvesting leads to nutrient losses from the site.

The majority of plantation area is covered by exotic species having the capacity to grow rapidly and produce wood of suitable quality specially with pulping properties. In some tropical countries for wood products teak plantation is having long history.

With the above information study was conducted under 4 different tree species (*Tectona grandis, Terminalia tomentosa, Terminalia arjuna* and *Terminalia bellarica*.) with the fallowing objectives:

1) To assess the soil fertility under different tree species at tree arboretum, GKVK Bengaluru.
2) To estimate the tree productivity of different tree species at tree arboretum, GKVK Bengaluru.
3) To assess the carbon sequestration potential of different tree species at tree arboretum, GKVK Bengaluru.

II REVIEW OF LITERATURE

The literature on **"Studies on influence of different tree species on soil fertility"** and other related literature pertaining to the objectives of the study are presented in this chapter.

2.1 Soil fertility under tree species

Jake *et al.* (1993) conducted study in Thurkana district, Northwestern Kenya to investigate the vegetation and the soil gradients of individual *Acacia tortilis* trees. In the shallow soils near the bole soil organic carbon and the total nitrogen concentrations were maximum (0.72% and 0.083%, respectively) and get declined rapidly with the interspaces and with the increasing depth.

Laurent *et al.* (2002) worked on European temperate forest tree species to know its effect on the soil fertility. Results indicated that impact of tree species was maximum in the topsoil. Coniferous tree *Picea abies* showed negative impact on some nutrients (Ca and Mg) and it promoted soil acidification and reduces soil pH. Hence, it is not suitable for very poor soils (areas of acidic atmospheric depositions).

Oleg *et al*. (2002) examined the effects of dominant tree species (Scots pine, Spruce, Arolla pine, Larch, Aspen and Birch) on C and N cycle of 30 year old plantation in the Siberia. Total N mineralization, nitrification and denitrification potentials were maximum under Arolla pine and Larch, transitional under deciduous Aspen and Airch and least under Spruce and Scots pine. NH_4^+ availability and N mineralization was adversely affected by grassland conversion.

Gary *et al*. (2002) conducted study in Catskill mountains of newyork state to examine the relationship among the properties of the forest floor, stream chemistry and the tree species watershed composition. They showed that soil C:N ratio variation is connected with variation of tree species composition. N preservation and its release in forested watersheds was controlled by tree species composition and variations in composition is affected by introduced pests, climate change, or forest management, could disturb the forest ecosystem capacity to retain atmospherically deposited N.

Sariyildiz *et al*. (2003) assessed the relations between litter quality, decomposition and soil fertility. They collected leaf litters of Oak (*Quercus robur* L.) and Beech (*Fagus sylvatica* L.) trees from deciduous, mixed and woodlands growing in three soil types. Litter quality varied within tree species according to the type of soil. Study conducted to examine litter quality and the substrate interactions. At 4th, 8th and 12^{th} months mass losses accur from oak and beech tree was significant in all the three sites.

Sharma *et al*. (2009) assessed the long-term impact of different land-use systems on the soil physical and chemical properties at Hayathnagar Research,CRIDA (Central Research Institute for Dryland Agriculture), Hyderabad, India. Soil samples were collected at different depths (0–0.05, 0.05–0.15, 0.15–0.30, and 0.30–0.60 m). Results revealed that soil chemical properties (pH, CEC, EC, OC and exchangeable nutrient cations Ca, Mg, and Na and total nutrients N, P, K, Ca, Mg, Cu, Mn, Zn, and Fe) were significantly influenced from the land-use systems. The highest Ca content was found (7.4 c mol kg^{-1}) in arable land system, Mg content (4.7 c mol kg^{-1}) in the agroforestry system and total N content (607.5 mg kg^{-1}) in the pastoral system and reduced with soil depth.

Baljit *et al*. (2010) conducted the experiment at punjab agricultural university to know the effect of different tree species (Eucalyptus, Neem, Dek, Shisham, Siris, Subabul and Kikar) and agroforestry systems like intercrop of pearlmillet-wheat with six years rotation and sole crops rotation of pearlmillet and wheat, on available N, P and K contents and soil organic carbon (OC). Outcome shows that there was significantly higher amount of Soil OC and available nutrients in the surface soil depths (0-15 cm) than below.

Bing *et al*. (2011) studied with an objective to determine changes in soil physical-chemical properties, microbial populationl and enzymatic activities in abandoned farmland over a period of 0, 1, 5, 7, 10, 15, 20, 25, 30, 40 and 50 years in Zhifanggou watershed (8.27 km^2), Shaanxi Province, NW China. Result showed that after land abandonment there was a significant improvement in chemical and microbiological properties of soil. And with the establishment of plantation soil organic C, available N and K, total N, soil microbial biomass C, N and P, as well as alkaline phosphatase, saccharase, catalase, and cellulase activity increased. On contrary soil bulk density, and pH declined after farmland abandonment. But no significant changes in available P and total P during the restoration.

Clement *et al*. (2011) assessed the effects of teak single cropping and cocoa-kola intercropping on the soil fertility. Analysis of results showed that the decomposition of cocoa and kola leaves improved the soil organic matter content in cocoa/cola site and same in teak site. Thus there was high soil organic matter content in forest site (9.12%) fallowed by cocoa/kola site (7.34) and was least in the teak site (3.04%).

Singh *et al*. (2012) conducted the study to know the effects of Ber, Drumstick, Karonda and Khejri on soil fertility at different soil depths (0–15, 15–30, 30–45 and 45–60 cm). observations showed that there was small decrease in the soil pH under vegetated area and no significant change in EC. But was substantial increase in soil organic carbon (0.04 to 0.13%) and available soil nitrogen content (69 to 100 kg ha^{-1}) in the locations under vegetation. Due to influence of the tree species the increase or decrease in soil properties is more at 0–15 cm and at 15–30 cm than in 30–45 and 45–60 cm.

Manejo *et al.* (2014) evaluated the fertility status of soil and leaf litter below the crown of Gliricidia and Sabia with different planting densities (400, 600, 800, 1000 and 1200 plants ha^{-1}). Soil and leaf samples were collected from the plantation. After doing the chemical analysis result showed that the nutrient content in the leaf litter of both the tree species was in the sequence Ca > N > Mg > K > P. And in case of soil an increase in tree density gives rise to increase in the levels of P, Mg, Na and Ca initially increased and later get decreased with higher density. But it had no effect on K, organic matter and pH.

Zhangquan *et al*. (2015) studied to understand the soil nutrient status and soil microbial activity under three forest types *i.e* an evergreen broadleaf forest (B F), a pine and broadleaf mixed forest (M F) and a pine (*Pinus massoniana*) forest (P F) in the Yingzuijie Biosphere Reserve, Hunan Province, China. Outcome presented that soil nutrients was higher in M F and B F plots and less in P F plots. In case of microbial biomass carbon was more in B F (522–1022 mg kg^{-1}) followed by MF (368–569 mg kg^{-1}) and less in P F (193-449 mg kg^{-1}). Forest succession improved soil microbial properties and soil nutrient status and thus increased carbon sequestration and primary productivity.

Joshua *et al*. (2015) examined soil fertility status under banana–coffee agroforestry systems in East Africa. Collected soil samples from 20 farms at the top and subsoil layers and were analyzed for numerous soil fertility parameters. Outcomes showed that banana–coffee agroforestry system had higher total soil organic matter and total N compared to banana monoculture. Average C pool in the banana–coffee agroforestry system was 26% higher than banana monoculture. Exchangeable K was higher under banana monocultures soil.

Mariama *et al.* (2016) investigated the influence of four different tree species (*Acacia albida, Combretum aculeatum, Acacia senegalensis, and Piliostigma reticulatum*) on soil fertility in semi-arid climate Niger. Collected soil sample at various depths (0-10, 10-20, 20-30, 30-40 and 40-50 cm) and two age classes (young and mature). Results showed that the OC was more under leguminous trees (*A. albida* and *P. reticulatum*) compared to non-leguminous trees (*A. senegalensis* and *C. aculeatum*). N, P and K were less under *C. aculeatum* than other tree species. However, Na, Mg and Ca concentrations were lower under *A. senegalensis* than other tree species. Matured trees are advised to grow under farmers field to improve crop production.

2.2 Carbon sequestration potential of trees

Hollinger *et al*. (1993) carried out research to know the carbon sequestration in New Zealand forest plantations of 1.24 million ha. It showed that annual storage was about 4.5±0.8 million tonnes C per year between 1 April 1988 and 1 April 1989. Without harvest annual carbon uptake was approximately 6.4 tonnes C ha^{-1}. In 1988-89 the annual carbon storage in the New Zealand plantation was approximately 70% of total fossil fuel emissions in New Zealand.

Afzal *et al*. (1999) determine the factors which affect carbon sequestration in trees. *Eucalyptus botryoides* tree of 53 years age and maximum diameter of 65.02 cm with 15.18 meter height sequestered maximum CO_2 (3527 kg) whereas *Robinia pseudoacacia* of 46 years age with minimum diameter of 4.57 cm and having 3.05 meter height stored only 6 kg CO_2. *Pinus roxburgii* tree of 51 years age with 55.12 cm diameter and having maximum height of 20.91 meter stored CO_2 (3492 kg CO2). Thus height and diameter of trees had significant effect on CO_2 sequestration but not age.

David *et al.* (2002) Estimated urban trees in USA had the gross carbon sequestration potential of 22.8 million tC yr^{-1}, whereas within cities carbon sequestration was about 1.2 million tC in New York, 19,300 tC in Jersey City. Urban forests in the Northeast, North central, Southeast and South central regions of USA store and sequester most carbon. The national average carbon storage density of urban forest is 25.1 tC ha^{-1}, compared with forest stands 53.5 tC ha^{-1}.

Meenakshi *et al.* (2010) calculated the carbon storage potential of Eucalyptus (*Eucalyptus tereticornis*), Sal (*Shorea robusta*), Teak (*Tectona grandis*) and Poplar (*Populus deltoides*) forests in India using dynamic growth model (CO_2FIX). Result revealed that net annual carbon storage potential for Poplar (8 Mg Cha^{-1} yr^{-1}) fallowed by Eucalyptus (6 Mg Cha^{-1} yr^{-1}) plantations, Teak forests (2 Mg Cha^{-1} yr^{-1}) and less in Sal forests (1 Mg Cha^{-1} yr^{-1})

Ishan *et al.* (2013) estimated the carbon storage of 25 different species in Gujarath using non-destructive or allometric method with the available data of trees girth and height. The carbon storage was maximum in *Tamarandus indica* 55.95 tC, 44.81 tC in *Terminalia arjuna* and the least value of carbon storage estimated in *Emblica officinalis* 1.77 tC.

Yuanqi *et al.* (2015) study conducted in four subtropical plantations and a natural shrubland (as a control) to know how the carbon storage potential. Results indicated that

Eucalyptus urophylla accumulated more carbon in its biomass, 1.9 times more than the 10-species mixed plantation, 2.2 times more than *Castanopsis hystrix* plantations and 1.5 to 3 times greater carbon than naturally recovered shrubland.. Information about the carbon allocation patterns was useful for climate change mitigation and sustainable forest management.

Chaturvedi *et al*. (2015) Investigated the carbon density (CD) and also carbon accumulation (CA) of *Tectona grandis* (Teak) and *Shorea robusta* (Sal) in mono and multi-specific stands in a tropical region of India. It was found that average aboveground carbon density and carbon accumulation across the stands were 136 tC ha^{-1} and 5.3 tC ha^{-1} yr^{-1} respectively. CA and CD of multi-specific stands was more compared to mono-specific stands.

