QUANTIFICATION OF LAND AVAILABILITY IN BUNDS OF AGRICULTURAL LANDS TO INCREASE TREE COVER ACROSS RURAL-URBAN GRADIENTS AROUND BENGALURU DISTRICT

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In

ENVIRONMENTAL SCIENCES

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AFFECTIONATELY DEDICATED TO

MY

FATHER (POOVAIAH)

MOTHER (PREMA)

AND INDIAN ARMY.

DEPARTMENT OF FORESTRY AND ENVIRONMENTAL SCIENCE
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CERTIFICATE

This is to certify that the thesis entitled **"Quantification of land availability in bunds of agricultural lands to increase tree cover across rural-urban gradients around Bengaluru district"** submitted by **Mr. ABHILASH K P., ID No. PALB 6220** in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture) in Environmental Science** to the University of Agricultural Sciences, Bengaluru, is a record of bona-fide research work done by him during the period of study in this university under my guidance and supervision and no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

BENGALURU
AUGUST, 2018

(A.S. DEVAKUMAR)
(MAJOR ADVISOR)

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Bengaluru
August, 2018 ***(ABHILASH, K. P.)***

Quantification of land availability in bunds of agricultural lands to increase tree cover across rural-urban gradients around Bengaluru district

Abhilash, K. P.

Abstract

The present investigation is an effort to Quantify land availability in bunds of agriculture lands to understand the possibility of increasing the tree cover. Study was conducted along the rural-urban gradients of Bengaluru district and compared with rural landscape of Tumakuru district with similar climatic conditions. Length and width of the bund is measured along with trees present on bunds. The length of bund varied significantly and width did not among the small, medium and large farmer’s. Tree density in general was found to be more in northern part of Bengaluru compared to southern parts. Number of tree species found in the rural parts of Tumakuru was more compared to rural Bengaluru. Number of tree species varied from eight in rural to thirteen in the urban areas. However highest number of trees belonged to *Tectona grandis* and *Azadirachta indica*. The number of trees seen on the bunds in Bengaluru regions remained almost same. Considering the total length of the bund and the spacing at which the trees are planted, the possibility of increasing the tree density on the available bunds among the small farmer’s is relatively more compared to medium and large farmer’s, while in case of rural area of Tumakuru there is a huge potential to increase the tree density on the bunds as the existing tree density is vary sparse compared to Bengaluru.

August, 2018 (A.S. DEVAKUMAR)
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ಬೆಂಗಳೂರು ಜಿಲ್ಲೆಯ ಗ್ರಾಮೀಣ–ನಗರ ಭಾಗದ ಕೃಷಿ ಭೂಮಿಯ ಬದುಗಳಲ್ಲಿ ಮರದ ಕವಚವನ್ನು ಹೆಚ್ಚಿಸಲು ಭೂಲಭ್ಯತೆಯನ್ನು ಪ್ರಮಾಣೀಕರಿಸಲು ಅಧ್ಯಯನ

ಅಭಿಲಾಷ್, ಕೆ. ಪಿ.

ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ತನಿಖೆನ್ನು ಕೃಷಿ ಭೂಮಿಗಳಲ್ಲಿನ ಬದುಗಳಲ್ಲಿ ಲಭ್ಯವಿರುವ ಜಾಗವನ್ನು ಪ್ರಮಾಣೀಕರಿಸಿ ಮರಗಳ ಕವಚವನ್ನು ಹೆಚ್ಚಿಸುವ ಸಾಧ್ಯತೆಯನ್ನು ನಿರ್ಣಯಿಸಲು ಕೈಗೊಳ್ಳಲಾಯಿತು. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವನ್ನು ಬೆಂಗಳೂರು ಜಿಲ್ಲೆಯ ಗ್ರಾಮೀಣ–ನಗರ ಪ್ರದೇಶದಲ್ಲಿ ನಡೆಸಿ ಒಂದೇ ರೀತಿಯ ಹವಾಮಾನವುಳ್ಳ ತುಮಕೂರು ಜಿಲ್ಲೆಯ ಗ್ರಾಮೀಣ ಭೂದೃಶ್ಯದೊಂದಿಗೆ ಹೋಲಿಕೆಮಾಡಲಾಯಿತು. ಬದುಗಳ ಉದ್ದ ಮತ್ತು ಅಗಲವನ್ನು ಅಳೆದು ಆ ಬದುಗಳ ಮೇಲಿನ ಮರಗಳ ಸಂಖ್ಯೆ ಮತ್ತು ಮರಗಳ ಬೆಳವಣಿಗೆಯ ಮಾನದಂಡಗಳನ್ನು ಅಳೆಯಲಾಯಿತು. ಸಣ್ಣ, ಮಧ್ಯಮ ಮತ್ತು ದೊಡ್ಡ ರೈತರ ನಡುವೆ ಬದುಗಳ ಉದ್ದವು ಗಮನಾರ್ಹವಾಗಿದೆ, ಅಗಲವು ಗಮನಾರ್ಹವಾಗಿಲ್ಲ. ಬೆಂಗಳೂರಿನ ದಕ್ಷಿಣ ಭಾಗಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಉತ್ತರ ಭಾಗಗಳಲ್ಲಿ ಮರದ ಸಾಂದ್ರತೆಯು ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿದೆ. ಗ್ರಾಮೀಣ ಬೆಂಗಳೂರಿಗೆ ಹೋಲಿಸಿದರೆ ತುಮಕೂರಿನ ಗ್ರಾಮೀಣ ಭಾಗಗಳಲ್ಲಿ ಕಂಡುಬರುವ ಮರಗಳ ಜಾತಿಯ ಸಂಖ್ಯೆ ಹೆಚ್ಚಾಗಿದೆ. ನಗರ ಪ್ರದೇಶದಲ್ಲಿ 13 ಮತ್ತು ಗ್ರಾಮೀಣ ಪ್ರದೇಶದಲ್ಲಿ 8 ಜಾತಿಯ ಮರಗಳು ದಾಖಲಾಗಿದೆ. ಆದಾಗ್ಯೂ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯ ಮರಗಳು ತೇಗ ಮತ್ತು ಬೇವಿನ ಜಾತಿಗೆ ಸೇರಿವೆ. ಬೆಂಗಳೂರು ಪ್ರದೇಶದ ಬದುಗಳಲ್ಲಿ ಕಂಡುಬಂದ ಮರಗಳ ಸಂಖ್ಯೆ ಬಹುತೇಕ ಒಂದೇ ಆಗಿತ್ತು. ಸಾಧಾರಣ ಮತ್ತು ದೊಡ್ಡ ರೈತರಿಗೆ ಹೋಲಿಸಿದರೆ, ಬದುಗಳ ಒಟ್ಟು ಉದ್ದವನ್ನು ಮತ್ತು ಮರಗಳು ನೆಡಲ್ಪಟ್ಟ ಅಂತರವನ್ನು ಪರಿಗಣಿಸಿ ಬದುಗಳಲ್ಲಿ ಲಭ್ಯವಿರುವ ಮರದ ಸಾಂದ್ರತೆಯನ್ನು ಹೆಚ್ಚಿಸುವ ಸಾಧ್ಯತೆಯು ಸಣ್ಣ ರೈತರ ಕೃಷಿ ಭೂಮಿಯ ಬದುಗಳಲ್ಲಿ ತುಲನಾತ್ಮಕವಾಗಿ ಹೆಚ್ಚು. ಬೆಂಗಳೂರಿಗೆ ಹೋಲಿಸಿದರೆ ತುಮಕೂರು ಪ್ರದೇಶದಲ್ಲಿ ಮರಗಳ ಸಾಂದ್ರತೆಯು ವಿರಳವವಾಗಿರಿವುದರಿಂದ ತುಮಕೂರು ಪ್ರದೇಶದಲ್ಲಿ ಮರಗಳ ಸಾಂದ್ರತೆಯನ್ನು ಹೆಚ್ಚಿಸಲು ದೊಡ್ಡ ಸಾಮರ್ಥ್ಯವಿದೆ.