Ram *et al.* (2016) assessed the species wise carbon sequestration in three community forests and three collaborative forests. Collected 31, 32, and 33 samples from Gadhanta-Bardibash, Banke-Maraha and Tuteshwarnath collaborative forests respectively. While 22, 25and 30 samples from Chyandanda, Buddha and Chureparwati community forests correspondingly. The estimated carbon stock of *Shorea robusta* in Banke-Maraha collaborative forest was the highest 35.93 t ha^{-1} in 2011 and was slightly decreased to 34.43 t ha^{-1} in 2012 and 32.02 t ha^{-1} in 2013. But in Chyandanda community forest it was the least 7.97 t ha^{-1}, 8.92 t ha^{-1}, and 10.29 t ha^{-1} in 2011, 2012, and 2013 respectively.

Rajni *et al* (2016) estimated the carbon stock in *Tectona grandis* (Teak) based agroforestry system. With girth at breast height (GBH), height and different age group teak trees (1.5, 3.5, 7.5, 13.5, 18.5 and 23.5 years). Obtain the result teak-wheat (56.92%) > teak-wild oat (54.94%) > teak-gram (37.15%) > teak-ashwagandha (11.86%).

Erik *et al*. (2016) investigated the urban vegetation carbon sequestration potential. It was found that the vegetation contribution to the total CO_2 change in Mexico and Singapore shows 1.4% and 4.4% at both sites respectively.

Ankith *et al.* (2017) carried out comparative analysis on carbon stock of three dominant tree species *Azadirachta indica*, *Acacia sp*. and *Cassia sp* in planned green city Gandhinagar and unplanned industrial town Mahesana in Gujarat State. In both Gandhinagar and Mahesana towns carbon stock estimated was maximum in *Azadirachta indica* compared to *Acacia sp*. and *Cassia sp*. Total number of trees in Gandhinagar town is much higher compared to Mahesana town. Thus estimated carbon stock of selected tree species in Gandhinagar is much higher as compared to Mahesana town which is more arid than Gandhinagar.

Inkyin *et al*. (2018) assessed the aboveground carbon sequestration potentials of four agroforestry tree species. The outcome of the aboveground carbon storages of *Morinda tinctoria*, *Terminalia oliveri*, *Rhus paniculata* and *Emblica officinalis* were 6.88, 6.59, 4.34 and 3.53 kg C tree^{-1} correspondingly. And they also did the comparision between mixture of agroforestry system. Mixture of *M. tinctoria* and *E. officinalis* had a higher carbon sequestration potential (1331 kg C ha^{-1}) than the mixture of *R. paniculata* and *T. oliveri* (1151.40 kg C ha^{-1}).

2.3 Productivity of trees

Surendra *et al*. (1991) study described the biomass, productivity, and nutrient cycling in an 8-year-old *Eucalyptu stereticornis* (*Eucalyptus* hybrid) plantation and compare them with those of a *Populus deltoides*. And plantation of the same age natural Sal (*Shorea robusta*) forest and other natural forests of the central Himalaya. Results indicated that the total vegetation biomass of the *Eucalyptus* plantation (126.7 t ha^{-1}) was lower than that of the species *populus deltoids* plantation (176 t ha^{-1}) and natural forests (163.4–786.7 t ha^{-1}). The net primary productivity of the *Eucalyptus* plantation (23.4 t ha^{-1} year^{-1}) was similar to that of the *P. deltoides* plantation (25 t ha^{-1} year^{-1}) and the natural Sal forest (22 t ha^{-1} year^{-1}).

Rosse (1991) analysed the simple model of photosynthetic and nutritional controls over foliar dynamics to compare the magnitude of the growth response of forest stands to increased rates of photosynthesis and nutrient supply. According to the model, plants growing under nutrient-limited conditions can only respond positively to enhanced photosynthetic rates, if they simultaneously increase their nutrient uptake or reduce nutrient concentrations in stem, branch, root or senescing leaf tissue or shift their carbon allocation in favour of biomass components with low nutrient concentrations.

David (2002) worked on the potential role of timber plantations**.** He accomplished that timber plantations are one of the few means by which large areas of cleared or degraded landscape can be reforested. These usually restore the productive capacity of the landscape but do little to recover biological diversity.

Ris *et al*. (2003) analysed Teak plantations (2 to 7year old) under an agroforestry system in East Java, from October 1996 to September 2000. The total biomass range was 2.76 t for 2 year old stands to 55.39 t ha^{-1} for 7 year old stands. In 7 year stands the annual amount of leaf litter fall was 5.58 t ha^{-1}. The NPP increased with age and the mean productivity was 36.05 t ha^{-1} yr^{-1} in 7 year old stands. At the young age the productivity of Teak trees in the Madiun forest istrict was moderate because of the temperatures and high humidity. productivity of teak plantation appears to be influenced by management practices contains cultural practices, fertilization and thinning.

Jose *et al*. (2008) studied on silvicultural effects on the productivity and wood quality of eucalypt plantations. They found that Eucalypt silviculture usually targets high growth rates and short rotations. High growth rates and to some extent low nutrient use efficiencies of Eucalyptus leads to high nutrient demand and a high potential for nutrient depletion.

Hernan *et al*. (2008) test the possibility of Growth, production and carbon sequestration of silvopastoral systems in costarica. They tested *Brachiaria brizantha* against *Hyparrhenia rufa* and established three indigenous tree species *Dalbergia retusa*, *Pithecellobium saman*, *Diphysa robinioides*. Plots were grazed for 4 to 5 days at 2 months intervals. Result shows that there was no effect of trees on grass yield and viceversa. The above and below ground biomass carbon in treeless pasture and silvopastoral systems was 3.5 and 12.5 Mg C ha^{-1} respectively. *B. brizantha* stimulated tree root production which was the result of TSOC (total soil organic carbon).

Brittain *et al*. (2015) assessed the effect of forest to urban land conversion on productivity and on biomass structure across Eastern Massachusetts. Urban land uses held mean biomass density of 33.5 ± 8.0 Mg C ha^{-1} which was less than half of the biomass of forest land. *Quercus rubra* tree analysis suggest that basal area increased from 17.1 ± 3.0 to 35.8 ± 4.7 cm2 yr^{-1} and aboveground biomass growth rate of 1.8 ± 0.4 Mg C ha^{-1} yr^{-1}.

Juha *et al*. (2016) assessed the variation in forest productivity among differnet tree species. Jack pine, Black spruce, Lodgepole pine, Trembling aspen and White spruce in Western Canada. Tree-ring data related to annual increase in diameter was used to estimate the wood volume annual growth increments. Annual growth estimates of 170 trees from 5 selected species showed inter-annual variability of whole tree growth and breast height increments were highly correlated for most trees.

Alvaro *et al*. (2018) conduct the study to develop yield and volume models for teak as living fences in silvopastoral structures. The estimated yield in silvopastoral system was 49 m^3 ha^{-1} at 26 years in the least productive sites and 225 m^3 ha^{-1} at 15 years in most productive sites in the selected study area. For the highest quality site mean annual yield was 15.3 m^3 ha^{-1} $year^{-1}$ at age 15 years for 160 trees per hectare. Obtained growth and yield model is used to estimate the teak productivity.

III MATERIAL AND METHODS

Study was conducted on **"Studies on influence of different tree species on soil fertility"** in tree arboretum, at GKVK Bengaluru. This chapter gives the brief description of study area, sampling procedure and techniques used for the selection of samples. The statistical tools and techniques used in analysing the data.

3.1 Site description

Our study was conducted during 2017-2018 in tree arboretum (Plate 1) at UAS, Bengaluru in block C, established in 1987. It is located about 15 Km away from Bengaluru City. Geographically, the place is located at 13^0 05´ N latitude and 77^0 34´ E longitude. The center is at an altitude of 924 meters above mean sea level. The annual rainfall ranges from 528 mm to 1374.4 mm with the mean of 915.8 mm. Temperature ranges from 27^0-33^0 C (maximum temperature) and 15^0-19^0C (minimum temperature).

Study area is a established tree arboretum plantation (Plate 1) of 31 year old. Consisting of 16 evergreen and 20 deciduous tree species planted at 2 x 2m spacing, totally it consists of 2500 trees of individual species. For the study 4 deciduos indigenous tree species were selected. Viz.

1. *Tectona grandis* (Teak)
2. *Terminalia tomentosa* (Kari matti)
3. *Terminalia arjuna* (Hole matti)
4. *Terminalia bellarica* (Thare)

3.1.1 Teak (*Tectona grandis*)

Teak is native to South and Southeast-asia, mainly India, Srilanka, Indonesia, Malaysia, Thailand, Myanmar and Bangladesh but is naturalised and cultivated in many countries in Africa and the Caribbean. Myanmar's teak forests account for nearly half of the world's naturally occurring teak. Age of the *Tectona grandis* (Teak) at tree arboretum is 31 year old (Plate 2).

Tropical hardwood deciduous tree species. Teak wood has a leather-like smell when it is freshly milled. It is particularly valued for its durability and water resistance, and is used for boat building, exterior construction, veneer, furniture, carving, turnings, and other small wood projects.

3.1.2 Kari matti (*Terminalia tomentosa*)

It is a prominent part of both dry and moist deciduous forests in southern India up to 1000 m. *Terminalia tomentosa* (Plate 3) has a remarkable attributes, some members of the species store water in the dry season. A survey conducted at Bandipur National Park, India showed that a proportion of trees store water and there is a girth dependent increase in the frequency and amount of water storage. The mechanism and ecophysiological significance of this water storage is not known. Age of *Terminalia tomentosa* (Kari matti) at tree arboretum is 31 year old.

3.1.3 Hole matti (*Terminalia arjuna*)

The tree is about 20–25 metres tall usually has a buttressed trunk, and forms a wide canopy at the crown, from which branches drop downwards. It has oblong, conical leaves which are green on the top and brown below; smooth, grey bark; It has pale yellow flowers which appear between March and June. Its glabrous, 2.5 to 5 cm fibrous woody fruit, divided into five wings, appears between September and November.

The tree is usually found growing on river banks or near dry river beds in Bangladesh, south and central India. The tree is one of the species whose leaves are fed on by the *Antheraea paphia* moth which produces the tassar silk, a wild silk of commercial importance. Age of *Terminalia arjuna* (Hole matti) at tree arboretum (Plate 4) is 31 year old.

3.1.4 Thare (*Terminalia bellarica*)

Terminalia bellarica is a large deciduous tree common on plains and lower hills in Southeast Asia, where it is also grown as an avenue tree. Two varieties of *T. belerica* are found in India, one with nearly globular fruit 1/2 to 3/4 inch in diameter, the other

Plate 1. Overview of the tree arboretum

Plate 2. Teak (*Tectona grandis*) tree plantation

Plate 3. Kari matti (*Terminalia tomentosa*) tree plantation

Plate 4. Hole matti *(Terminalia arjuna)* tree

Plate 5. Thare *(Terminalia bellarica)* tree

with ovate and much larger fruit. The pulp of the fruit (*Beleric myrobalan*) is considered by Hindu physicians to be astringent and laxative, and is prescribed with salt and long pepper in affections of the throat and chest. Age of *Terminalia bellarica* (Thare) at tree arboretum (Plate 5) is 31 year old.

3.2 Collection of soil samples

The soil samples were collected from the tree arboretum at two different depths (0-15cm and 15 -30cm) under the tree species (*Tectona grandis, Terminalia tomentosa, Terminalia arjuna* and *Terminalia bellarica),* and also collected from agricultural land for soil analysis. 6 samples were collected under each tree species (3 replications X 2 depths). And a total of 24 samples were collected from tree arboretum (4 tree species X 6 samples) and another 6 samples from agricultural land. Soil sampling was done according to the standard procedure. Soil samples were collected in a polythene bags and labelled.

3.3 Laboratory analysis of soil samples.

Soil samples then brought to the lab. Samples were dried under shade and gently crushed in morter and sieved using 2 mm sieve for pH, EC, N, P, K and for organic carbon, soil was sieved with 0.2mm sieve and stored for further analysis.

Table 1: The details of the methodology adopted for soil analysis

Particulars	Methodology adopted	Reference
pH	1:2.5 soil water suspension with the help of digital pH meter	Jackson (1973)
EC (ds/m)	1:2.5 soil water suspension using conductivity bridge	Jackson (1973)
Organic Carbon (%)	Walkley and Black rapid titration method	Walkley and Black (1934)
Available N (kg ha^{-1})	Alkaline potassium permanganate method	Subbiah and Asija (1956)
Available P_2O_5 (kg ha^{-1})	Spectrophotometric (Olsen Extraction method with 0.5 M $NaHCO_3$)	Jackson (1973)
Available K_2O (kg ha^{-1})	Flame photometric (Extraction with N NH_4OAc of pH 7)	Jackson (1973)

3.4 Estimation of tree productivity (m^3/tree or m^3/ha)

Productivity defines various measures of the efficiency of production. A productivity measure is expressed as the ratio of output to inputs used in a production process

The tree productivity indicates increase of tree biomass per unit area. It is calculated by non harvest method by taking the measurement of tree girth and height and then volume was calculated. I randomly selected 20 trees in each species and mean volume, height and girth were recorded and then finally calculated total productivity per hectare.

$$V = \text{Basal area} \times \text{height} \times \text{farm factor}$$

$$\text{Basal area} = g^2/4\pi$$

Where 'g' is the girth at breast height (m) and 'π' is 3.4125(Chaturvedi and Khanna, 1981)

3.4.1 Tree height

The total tree height was measured with help of Ravi altimeter (Chaturvedi and Khanna, 1981) from the ground level to the tip of the tree and it is expressed in meter (m).

3.4.2 Tree girth

The girth at breast height (GBH) 1.37 m from the ground level was measured with the help of measuring tape or callipers and expressed in cm.

3.5 Computation of above ground biomass of tree

The tree biomass was estimated by multiplying mean volume with specific wood density and expressed in kg $tree^{-1}$.

Above ground biomass (dry biomass) = Volume × Specific wood density.

The specific wood density used in the study was obtained from the (FAO, 1998) The specific wood densities of *Tectona grandis* is 0.55gm^{-3}, *Terminalia tomentosa* is 0.74 gm^{-3}, *Terminalia arjuna* is 0.68 gm^{-3} and *Terminalia bellarica* is 0.72 gm^{-3}.

3.6 Above ground biomass of tree in terms of carbon equivalent (C kg tree^{-1}) or carbon sequestration potential of tree

Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide or other forms of carbon to mitigate global warming. Carbon dioxide is naturally captured from the atmosphere through biological, chemical and physical processes. Trees subsurface saline aquifers, reservoirs, ocean water, aging oil fields are the carbon sinks.

Carbon sequestration in *Tectona grandis, Terminalia tomentosa, Terminalia arjuna* and *Terminalia bellarica* at tree arboretum was calculated by adopting non destructive method of biomass estimation. Sampling was carried out by randomly selecting 20 plants in each species. Tree girth at breast height (GBH), height of individual trees was recorded. The above ground biomass of standing trees was estimated by working out the basal area.

The above ground dry biomass of trees in terms of carbon equivalent was computed by multiplying the total dry biomass with default value i.e. 0.45 as it is assumed that the carbon content of the biomass varies between 0.45 to 0.50 and expressed in terms C kg tree^{-1} or ha^{-1} out of the total dry biomass

$$\text{Carbon sequestration (C kg ha}^{-1}\text{)} = \text{Biomass} \times 0.45\text{(default value)}$$

3.7 Statistical analysis

The data was analysed statistically for the test of significance using Fisher's method of analysis of variance. The level of significance of F-test was at 5%. The interpretation of data was done using critical difference (CD) values.

IV RESULTS AND DISCUSSION

Many forestry experts claim that the establishment of plantations will reduce or eliminate the need to exploit natural forest for wood production. Worldwide, an estimated 15% of plantations in tropical countries are established on closed canopy natural forest.

In the Kyoto Protocol, there are proposals encouraging the use of plantations to reduce carbon dioxide levels. Trees remove carbon dioxide from the air as they grow, tree planting can be used as a geoengineering technique to remove CO_2 from the atmosphere. Desert greening projects are also motivated by improved biodiversity and reclamation of natural water systems, but also improved economy and social welfare due to increased number of jobs in farming and forestry.

Throughout the tropics in Africa, Asia and Latin America, one billion people are in need of food security and sustainable development. Reforestation and farm forestry can help diversify incomes and provide some of the goods and services required by these communities. It is important to identify appropriate technical and socio-economic measures for establishing tree plantations.

Study was carried out with three main objectives to analyse the soil fertility status under different tree species, to estimate tree productivity and to estimate the carbon sequestration potential of tree species in tree arboretum, GKVK Bengaluru.

4.1 Assessment of tree productivity under different tree species

Assessment was done based on the data of growth performances *viz.,* height (m), girth (m), basal area (m^2), volume (m^3) of four tree species *Tectona grandis, Terminalia bellarica, Terminalia tomentosa* and *Terminalia arjuna.*

Productivity defines various measures of the efficiency of production. A productivity measure is expressed as the ratio of output to inputs used in a production process.

Table 2: Average growth performance of different tree species at tree arboretum

Particulars	Height (m)	Girth (m)	Productivity (m^3 tree^{-1}year^{-1})
Terminalia bellarica	13.14^{a}	0.53^{bc}	0.22^{a}
Tectona grandis	11.16^{b}	0.59^{a}	0.23^{a}
Terminalia tomentosa	9.31^{c}	0.48^{c}	0.12^{b}
Terminalia arjuna	10.12^{bc}	0.60^{a}	0.22^{a}
F value (<0.05)	0.0001^{*}	0.0056^{*}	0.0091^{*}
SEM	0.58	0.026	0.024
CD 5%	1.11	0.074	0.069

* Significance at 5%

Value within the column following same letter are not significantly different (P<0.05)

4.1.1 Assessment of tree height(m)

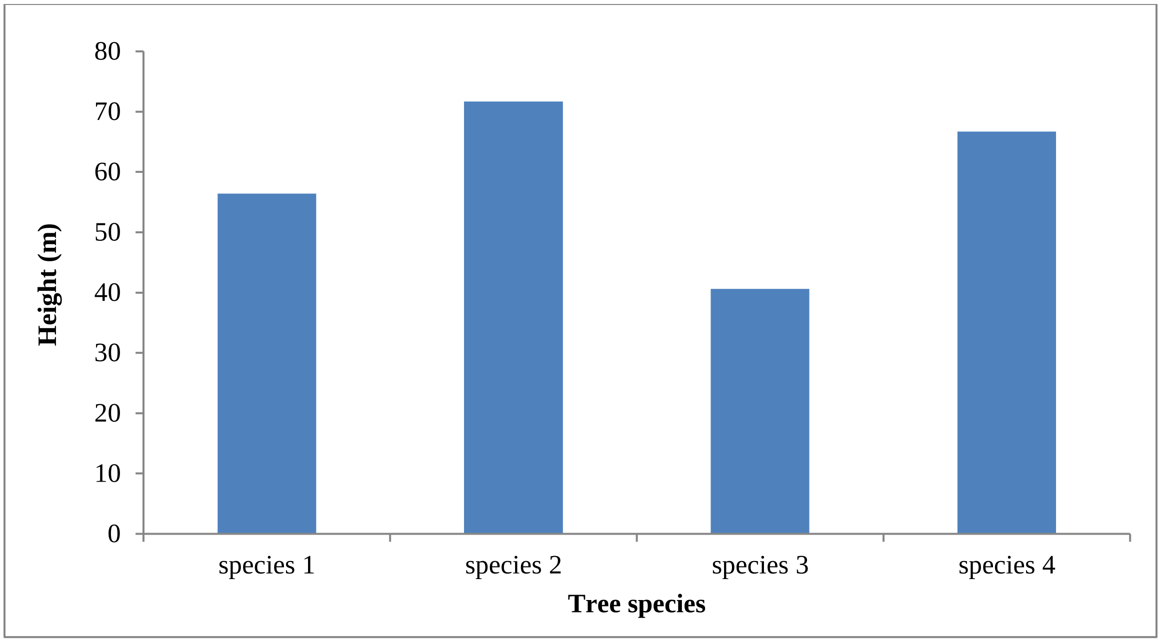
In case of tree height (given in Table 2.) measured heights of selected tree species were 11.16m, 13.14m, 9.31m and 10.12m for *Tectona grandis, Terminalia bellarica, Terminalia tomentosa, Terminalia arjuna* respectively. Among those four tree species *Terminalia bellarica* shows maximum height fallowed by *Tectona grandis, Terminalia arjuna* and least was *Terminalia tomentosa*(Fig.1). Height growth shows significant difference among four selected tree species.

Terminalia tomentosa and *Terminalia arjuna* tree species are having values 9.31m and 10.12m respectively. Thus they are not showing much difference with respect to height.

Mean height of *Terminalia bellarica* was 13.14m which was highest and for *Terminalia tomentosa* was 9.31m which was the least value among other tree species.

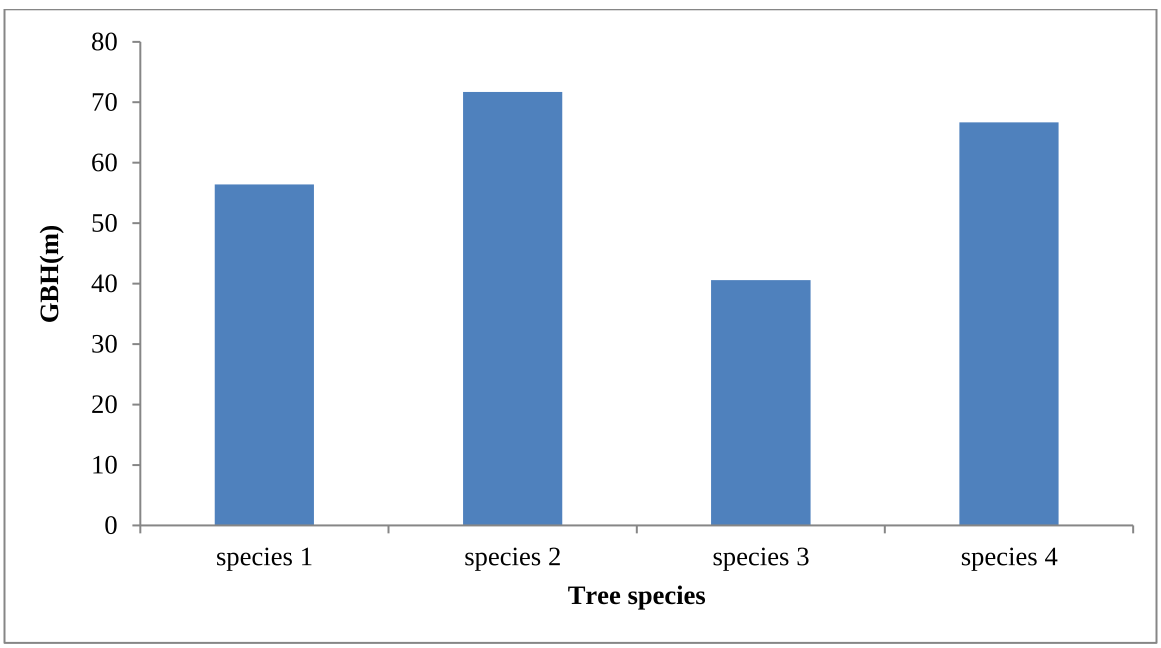
4.1.2 Assessment of tree girth(m)

Among the four tree species girth value was found that 0.59m ,0.53m ,0.48m, and 0.60m (Table 2) of *Tectona grandis, Terminalia bellarica, Terminalia tomentosa and*



Species 1: *Tectona grandis*
Species 2: *Terminalia bellarica*
Species 3: *Terminalia tomentosa*
Species 4: *Terminalia arjuna*

Fig. 1. Height(m) of different tree species at tree arboretum



Species 1: *Tectona grandis*
Species 2: *Terminalia bellarica*
Species 3: *Terminalia tomentosa*
Species 4: *Terminalia arjuna*

Fig. 2. Girth at breast height (m) of different tree species at tree arboretum

Terminalia arjuna respectively. Result showed heighest girth value at *Terminalia arjuna* fallowed by *Tectona grandis, Terminalia bellarica,* and least at *Terminalia tomentosa* (Fig. 2). All the four selected tree species were significantly different with respect to Girth.