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ಎ. ಎಸ್. ದೇವಕುಮಾರ್
(ಮುಖ್ಯ ಸಲಹೆಗಾರರು)

Quantification of Land Availability in Agricultural Land scape to Increase Tree Cover Through Agro Forestry Ecosystem

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Introduction

- India is one of the fastest growing economy in the world. Economic progress of the country has seen a wide range of land use change. Climate change and pollution is one of the major issues that influence the health and the economic growth.
- Global climate change is predicted to have serious implication especially in tropical countries
- Increasing tree cover is one of the major adaptive strategy to reduce pollution and climate change impact. Carbon sequestration through increased tree cover is considered to be an ecologically and economically sustainable option.
- The trees act as major CO_2 sink which reduce carbon from the atmosphere and also help in trapping pollutants and particulate matter.
- However land availability is a major concern for increasing tree cover due to land constraint. Land availability being a major constraint, increasing tree cover in agricultural land through agro forestry system is one of the viable option recommended by IPCC.
- Trees with large evergreen canopies and thick cuticle and plumose structures help in accumulation of particulate pollutants. However there is no information on what is the land availability in agricultural lands where trees can be grown without encroaching the cultivable land, especially in small and medium size land holdings one possible areas is bunds.
- In this background current study is conducted to quantify the bund area and the existing tree diversity on the bund.

Objectives

1. To quantify the bund area available in different size land holdings.
2. To identify the tree diversity and density on existing bund and assess the scope of increasing tree density on bunds.

Material and Methods

1. **Study site-** The study was conducted in Tumkur district .Based on the size group certain villages were selected and land was divided into three category small, medium and large. In these three land use system the study was conducted**.**
2. **Selection of contact farmers for data collection:** Based on the above classification farm lands grouped into small (< 2.5 acre) 43 farmers where considered , medium (2.5-5 acre) 46 farmers and large (>5 acre) 25 farmers were considered in Tumkur areas.
3. **Measuring of the bund area in the farmer's field:** The length and width of bund is measured and expressed in meters.
4. **Tree diversity-**Tree species planted in this area is identified to species level as per taxonomic classification and diversity in the tree species present in bund is noted.
5. **Carbon sequestration assessment –** This is assessed by deriving the standing tree biomass my measuring girth, height and carbon content of the trees.
6. **Measurement of girth of tree**: The girth of the tree is measured using measuring tape graduated to measure a minimum of 1mm.
7. **Measurement of height of the tree:** The height of the tree is measured with the help of Blume Leiss altimeter.
8. **Calculation of volume of the tree(M3)**= $\pi r^2 h$
9. **Estimation of biomass from the volume and density(Kg):** volume × density of the species
10. **Carbon content of the biomass(Kg):** Standing Biomass × 0.45.
11. **Calculation of Alpha Diversity Index:**
    Shannon Alpha Diversity index(H)= $-\sum (P_i * \ln P_i)$
12. **Calculation of Beta Diversity Index:**
    Jaccard β diversity $C_j = j/(a+b-j)$

Experimental Results

Table 1. Tree and Bund details

	Number of trees /acre		Total number of trees on bund	No of species	Number of bunds /acre
	Average	Range			
Small (n=43)	4.00	(0-26)	191 (n=37)	19	6
Medium (n=46)	4.00	(0-25)	181 (n=38)	16	6
Large (n=25)	5.00	(0-27)	120 (n=20)	18	8

Table 2. hypothetical spacing and number of trees that is possible to accommodate on bunds of different land holdings

	Total length of bund (meters)	Number of trees present on bund	Number of trees possible at spacing			
			5 m	10 m	20 m	30 m
Small	301	4	60	30	15	10
Medium	212	4	42	21	11	7
Large	195	5	38	19	10	6

Table 3. Jaccard beta diversity index

	Small	Medium	Large
Small	---	---	---
Medium	0.52	---	---
Large	0.47	0.21	---

Table 4. Shannon alpha diversity index

Land holdings	Diversity index
Small	2.01
Medium	2.11
Large	1.65

Table 5. carbon stocks in the above ground biomass of Standing tree

	carbon(tons)	CO_2(tons)
Small	35±0.29	126
Medium	43±0.65	157
Large	19±0.2	69
Total	97±1.14	352

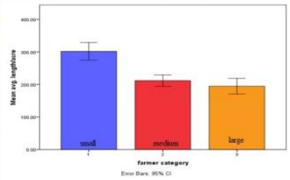

Fig 1.Average bund length in different farmer category

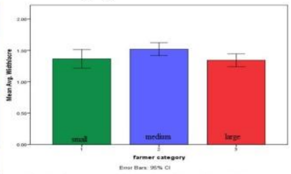

Fig 2.Average bund width in different farmer category

Discussion

- The bund length ranged from 194.84m/acre to 301.86m/acre, with a mean length of 242.14m/acre. Average length of bund varied significantly among the land holding categories. The average length of farm bund was highest under small farmer category(301.86) followed by medium(212.02) and large(194.84) meter per acre(fig 1).
- The bund width ranged from a minimum of 1.37m to 1.52m, with the mean width of 1.42m/acre. Average width of bund did not varied significantly among the different land holding category. The average width of farm bund is almost similar under small farmers category(1.37), medium(1.52) and large(1.35) meter (fig 2).
- There are 24 tree species found in the study area across the land size holdings. The total number of trees found in the study area was 492 of which 191 were found in small farmer category, 181 were planted in medium farmer category and 120 trees were found in large farmer category.
- The total carbon stock was estimated from the biomass of standing tree (Table 5).The total carbon accumulated from all the trees present on bund is 97tons,. From this a total of 352 tons of CO_2 from the atmosphere has been sequestered in to trees.
- Since the number of trees actually present on the bund is very less(table 1), this is a possibility of increasing trees on bund . The hypothetical spacing and the possibility of number of trees that can be accommodated is shown in (table 2).

Summary

From the study it is found that the number of trees existing on the bund is very less and therefore there is a possibility of increasing the trees on the bunds across all the three land size holdings study. This will show growing trees not only help in providing clean atmosphere but also helps in conserving the tree diversity which is an important concern under the current climate scenario.

Advisory committee

Chairperson: Dr. A.S. Devakumar

Member: Dr. M. Mahadeva Murthy
Dr. R. Krishna Murthy
Dr.V.V. Belavadi

CONTENT

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I INTRODUCTION

Increasing greenhouse gas emission into the environment has become a major global concern due to its primary influence on global temperature. While world struggle to overcome the greenhouse gas emissions, complimentary efforts are on to enlarge the sinks of greenhouse gases, mainly carbon dioxide to stabilize the climate. The increased greenhouse gas concentration in the atmosphere leading to climate change that has serious ramifications on biological processes of most living organisms that will affect the health, growth as well as economy of most nations and specifically of developing nations. Climate negotiations have highlighted the importance of land use sectors in mitigating the climate change. About 50% of the 1.6-1.8 Pg/yr is lost due to deforestation and other agricultural activities. Agriculture alone accounts for 10-12% of the total global anthropogenic emissions of GHGs with an estimated non-CO_2 GHG emission of 5120 to 6116 MtCO_2/yr during 2005 (Murthy *et al*., 2013). Both enhanced intensive management as well as improper practices are responsible for increased emissions. Hence, there are many opportunities to improve agronomic practices, nutrient and water management and land use practices to reduce the emission of greenhouse gases from this sector (Sah and Devakumar, 2018).

The emphasis of land use systems that have higher carbon content than existing plant community can help achieve net gains in carbon and significant increase in carbon sequestration by moving from lower biomass land uses [e.g. grasslands, crop fallows, etc] to tree based systems such as forests, plantation forests and agroforestry. Agroforestry provides a unique opportunity to combine the twin objectives of climate mitigation and livelihood security. Although agroforestry systems are not primarily designed for carbon sequestration, there are many recent studies that substantiate the evidence that agroforestry systems can play a major role in storing carbon in aboveground biomass and in soil and in ground below biomass (Murthy *et al*., 2013). Studies on assessments of national and global terrestrial carbon dioxide sinks reveal two beneficial attributes of agroforestry systems (a) direct near term storage [decades to centuries] in trees and soils and (b) the potential to offset immediate GHG emissions associated with deforestation and subsequent shifting cultivation (Dixon, 1995). Among the various means of mitigating climate change, sequestration of carbon by growing trees is considered to be ecologically and economically sustainable option, because there will be many tangible and non-tangible benefits derived from a land use system with tree cover. Carbon sequestration refers to the provision of long-term storage of carbon in the terrestrial biosphere to improve environmental conditions and check the processes of environmental degradation. Agroforestry systems can be a better climate change mitigation option than ocean and other options, because of the secondary environmental benefits such as food security and secured land tenure, increasing farm income, restoring and maintaining above ground and below ground biodiversity, maintaining watershed hydrology and soil conservation (Pandey, 2011). Trees because of their long life span and stress tolerance can retain carbon in the standing biomass for long period and thus help in sequestering atmospheric carbon dioxide.