Average girth of *Terminalia arjuna* was maximum (0.60m) and *Terminalia tomentosa* was minimum (0.48m).

In both the cases (height and girth) *Teminalia tomentosa* had the lowest value. But *Terminalia bellarica* had highest height and *Terminalia arjuna* had highest girth. It shows trees having highest height are not necessarily be having maximum girth.

4.1.3 Assessment of different tree productivity

Results depicted in the Table 2. shows that the productivity is different for different trees. Study presented that all the tree species which are considered in work are showing different productivity values 0.23 m^3 $tree^{-1}$, 0.22 m3 $tree^{-1}$, 0.12m^3 $tree^{-1}$ and 0.22m^3 $tree^{-1}$ for *Tectona grandis. Terminalia bellarica, Terminalia tomentosa* and *Terminalia arjuna* respectively (Fig.5). The productivity of *Tectona grandis* is maximum and *Terminalia tomentosa* is having lowest productivity among four species considered.

Mean productivity of *Tectona grandis* was 0.23 m^3 $tree^{-1}$ with maximum calculated value and *Terminalia tomentosa* with minimum calculated value of 0.12m^3 $tree^{-1}$.

Terminalia tomentosa showing lowest result in all the cases. viz Height. Girth, biomass and productivity. Different factors attribute for increase and decrease in productivity. There is a positive correlation between the height, girth(GBH) biomass and productivity of different tree species(Fig.3 and Fig.4).

Productivity of a tree is controlled by multiple number of genes. Each gene determines the expression of certain character, and contributes to the final yield through the additive and/or interactive effect.

The productivity of most forest plantations is less than their physiological potential as defined by the prevailing climate, because the supply or capture of light, water and nutrients is less than optimal. However, maximum growth does not equate to maximum wood values as reported by Jose *et al*. 2004. Timber plantations are one of the few means by which large areas of cleared or degraded landscape can be reforested. These usually restore the productive capacity of the landscape but do little to recover biological diversity. (David, 2002)

Use of indigenous species than exotic species increase the yield of the timber and encouraging the different plant understories to improve the degree of ecological restoration and to restore their former biodiversity.

In Northern Ireland, researchers have found that temperature alone (rainfall, within the ranges experienced, was not important) influenced leader growth in lodgepole pine and Sitka spruce (Kilpatrick and Seaby 1990). Similarly, in Northern Britain, workers have found that accumulated temperature and windiness were the main factors determining productivity in Sitka spruce (Worrell and Malcolm 1990).

Frost can have a far greater effect on survival and early growth of trees. Frost damage represented over 60 percent of all incidences of damage recorded by the Forest Service under the 'Reconstitution' scheme in the mid-1990 (Aldhous 1974).

Trees on the edges of plantations have greater taper and larger root systems than those from the centre of the plantation. In extreme cases, individual trees can take on a form where the branches are swept to the leeward, resulting from the death of buds on the windward side. All of these results of wind damage will decrease the economic value of the crop. (Ni Dhubhain *et al*. 2001).

Thinning and pruning usually improve average crop-tree form, and improve value and harvest index (Bower 1999), thus resulting in improving and even increasing net wood productivity compared to unthinned and unpruned stands. It includes removal of diseased and insect-infested trees and thus maintain the better vigour.

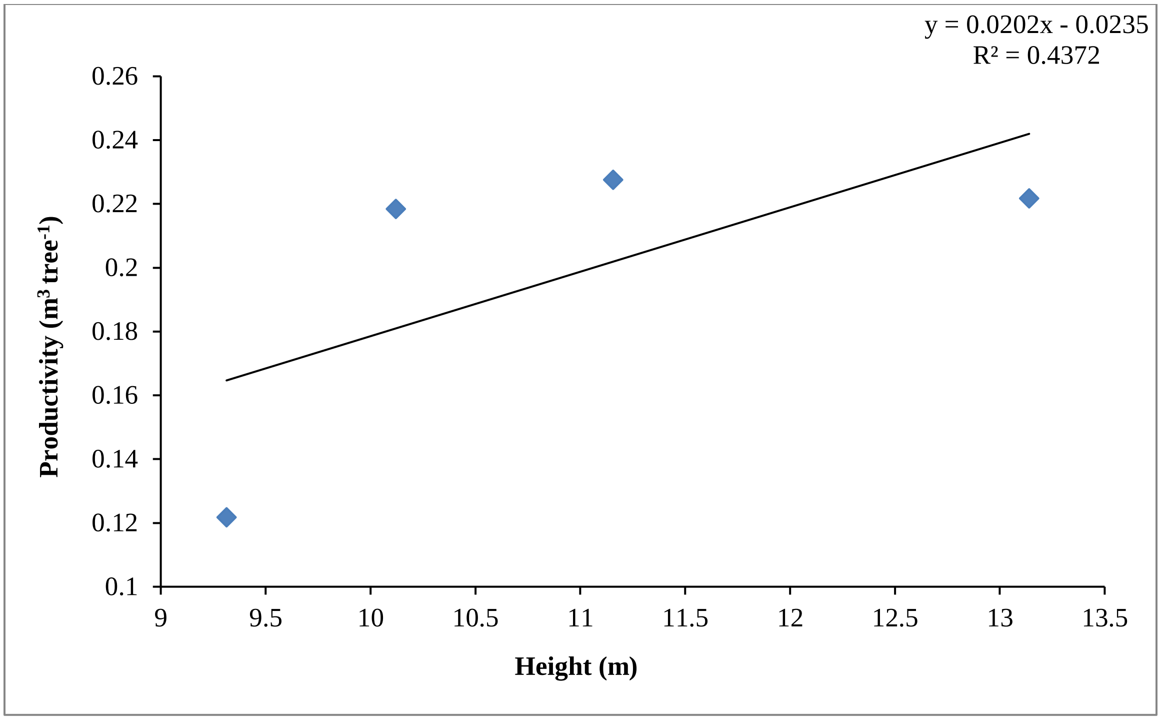


Fig. 3. Correlation between productivity (m^3 $tree^{-1}$) and Height (m) of different tree species

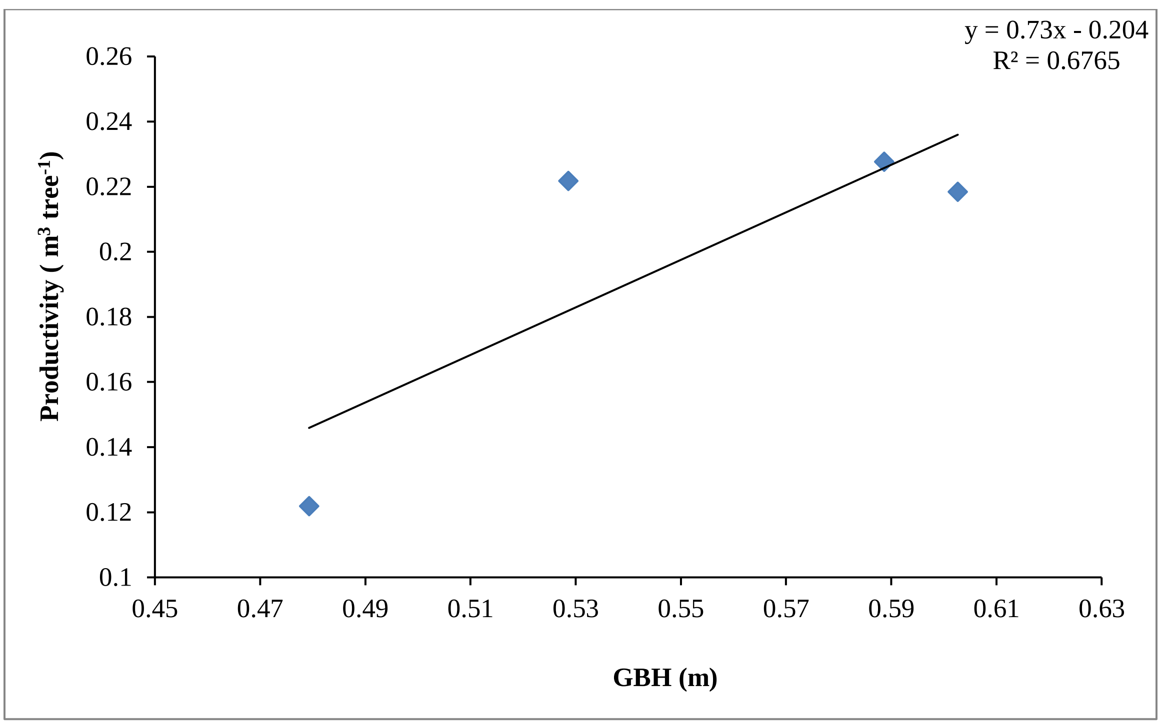
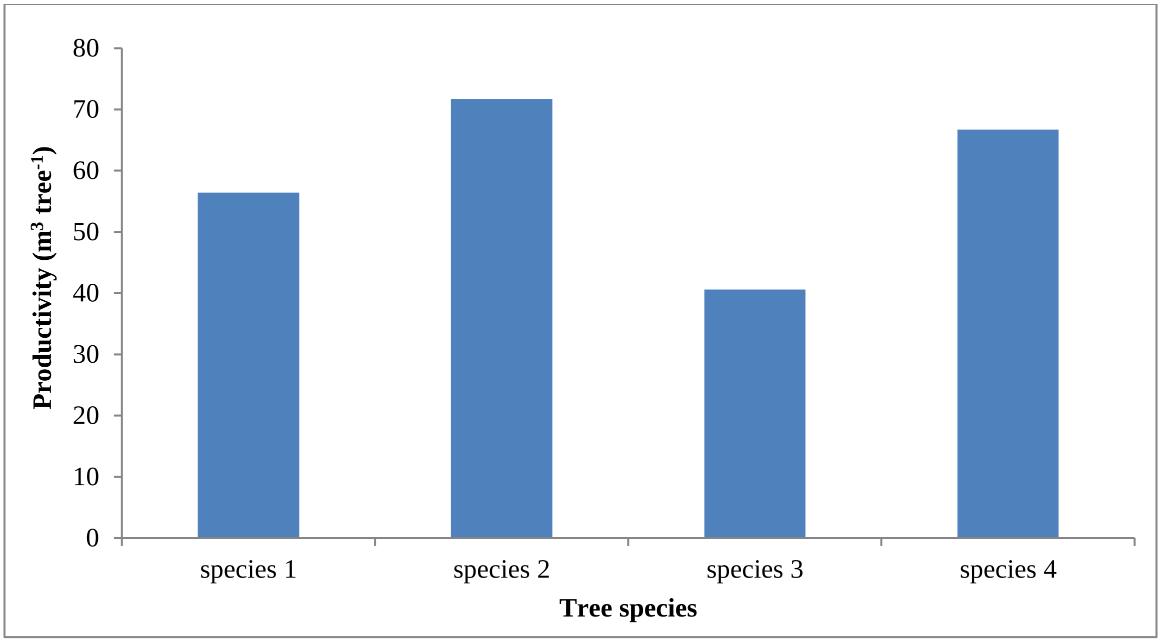
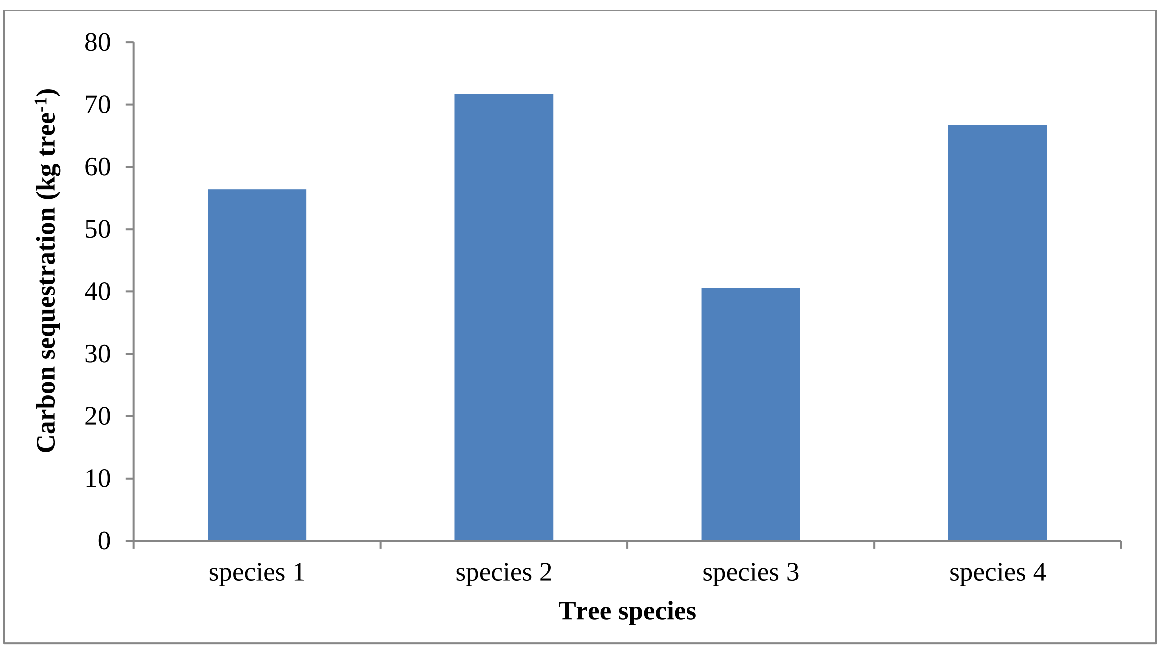