Thus, promoting agroforestry can be one of the options to deal with problems related to land use and global warming. The amount of carbon sequestrated, however, will largely depend on the agroforestry system, the structure and function of agroforestry systems which to a great extent, are determined by environmental factors, species composition and socio-economic factors and also tree species and system management can influence carbon storage in agroforestry systems (Albrecht and Kandji, 2003). Average sequestration potential in agroforestry has been estimated to be 25t C ha^{-1} over 96 Mha of land in India and 6-15 t C ha^{-1} over 75.9 Mha in China. Sathaye and Ravindranath, (1998) estimated carbon gain of 0.72 Mg C $ha^{-1}yr^{-1}$ on 4000 million ha land under agroforestry, with potential for sequestering 26 Tg C yr^{-1} by 2010 and 45 Tg C yr^{-1} by 2040.

India is the largest developing economy where more than seventy percent of population earn their livelihood from agriculture. However, considering no significant increase in arable land over years and rapid rate of urbanization, land available to extend the area under tree cover is limited (Sah and Devakumar, 2018). It may not be possible to divert arable land for tree cultivation because majority of the land is with marginal and small farmers whose income completely depended on agriculture. Although there are large areas of wasteland, most of it may not be amenable for growing trees without special care. Thus, availability of land is a major issue for further increasing tree cover. In order to increase the tree cover with reasonably good growth, the possible land one may consider is the bunds along the agriculture lands and the borders of individual land holding. Because bunds and borders are part of the cultivable land areas and most often remain unused for cultivation. Essentially bunds are fertile in nature and amenable for management without extra efforts. Hence, it can be utilized for growing trees. However there is very little information on how much of bund area is available and how much of area on the bunds and borders is available for adding more trees. Hence, in this background, present study is an attempt to assess the area available for planting trees, the existing tree diversity and their contribution towards ameliorating the environment with following objectives.

1. To quantify the bund area available among different size land holdings in rural, urban and peri-urban agricultural lands
2. To identify the tree diversity and density on existing bunds
3. To quantify the carbon sequestration from the existing tree composition on bunds

II REVIEW OF LITERATURE

In the present study bund area is calculated by measuring bund length and bund width and assessment of tree diversity, carbon stock and climate mitigation from the tree species have been studied. The literature relevant to identification of trees in the bund area, species richness, evenness and similarity between the ecosystems and tree carbon stock in rural, peri urban and urban areas have been reviewed and presented in this chapter.

2.1Trees in the bund area

Maghembe *et al.* (1984) studied plant species on farms, farm boundaries and homesteads in the Kilimanjaro agroforestry system. The survey covered 30 farms in 6 villages in Hal District on the slopes of Mount Kilimanjaro, Tanzania. Over 100 plant species spread over 40 families were identified and their uses obtained through inter-views with farmers. The species identified include 53 tree species, 29 food crop species, 21 non-woody plants of economic value and 8 weed species. The food crops, trees and other economically useful plants are carefully chosen by the local farmers and intimately intercropped on the same unit of land. In most cases, the plants had two or more uses of which food, fuelwood, medicine, poles, timber and fodder were the most important.

Sharma (1992) studied the influence of single row bund plantation of *Acacia nilotica* var. juquemontii on the growth and yield of associated wheat crop under irrigated conditions in Haryana, India. The indications are that the tree line does affect all crop parameters like height growth, shoot numbers, ear length, grain number and grain yield in the vicinity of trees upto 4 m distance from the tree line and establishes that as the distance from the tree line increases the growth and yield of wheat crop also improves. The effect on wheat crop was found more pronounced in the plots laid out towards the middle of the tree line as compared to plots towards the outer border.