Fig. 4. Correlation between productivity (m^3 $tree^{-1}$) and Girth at breast height (m) of different tree species



Species 1: *Tectona grandis*
Species 2: *Terminalia bellarica*
Species 3: *Terminalia tomentosa*
Species 4: *Terminalia arjuna*

Fig. 5. Productivity(m^3 tree^{-1}) of different tree species at tree arboretum



Species 1: *Tectona grandis*
Species 2: *Terminalia bellarica*
Species 3: *Terminalia tomentosa*
Species 4: *Terminalia arjuna*

Fig. 6. Carbon sequestration (kg tree^{-1}) of different tree species established at tree arboretum

Forests on sites with the coldest conditions experienced on average an increase in productivity, while forests on the warmest sites showed a productivity decrease (Xavier *et al*. 2017) Mixed stand type plantation are more productive and economic. since they can provide many social ecosystem, ecological functions and services better than mono-specific stands.

Table 3: Correlation co-efficient of productivity for different tree species.

Height v/s productivity	+0.437
Girth v/s productivity	+0.676
Biomass v/s productivity	+0.732

4.2 Carbon sequestration potential of different tree species

Carbon sequestration in *Tectona grandis, Terminalia tomentosa, Terminalia arjuna* and *Terminalia bellarica* at tree arboretum was calculated by adopting non destructive method of biomass estimation. Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide or other forms of carbon to mitigate global warming.

Table 4: Carbon sequestration (kg/tree) of different tree species established at tree arboretum

Tree species	Height (m)	Girth (m)	Volume (m^3)	Carbon sequestration (kg $tree^{-1}$)
Tectona grandis	13.14[a]	0.53[bc]	0.22[a]	56.4[ab]
Terminalia bellarica	11.16[b]	0.59[a]	0.23[a]	71.7[a]
Terminalia tomentosa	9.31[c]	0.48[c]	0.12[b]	40.6[b]
Terminalia arjuna	10.12[bc]	0.60[a]	0.22[a]	66.7[a]
F value (<0.05)	0.0001*	0.0056*	0.0091*	0.0202*
SEM	0.58	0.026	0.024	0.007
CD5%	1.11	0.074	0.069	0.020

* Significance at 5%

Value within the column following same letter are not significantly different (P <0.05).

4.2.1 Carbon sequestration

Data related to carbon sequestration (Table 4) documented that Carbon sequestration potential is different for different tree species. The values are 56.4kg $tree^{-1}$, 71.7 kg $tree^{-1}$, 40.6 kg $tree^{-1}$ and 66.7kg $tree^{-1}$ for *Tectona grandis, Terminalia bellarica, Terminalia tomentosa* and *Terminalia arjuna* respectively. *Terminalia bellarica* is having maximum Carbon sequestration potential fallowed by *Terminalia arjuna*, *Tectona grandis* and minimum *Terminalia tomentosa* (Fig. 6). It was found that all the four different species have significantly different with respect to Carbon sequestration potential. But in case of *Terminalia bellarica* and *Terminalia arjuna* they are not showing much difference as their carbon sequestration potential is nearly same 71.7 kg $tree^{-1}$ and 66.7 kg $tree^{-1}$ respectively.

Average Carbon sequestration potential of *Terminalia bellarica* was 71.7 kg $tree^{-1}$ which was highest among the four species and *Terminalia tomentosa* was 40.6 kg $tree^{-1}$ with lowest value. There is a positive correlation between height, girth, productivity and carbon sequestration (Fig. 7, 8 and 9) of tree species in tree arboretum.

Carbon storage value of all the trees is depending on various factors height and productivity of trees. And it mainly depends on biomass value of trees.

The site-specific quantifications of carbon storage potential is necessary for the management of qualitative and systematic land use system. This study showed that the selected deciduous tree species in the tree arboretum plantation GKVK Bengaluru, possessed the considerable amount of carbon storage potential.

(Bhadwal *et al*.2002) Estimated high potential of carbon storage in Indian forests, especially through raising plantations and they used the Land Use and Carbon Sequestration Model (LUCS) model and estimated that under a regular plantation forestry scenario in India, 7 Pg of carbon would be sequestered between 2000 and 2050.

This study indicated that *Terminalia bellarica* has faster growth compared to other tree species. Thus it is able to penetrate well into the soil to absorb water and the

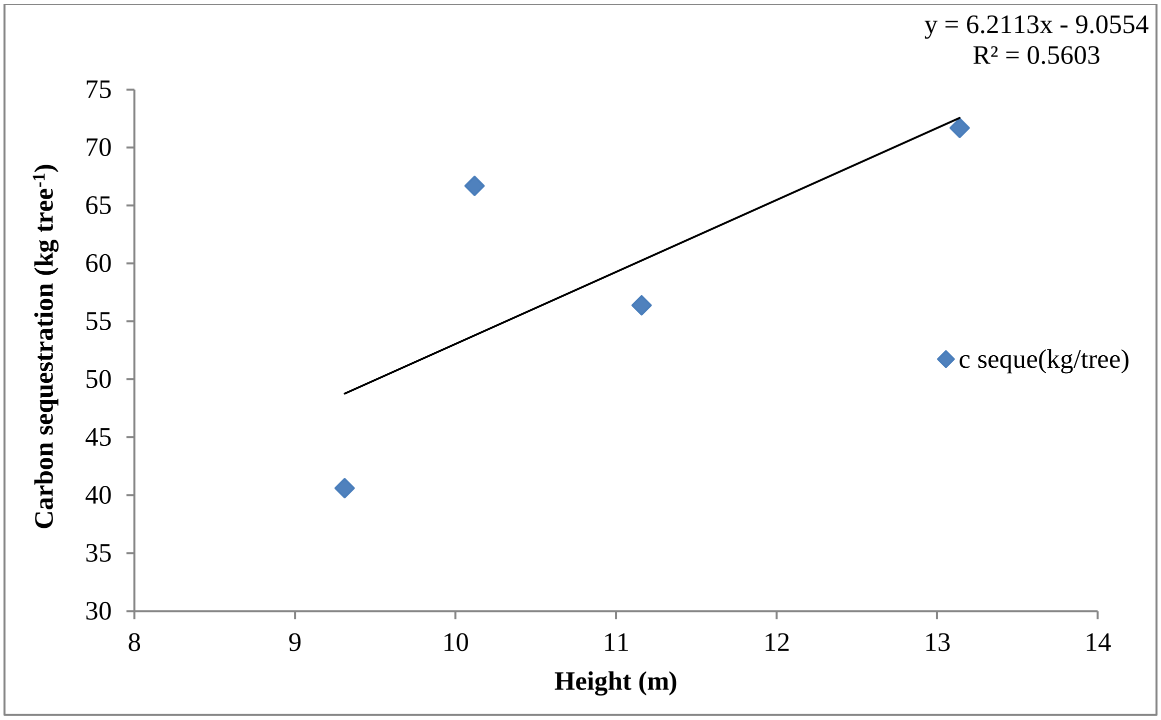


Fig. 7. Correlation between Carbon sequestration (kg tree^{-1}) and Height (m)

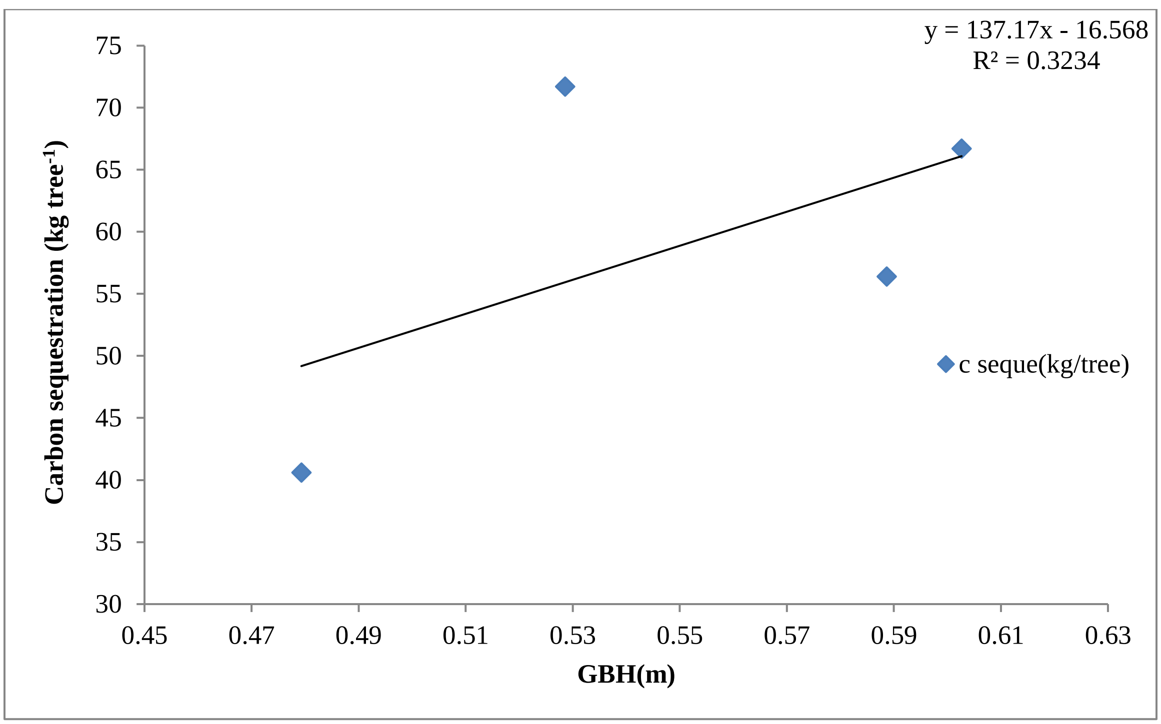


Fig. 8. Correlation between Carbon sequestration (kg tree^{-1}) and GBH (m)

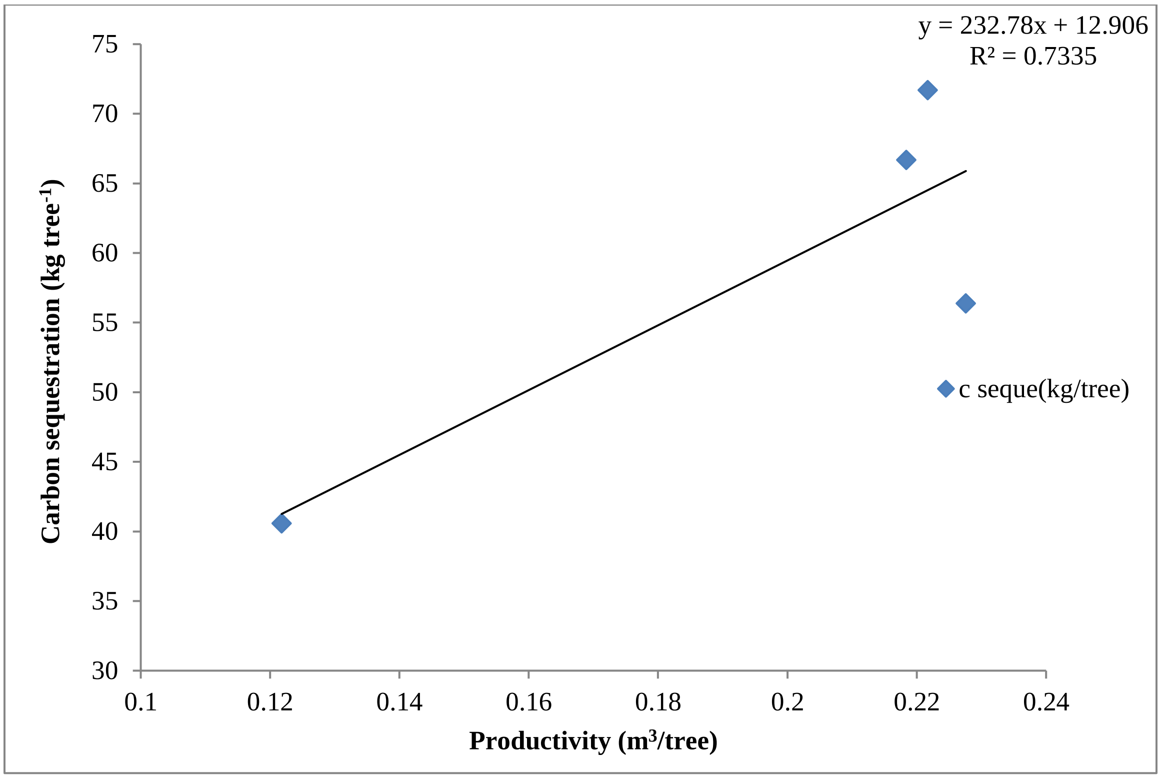


Fig. 9. Correlation between Carbon sequestration (kg tree^{-1}) and Productivity (m^3 tree^{-1})

nutrient than other tree species in the plantation. This made the tree species to utilize the land resources efficiently.

Among four tree species *Terminalia bellarica* and *Terminalia arjuna* are showing more carbon sequestration potential. This would be due to their maximum height, girth and its biomass value (Table 4).

Baishya *et al*. (2009) compared the carbon storage potential of natural semi-evergreen forest and Sal plantation forest in the humid tropical region of northeast India. Their results suggest that the natural forest had lower aboveground biomass (324 Mg ha^{-1}) than the plantation forest (406.4 Mg ha^{-1}).

In case of short rotation forests the carbon pool in soil was higher than the carbon levels in living biomass. Post *et al*. (1990) reported that the ratio between SOC and biomass carbon is 2.5 to 3 times in the terrestrial ecosystem. However, in the tropical forest, the carbon in the soil is roughly equivalent to or less than the above-ground biomass due to degradation as reported by Ramachandran *et al*. (2007).

Due to the increase in litter production and harvest residues, the carbon stock in soil also increased, thereby substantially enhancing the carbon sink function of forests. The carbon stocks also depend upon the tree species, site properties, spacing, climate conditions, age class distribution etc. (Vucetich *et al*. 2000).

Table 5: Correlation coefficient of carbon sequestration for different tree species

Height v/s carbon sequestration	+0.56
Girth v/s carbon sequestration	+0.32
Productivity v/s carbon sequestration	+0.73
Biomass v/s carbon sequestration	+1.00

4.3 Assessment of soil fertility

Soil fertility status under deciduous tree species of tree arboretum is analysed at two different depths (0-15cm and15-30cm). In this study six soil parameters were considered. Viz. Soil pH, Electrical conductivity (EC), Organic carbon(OC), available soil nitrogen(N), phosphorous(P) and potassium(K).

4.3.1 Soil pH under different tree species

Table 6: Depth-wise Soil pH under different tree species at GKVK Bengaluru.

Tree Species	**Soil pH at different depths**	
	0-15 cm	**15-30 cm**
Terminalia bellarica	4.75[b]	4.45[c]
Tectona grandis	5.06[a]	4.88[b]
Terminalia tomentosa	5.37[a]	5.24[a]
Terminalia arjuna	5.15[a]	5.10[a]
Agricultural land	5.41[a]	5.12[a]
F value (<005)	*	*
SEM (±)	0.12	0.07
CD (5%)	0.35	0.22

* Significance at 5%

Value within the column following same letter are not significantly different (P<0.05)

Table 6 represent the changes in the soil pH over depth. The soil reaction (pH) ranged from 4.7 to 5.3 at 0-15cm depth and in 15-30cm depth it ranged from 4.4-5.2. This range of pH is under different tree species like *Terminalia bellarica*, *Tectona grandis*, *Terminalia tomentosa*, *Terminalia arjuna* and in agricultural land. No regular trend in soil pH along the depth of these soils was observed. However, there was slight reduction in pH was noticed along the depths (0-15cm and 15-30cm) of all the selected tree species. It is evidenced that agricultural land showed more pH value than in soil under tree species.

Agriculture land showed maximum pH of soil (5.413) followed by *Terminalia tomentosa*(5.37), *Terminalia arjuna*(5.147), *Tectona grandis* (5.060) and minimum pH of soil was obtained in *Terminalia bellarica* (4.75). This is in case of top layer 0-15cm. However in case of 15-30cm depth pH value ranged from 5.237, 5.123 , 5.097, 4.883 and 4.447 in *Terminalia tomentosa*, Agricultural land, *Terminalia arjuna*, *Tectona grandis* and in *Terminalia bellarica* respectively. (Fig.10). Statistical analysis revealed that all the tree species are significantly different and also it is showing significant difference in both the depths.

In case of agriculture land which is showing maximum pH value. It might be due to applied manure, since it is a cultivated land. However in the tree arboretum plantation decomposition of leaf litter might be the reason for change in pH value along the depth and also among the tree species. Decomposition of leaf litter is known to produce weak acids (Vijay et al. 2007). The soil of broadleaf forests had a stronger acidity.

4.3.2 Soil Electrical Conductivity(ds m^{-1}) under different tree species

Table 7: Depth-wise average soil electrical conductivity (ds m^{-1}) under different tree species in tree arboretum at GKVK Bengaluru.

Tree Species	Electrical conductivity (ds m^{-1}) at soil depths	
	0-15cm	15-30cm
Terminalia bellarica	0.50[a]	0.47[a]
Tectona grandis	0.15[c]	0.13[bc]
Terminalia tomentosa	0.15[c]	0.11[c]
Terminalia arjuna	0.14[bc]	0.11[c]
Agricultural land	0.17[bc]	0.14[bc]
Mean value	0.22[b]	0.19[b]
F value	NS	NS
CD (5%)	0.023	0.014
SEM (±)	0.008	0.005

NS-Non Significance at 5%

Value within the column following same letter are not significantly different ($P<0.05$)

The EC showed in the Table 7 a gradual vertical decreasing tendency as the soil layers deepened. A marginal decrease occurred when the tree species changed from *Terminalia bellarica* (0.503ds m^{-1}), *Tectona grandis* (0.153ds m^{-1}), *Terminalia arjuna* (0.137ds m^{-1}) and *Terminalia tomentosa* (0.147ds m^{-1}). Heighest EC was recorded under *Terminalia bellarica* (0.503ds m^{-1}) and the lowest in *Terminalia tomentosa* (0.147ds m^{-1}) and the agricultural land showed 0.167ds m^{-1}. Compared to the agricultural land *Terminalia bellarica* showed more variation.

Electrical conductivity of soil under selected tree species in my study showing normal value. which is less than 0.8ds m^{-1}. Means it has maintained good soil condition and is favourable for plants to grow.

Statistical analysis revealed that there is no significant difference among the tree species and and with the control plot. Only the *Terminalia bellarica* is exhibiting much difference among the tree species.