Kapp *et al*. (1997) conducted a study with five timber tree species planted in single lines on twelve farm boundaries. Considering the growth rates, planting of *Cordia alliodora, Eucalyptus deglupta* and *Tectona grandis* in lines on farm boundaries should be promoted. *T. ivorensis* and *A. mangium*are not recommendable for sites with impeded drainage because of mortality caused by root rot, mostly due to *Rosellinia* sp.

Kumar *et al*. (2005) found that poplar-based agroforestry is one of the major commercial agroforestry systems practised by the farmers in Western Uttar Pradesh of India. In Saharanpur district, which is near the markets for poplar wood, about 78 per cent of the sample farmers practise poplar-based bund/boundary systems while the rest use agri-silviculture. The tree density in bund/boundary system was 146 trees ha^{-1}, as against 481 trees ha^{-1} in agri-silviculture. Additional income (> 70%) and an emergency source of cash (nearly 20%) were the farmers' major reasons for adopting agroforestry.

Devaranavadgi *et al*. (2010) conducted a study in five northern districts of Karnataka *viz*., Bijapur, Bagalkot, Gulbarga, Koppal and Raichur to find out prominent agroforestry practices. The bund planting was found to be most prominent agroforestry practice in both rainfed and irrigated conditions in all the five districts. Nearly 88.4 per cent of the respondents followed bund planting in rainfed situation, whereas it was 86.1 per cent in irrigated situation. The other potential agroforestry practices followed were boundary planting and scattered planting in all the five districts. Neem and babul *(Acacia nilotica*) are frequently occurring tree species in all the five districts under both rainfed (82.9 per cent and 46.2 per cent, respectively) and irrigated ecosystems (74.4 per cent and 35.4 per cent, respectively). The highest preference is seen for fruit yielding trees followed by timber and fuel wood tree species in all the five districts in rainfed (70.1 per cent, 64.6 per cent and 37.3 per cent, respectively) and irrigated situations (59.6 per cent, 63.7 per cent and 35.9 per cent, respectively).

2.2 Tree diversity

Uma Shankar (2001) have presented tree diversity in Himalaya low land region of Mahanand Sanctuary, Darjeeling. In his observation he recorded, higher species richness of 968 individual and 959 were identified to species level. There were 9 unidentified trees belong to 4 species that could be identified by its local names. The identified trees belong to 42 families and rare species constitutes 36 per cent of the flora and were randomly distributed. He also studied floristic composition, conservation and regeneration.

Jangid and Sharma (2010) study was carried mainly on tree species diversity in Modasataluka of Sabarkantha dist. (Gujarat). They represented tree diversity in their research work and have collected data of tree species and it's components from various villages and forest area. This region of samples collected consists of scrubs of thorny and xerophytic plant species. Total 131 tree species belonging to 94 genera and 38 families have been enumerated.

Nirmal Kumar *et al*. (2010) studied on tree diversity and soil nutrient in forest of western parts of India. There they found 93 tree species which belong to 85 genera and 24 families. They studied soil nutrient in detail and finally concluded that each variable in soil demonstrated show positive correlation with species richness. But tree density has shown negative correlation with varied phosphorous and nitrogen and positive correlation with carbon.

Patel and Patel (2010) recorded 100 tree species belong to 74 genera and 38 families. The samples were collected from forest of Dantataluka- Banaskantha dist. Their work witness two of tree species from monocotyledons and rest were from Dicotyledons. Families that had dominating tree species were Mimosaceae, Papilionaceae, Combretaceae, Caesalpiniaceae, Moraceae, Apocynaceae respectively.

Mulia *et al*. (2010) studied on tree species diversity they are from M.G. Science Institute of Ahmedabad and recorded 72 species from 27 families including some of rare tree species like *Bombax ceiba*, *Adansonia digitata, Saraca indica* and *Guacum officinalis.*

Dabgar *et al*. (2010) studied on available tree species in Visnagartaluka of north Gujarat, India and studied the geographical distribution of plants. They recorded 442 tree species consists 314 genera of 101 families. Favorable climate from growth may result in highest percentage of therophytes.

Nakakaawa *et al*. (2010) they mainly focused on carbon stocks in relation to tree diversity. Their study area was carried out in Western Uganda. They find positive correlation between carbon density and tree diversity. They reveal that offering payments for bundled ecosystem services rather than one environmental service likewise carbon sequestration can help avoiding problems related to loss of other ecosystem services.

2.3 Standing tree biomass and carbon storage

The biomass storage and estimations in trees are formally assessed by the using specific species by allometric equations and factor wise *viz*., tree stem, branch, foliage and root biomass are calculated in both tree and shrub layer (Mishra, 1968: Odum, 1983: Rai, 1984). In this method of approach, the accessibility of species-specific local regression equations is made essential for exact estimating the forest biomass.

Pande *et al.* (1986) in his study he showed that the production of biomass and nutrient distribution in moist deciduous forests in Goa and there he found the dominant species were *Terminalia tomentosa* in the upper and under forest floor where *Careya arborea* and *Lannea grandisin* found in under forest floor and reported that 92 per cent of the total biomass which is more was contributed by *Terminalia tomentosa* with only 8 percent by the other two species.

Castellanos *et al*. (1991) estimated that the root biomass in dry deciduous tropical forest in Mexico and observed that the below and above ground biomass of all important trees, shrubs and lianas in that forest was 73.6 t $ha^{-1}$and 31 t ha^{-1}, respectively. So as root: shoot biomass ratio of 0.42 was calculated.

Hall and Uhling (1991) estimated the tree diversity and biomass density of forest in South East Asia by using volume estimates and biomass equivalence factors derived from Brown *et al*. (1989). Their biomass estimates in India at a range of 116 Mg ha^{-1} for undisturbed forest cover for 60-80 years and 35, 66 and 84 Mg ha^{-1} for logged, managed and unproductive forestlands respectively. However, this assessment were only made from 9 per cent of forest area and no other information was given in relation to forest types and species composition.

Singh and Singh (1991) studied the species diversity and its composition, tree biomass and diversity index in mixed dry deciduous forests of Vindhyan region. They found the standing biomass of vegetation with average mean of 66.98 t ha-1 with 46.70 t ha^{-1} in tree layer and 13.97 t ha^{-1} in the fine root system. The total of 83 per cent vegetation carbon was stored in above ground vegetative parts, while the above ground biomass was responsible for 72 percent of the total carbon input into the system.

Mishra *et al*.(1998) studied the biomass status in two biological sites one is biotically disturbed (BD) and another as undisturbed site (UD) of mixed dry deciduous forest carried out in Shiwalik hill of Haryana. The total basal area was 7.9 m^2 ha^{-1}in BD and 9.7 m^2 ha^{-1}in UD .They considered three important tree species *Anogeissus latifolia*, *Acacia catechu,* and *Terminalia tomentosa* and reported that 88 percent of total tree density in BD and 66 percent in UD. Total ground above biomass was 22.05 t ha^{-1}in BD and 31.19 t ha^{-1} in UD, varied significantly.

Sudha and Ravindranath (1998) reported that they have assessed the availability of land and the potential for biomass production in India to meet various demands for biomass, including modern bio energy. The biomass production potential of energy plantations is assessed for different agro-ecological zones. The total woody biomass production is estimated to be 321 Mt, based on biomass productivity in the range 2 to 17 t/ha/year for the different agro-ecological zones and considering the conservative estimate of 43 m ha land availability for biomass production. A surplus of 231 Mt of biomass is estimated to be available for energy, which has an electricity generation potential of 231 T Wh. As a first step, only the feasible physical potential of biomass production is assessed, along with an analysis of barriers.

Haripriya (2000) estimated the above tree biomass ground tree diversity, density and carbon storage in biomass of 21 major forests of India from which data is collected from 1,70,000 sampling units distributed from all the parts country in 1993. Biomass densities ranged from 14 to 210 Mg ha^{-1} with average of 67.4 Mg ha^{-1}, which equals around 34 Mg ha^{-1}.

Tian *et al*. (2000) studied on annual carbon storage in Amazon ecosystem based on climatic and biotic control. They found that the total carbon storage in the Amazon Basin during 1980s was estimated to be 127.6 Pg C, with about 94.3 Pg C in tree vegetation and 33.3 Pg C in the soil organic carbon pool. Total 83% of carbon storage occurred in tropical evergreen forests which results in strength of inter annual variations in current carbon storage like undisturbed ecosystems in the Amazon Basin.