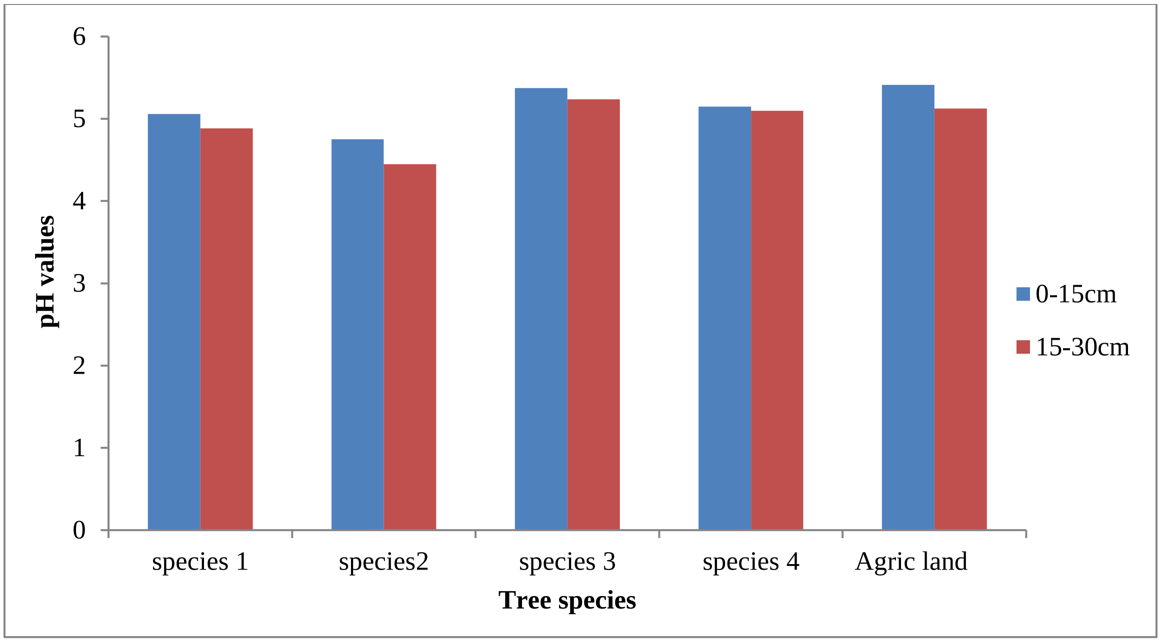
4.3.3 Total soil Organic carbon(%) under different tree species

Table 8: Depth-wise average soil organic carbon (%) under different tree species in tree arboretum at GKVK Bengaluru.

Tree Species	Organic carbon (%) at soil different depths	
	0-15cm	**15-30cm**
Terminalia bellarica	1.27^{b}	0.93^{b}
Tectona grandis	1.52^{a}	1.25^{a}
Terminalia tomentosa	0.93^{c}	0.87^{b}
Terminalia arjuna	1.18^{b}	0.88^{b}
Agriculture land	0.86^{c}	0.82^{bc}
F value	*	*
S.EM(±)	0.006	0.009
CD (5%)	0.019	0.029

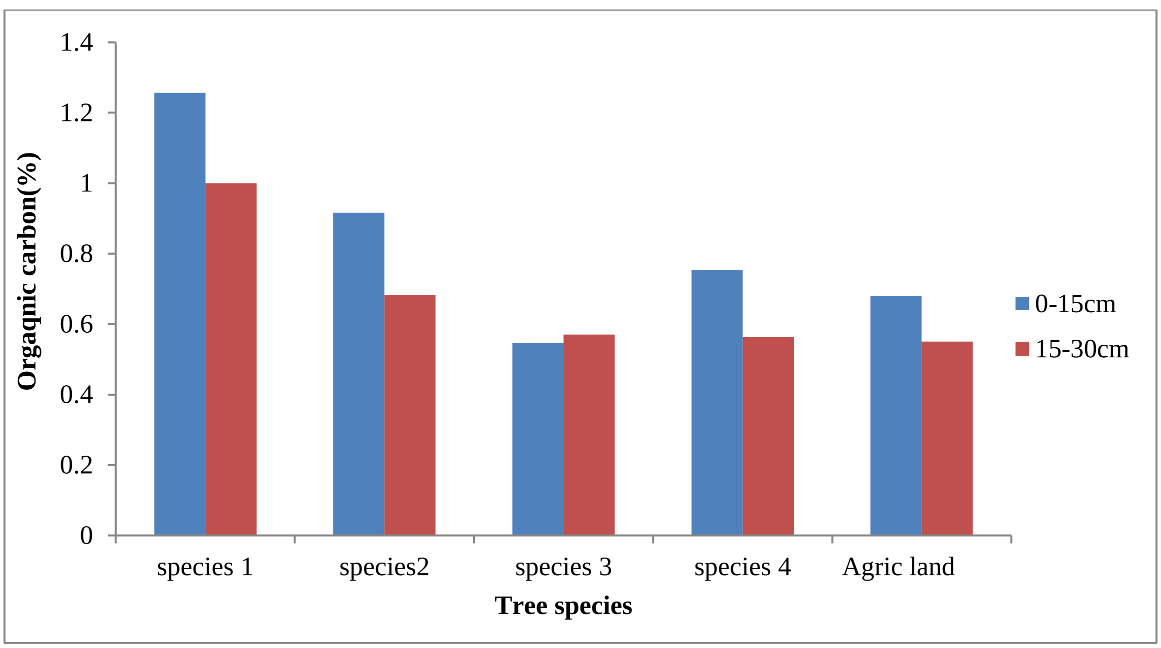
* Significance at 5%

Value within the column following same letter are not significantly different (P <0.05)



Species1: *Tectona grandis* Species 3: *Terminalia tomentosa*
Species 2: *Terminalia bellarica* Species 4: *Terminalia arjuna*

Fig. 10. pH of the soil at different depths



Species1: *Tectona grandis* Species 3: *Terminalia tomentosa*
Species 2: *Terminalia bellarica* Species 4: *Terminalia arjuna*

Fig. 11. Soil Organic carbon (%) at different depths

The maximum amount of organic carbon was observed at the surface layer (0-15cm) than at subsurface layer (15-30cm). Table 8 shows that at surface layer OC values are, *Tectona grandis* is having maximum organic carbon (1.52%) fallowed by *Terminalia bellarica*(1.27%), *Terminalia arjuna*(1.18%), agricultural land (0.86%) and minimum under *Terminalia tomentosa*(0.93%). At subsurface layer OC values are 1.25%, 0.93%, 0.88%. 0.87%, and 0.82% of *Tectona grandis*, *Terminalia bellarica*, *Terminalia arjuna*, *Terminalia tomentosa* and in agricultural land respectively (Fig. 11). Statistical analysis reported that there is a significant difference in soil organic carbon among the selected tree species and also along the depth.

This may be due to maximum canopy growth, stem girth and overall root biomass. As indicated in the Table 2 and Table 4 *Tectona grandis* and *Terminalia bellarica* is having maximum girth and biomass value. Here also those two species are showing maximum values of organic carbon. Decrease in OC value along the depth might be due to lower canopy growth and subsequently less addition of biomass to the subsurface soils. Awasthi *et al.* (2010) reported an improved organic carbon status of soil under the canopy of ber plants. Content of organic carbon underneath the canopy of all the plantations. In general decreased with depth.

4.3.4 Total soil Nitrogen under different tree species

Table 9: Depth-wise average soil Nitrogen (Kg ha^{-1}) under different tree species in tree arboretum at GKVK Bengaluru.

Tree Species	Soil Nitrogen (Kg ha^{-1}) under different depths	
	0-15cm	**15-30cm**
Terminalia bellarica	268.76^{b}	266.55^{b}
Tectona grandis	250.65^{c}	166.48^{e}
Terminalia tomentosa	234.68^{e}	217.00^{d}
Terminalia arjuna	244.49^{d}	223.98^{c}
Agriculture land	292.92^{a}	281.50^{a}
F value	*	*
S.EM(±)	0.7	2.4
CD 5%	2.085	7.938

* Significance at 5%

Value within the column following same letter are not significantly different (P <0.05)

The soil total nitrogen is also concentrated in the top 15 cm under the canopy of all trees. Furthermore, the variation in available N content in the soil column is higher under selected agriculture land (292.92kg ha^{-1}) than under tree species.

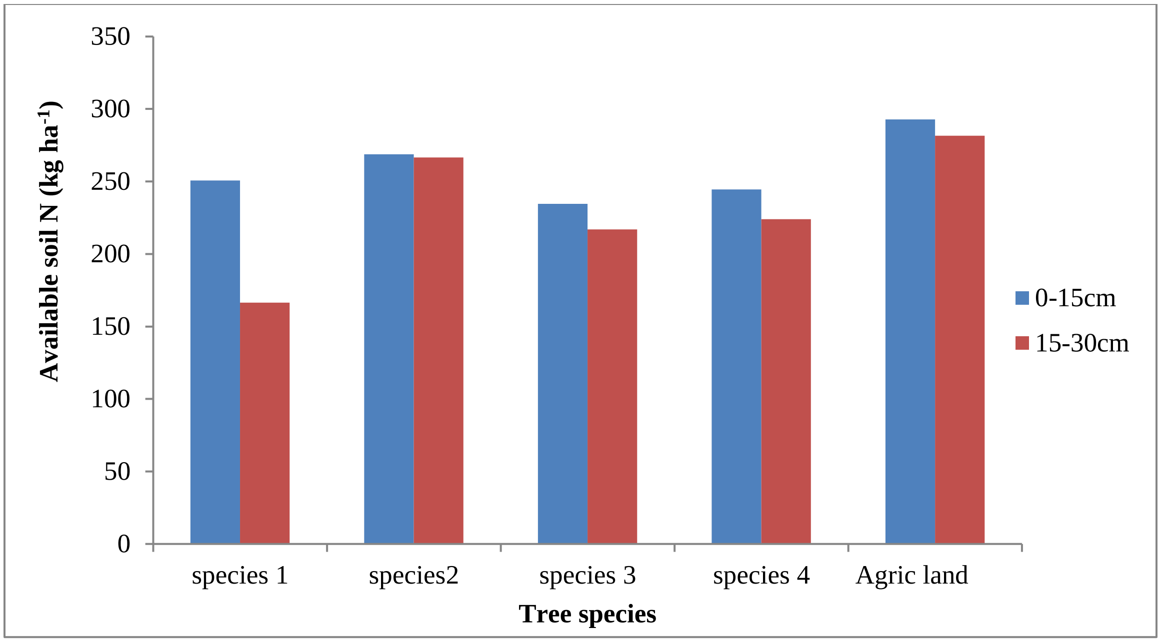
At the surface layer of 0-15cm soil nitrogen was more under *Terminalia bellarica* fallowed by *Tectona grandis* and *Terminalia arjuna* and low under *Terminalia tomentosa* which is 268.76kg ha^{-1}, 250.65kg ha^{-1}, 244.49kg ha^{-1} and 234.68kg ha^{-1} respectively. In case of subsurface layer of 15-30cm agricultural land is showing maximum value of 281.50kg ha^{-1}.

Terminalia bellarica having maximum soil N content fallowed by *Terminalia arjuna*, *Terminalia tomentosa* and minimum under *Tectona grandis* (Fig. 12).

According to the statistical analysis all the tree species showing significant different with respect to the soil N content. *Terminalia bellarica* showing greater significant difference compare to other tree species. There is a less significant difference between *Tectona grandis* and *Terminalia arjuna*.

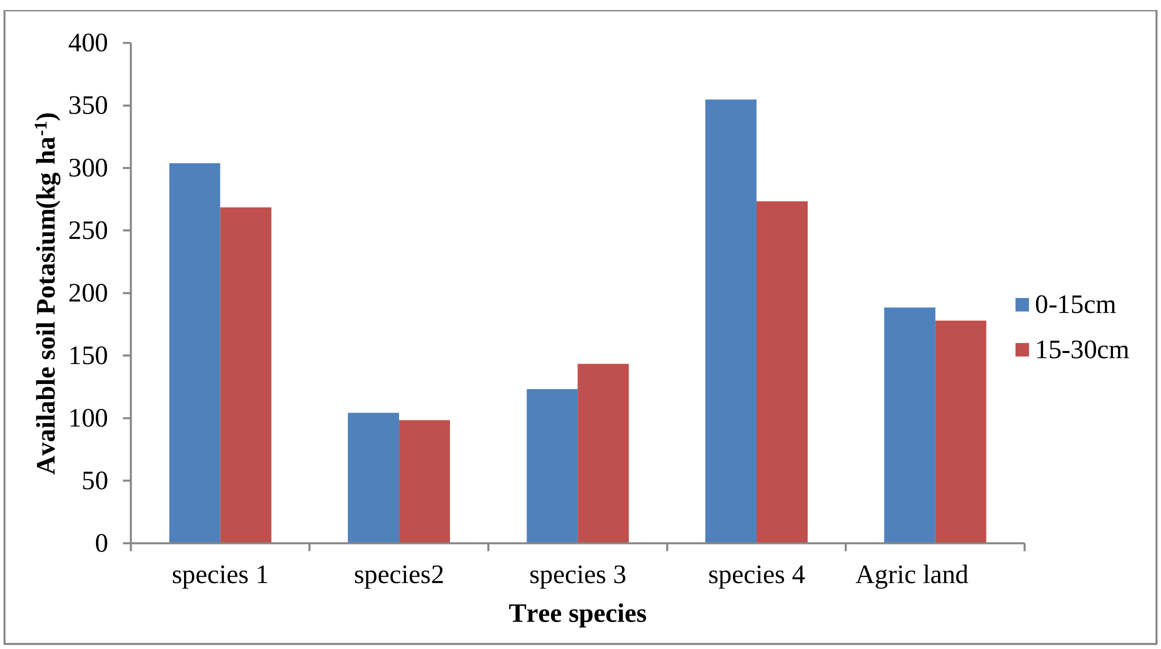
Less N storage is due to comparatively lesser litter input. Many studies on soil nutrient status have shown that soils under trees are richer in nutrients compared with barren soil (Sharma, 2003). The results related to available nutrient status of bare soils are in agreement with the values reported by Sharma (2005).

The result is in close conformity with the findings of Sharma and Gupta (2001) who stated that leaf litter is related more closely with N-cycling as nitrogen is bound up in organic molecules. Sharma (2005) also reported that available N content in soil under *Prosopis cineraria* and *Acacia albida* was considerably higher than that of the bare field.



Species1: *Tectona grandis* Species 3: *Terminalia tomentosa*
Species 2: *Terminalia bellarica* Species 4: *Terminalia arjuna*

Fig. 12. Available soil Nitrogen (kg ha^{-1}) at different depths



Species1: *Tectona grandis* Species 3: *Terminalia tomentosa*
Species 2: *Terminalia bellarica* Species 4: *Terminalia arjuna*

Fig. 13. Available soil Potasium (kg ha^{-1}) under different tree species

4.3.5 Total soil Phosphorous under different tree species

Table 10. Depth-wise soil phosphorous (Kg ha^{-1}) under different tree species in tree arboretum at GKVK Bengaluru.

Tree Species	Soil phosphorous (Kg ha^{-1}) at different depth	
	0-15 cm	15-30 cm
Terminalia bellarica	35.83^{b}	17.67^{b}
Tectona grandis	28.56^{c}	12.31^{c}
Terminalia tomentosa	13.91^{e}	11.31^{cd}
Terminalia arjuna	22.89^{d}	12.30^{c}
Agriculture land	97.49^{a}	84.53^{a}
F value	NS	NS
S.EM(±)	0.93	0.52
CD 5%	2.73	1.72

NS :-Non Significance at 5%

Value within the column following same letter are not significantly different ($P < 0.05$)

The content of available soil phosphorus showed decreasing pattern through depth (0-15cm and 15-30cm). However, including control plot, soil phosphorous under plantation sites showing highest content of available phosphorus at surface layers. As indicated in the Table 10 the concentration of soil phosphorus in agricultural land was 97.48 kg ha^{-1} at 0-15cm depth and 84.53kg ha^{-1} at 15-30cm depth. And with related to tree species, concentration at both the depths was 35.83kg ha^{-1} and 17.67kg ha^{-1}, 28.56kg ha^{-1} and 12.30kg ha^{-1}, 13.91kg ha^{-1} and 11.31kg ha^{-1}, 22.89kg ha^{-1} and 12.30kg ha^{-1} for *Terminalia bellarica, Tectona grandis, Terminalia tomentosa* and *Terminalia arjuna* respectively.

Available soil phosphorus concentration was recorded heighest under *Terminalia bellarica* (35.83kg ha^{-1}) fallowed by *Tectona grandis* (28.56kg ha^{-1}), *Terminalia arjuna* (22.89kg ha^{-1}) and least under *Terminalia tomentosa* (13.91kg ha^{-1}). Agriculture land had more phosphorous concentration compared to plantation site. This is due to more fertilizer application in agriculture land. Since phosphorous is one of the limiting nutrients, farmers tend to apply more P than is required to satisfy any P loss after its application at planting.

The exact reason behind this increase is not known. Thus, the result revealed that in case of soil enrichment. The parent material may determines more significantly the fraction of available P rather than the amount of litter fall received to the soil surface and characteristics of litter material as indicated in the paper by Shershah *et al.*(2016) which is on the topic Comparative effects of dominant forest tree species on soil characteristics.

Statistical analysis revealed that among different forestry tree species and at different depths soil phosphorous showing non significant effect.

4.3.6 Total soil Potasium under different tree species

Table 11. Depth-wise available soil potassium (kg ha^{-1}) under different tree species in tree arboretum at GKVK Bengaluru

Tree Species	Soil potassium (kg ha^{-1}) at different depths	
	0-15cm	**15-30cm**
Terminalia bellarica	104.32^{e}	98.46^{e}
Tectona grandis	303.87^{b}	268.61^{b}
Terminalia tomentosa	123.33^{d}	143.52^{d}
Terminalia arjuna	354.69^{a}	273.46^{a}
Agricultural land	188.44^{c}	177.90^{c}
F value	*	*
S.EM(±)	6.33	3.8
CD 5%	18.67	11.81

* Significance at 5%

Value within the column following same letter are not significantly different (P <0.05)

The available K content in the agricultural land was ranged from 188.44kg ha^{-1} at 0-15cm and 177.9kg ha^{-1} at 15-30cm depth. Whereas in the plantation, soil potassium at

0-15cm and 15-30 cm was 104.32kg ha^{-1} and 98.46kg ha^{-1}, 303.88kg ha^{-1} and 268.61kg ha^{-1}, 123.33kg ha^{-1} and 143.5167kg ha^{-1}, 354.69kg ha^{-1} and 273.4567kg ha^{-1} for *Terminalia bellarica*, *Tectona grandis*, *Terminalia tomentosa* and *Terminalia arjuna* respectively.

Among the tree species *Terminalia arjuna* is showing maximum soil potassium concentration fallowed by *Tectona grandis, Terminalia tomentosa and* minimum at *Terminalia bellarica* (Fig. 13).

Statistical analysis showing significant result among the selected tree species in the plantation site. *Terminalia arjuna* showing maximum significant difference compared other tree species. *Terminalia bellarica* and *Terminalia tomentosa* are showing less difference with respect to soil potassium concentration.

The contents of K seems to be more under plantation site than in agricultural land which may be due to constant replacement of K by the plant roots and addition of considerable amount of leaf litter to the soil mass.

V SUMMARY

Analysis of soil fertility under four different deciduous tree species (*Terminalia tomentosa, Terminalia arjuna, Terminalia bellarica* and *Tectona grandis*) and in agricultural land. Results revealed that soil physico-chemical properties like pH, EC, Organic carbon N, P and K were having variation among different tree species and also at different depths (0-15cm and 15-30cm). Agricultural land is showing maximum difference compared to plantation site, with respect to soil pH 5.41, available nitrogen 292.92Kg ha^{-1} and available phosphorous 97.49kg ha^{-1} since it is a managed field and there is a periodic application of fertilizers.

Plantation site even though it is undisturbed land and no management practices had been carried out it is showing good results at soil organic carbon which is more under *Tectona grandis* 1.52%. But in case of available Nitrogen soil under plantation site showing minimum value. In case of phosphorous *Terminalia tomentosa* is showing minimum value of 13.91kg ha^{-1} which is at deficiency level. But other tree species are having medium phosphorous concentration. For potassium concentration *Tectona grandis* and *Terminalia arjuna* are having sufficient soil potassium concentration of 303.87kg ha^{-1} and 354.69kg ha^{-1} respectively. But *Terminalia bellarica* and *Terminalia tomentosa* showing minimum value of 104.32kg ha^{-1} and 123.33kg ha^{-1} respectively.

Results also revealed that with the increasing depth nutrient status get reduced. Surface soil is having more nutrient status than under subsurface soil. Abundance of litter on the forest floor provides habitat and medium for soil microbial to regulate nutrients to be available for plants uptake. Subsequently, it is recommended that in future inclusive studies on soil biological properties need to be implemented, which might influence the tree growth performance. In addition, early establishment of plantations at nursery, field trials should be carried out in order to obtain the initial data about the seedling growth performance.

The enrichment planting improves soil productivity in terms of bulk density carbon reserve, nitrogen content and exchangeable magnesium. It shows that enrichment planting establishment at degraded forestland gave better improvement of soil fertility compared to single species plantation because it provides variety of composing materials which acts a medium for soil microbes decomposing activities and nutrients reservoir in the soil.

Productivity is different for different trees. The productivity of *Tectona grandis* ($0.23 m^3$ $tree^{-1}$) is maximum and *Terminalia tomentosa* ($0.12 m^3$ $tree^{-1}$) is having lowest productivity among four species considered. *Terminalia tomentosa* showing lowest result in all the cases. Viz. Height. Girth, and productivity. Mixed stand type plantation are more productive and economic. Different factors attribute for increase and decrease in productivity.

Use of indigenous species than exotic species increase the yield of the timber and encouraging the different plant understories to improve the degree of ecological restoration and to restore their former biodiversity. The site-specific quantifications of carbon storage potential is necessary for the management of qualitative and systematic land use system. Average Carbon sequestration potential of *Terminalia bellarica* was 170.59 kg ha^{-1} which was highest among the four species and *Terminalia tomentosa* was 101.43 kg ha^{-1} with lowest value. plantation forest estate stored a substantial amount of carbon. Carbon storage value of all the trees is depending on varous factors height and productivity of trees and it mainly depends on biomass value of trees.

To rescue the world from global warming and climatic change, the sustainable management of forest with the objectives of carbon sequestration is mandatory. There are many other ways of development terrestrial carbon storage, such as allowing land to regenerate in native forest or by planting carbon storage forests. The carbon storage potential of plantation forests should be considered as just one of many tools in efforts to deal with the problem of increasing atmospheric carbon dioxide.

Among the 4 different tree species selected for research, *Terminalia bellarica* was found to be dominant that sequestered more carbon and having more productivity compared to other tree species. This experiment suggested that planting of fast growing tree species in the subtropical condition was an effective choice for carbon sequestration and to maintain the soil nutrient status. Since these tree species can grow well under low nutrient condition can be recommend for soil having low soil nutrients. The research can be useful for estimating productivity, carbon sequestration potential and to analyse the soil nutrient status under decidous tree species in tree arboretum at GKVK Bengaluru.

Since our campus (GKVK) is having numerous types of tree species and having abundant vegetation, we can call it as LUNGS OF THE CITY Bengaluru.

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