Variation can be seen in carbon source of 0.2 Pg C per year to carbon sink of 0.7 Pg C per year.

Sedjo (2001) reported that a number of current issues related to mitigating the global warming problem through forestry. The potential impact of forests on the build-up of atmospheric carbon is examined. A major focus is the means by which forests and forest management can contribute to the sequestration of carbon. The potential role of forests and tree cover in sequestrating carbon to reduce the build-up of greenhouse gases in the atmosphere is now well recognized. A number of alternative approaches to utilizing forestry and forest management for carbon sequestration are examined.

Nascimento and Laurance (2002) studied above ground tree biomass in central Amazon rain forests and measured total above ground dry biomass (TAGB) with an area of 201 ha plots in undisturbed site. TAGB values found very high with mean value of 397.7 +30.01 ha^{-1}. The important component of above ground biomass were considered large tree (< or >10 cm DBH) which comprised 81.9 percent of TAGB followed by downed wood debris (7.0 per cent), small trees, tree saplings and seedlings (< 10 cm DBH; 5.3 per cent), lianas (2.1 per cent), litter (1.9 per cent), snags (1.5 per cent), and stem less palms (0.3 per cent). Among the larger trees above ground biomass it is found greatest in intermediate sized (20-50 cm DBH) stems (46.7 percent of TAGB) with a very large (< or >60 cm DBH) trees containing substantial biomass (13.4% of TAGB). They also noted that there were no significant correlations among large tree biomass and that of any other live or dead biomass components.

Raizada *et al*. (2003) studied the C flux through leaf litter fall (total and leaf litter fall alone) in four major forest plantations groups in India. Using research and publication studies covering 82 stands and 24 species raised in plantations the total annual C flux rates were calculated. The leaf litter alone from were the highest C flux rates (3.03 Mt C per year) noted in the montane sub-tropical forests. Results indicate that plantations of short rotation tree species in forest with regular leaf shedding patterns is having more C sequestering capacity than tree species with unimodal or bimodal leaf shedding patterns. Therefore, such species could be raised in all kind of wastelands for twin purposes biomass production and carbon sequestering.

Hengsdijk *et al*. (2004) reported that bunds slightly increased crop productivity at sowing dates when water-limited yields were low, while productivity decreased at more favorable sowing dates due to the reduction in cropped area required for the construction of bunds. Tree planting reduced erosion up to 14% but this is insignificant compared to the sacrifice in cultivated land, which needs to be reforested. Applied tools allow rapid ex-ante evaluation of soil and water conservation practices and may contribute to improved cost-benefit analysis of proposed measures, and identification of more appropriate means to combat land degradation.

Murali *et al*. (2005) studied biomass estimation equation for tropical evergreen and deciduous forests and developed linear regression equations for estimation of above ground biomass of tropical forests. Basal area and tree height were found to give goodness of fit and reduce percentage of errors for deciduous forests. They cited that generally the coefficient of determination (r^2)was very low for evergreen forests. The coefficient of determination was literally high and error was low for deciduous forests. They concluded with the biomass estimate equations for deciduous forests were precise and hence it is useful for field applications.

Srivastava and Singh (2007) estimated carbon sequestration and mitigation through conservation strategy and the process of recognizing that the reforestation and afforestation, as well as combating deforestation can not only contribute to the local socio economic physical conditions and climate but the intrinsic part to take along to preserve and conserve biodiversity which also serves the important purpose of acting and storing carbon.

Ramachandran *et al*. (2007) studied the carbon management in forest floor-an important struggle of 21st century in Indian forestry scenario. Forests degradation is very common in India since 1901 to to-date. The reasons not exactly the same but are more the less like removal of large scale timber tree species for railway sleepers, construction, ship building charcoal for different kinds of transports, shifting cultivation in the forest woodlands and miscellaneous species, animal grazing and human induced or natural forest fires. The aforementioned problem of degradation of trees lead to loss of carbon stock not only in the standing but also in soil carbon pool. Such kind of loss of huge amount carbon in both standing biomass and soil leads in breakdown of carbon cycle results in climatic imbalance.

Raizada *et al.*(2007) studied the biomass prediction and production models for *Acacia nilotica* in salt affected regions of Karnataka and they observed that although the trees present over there is even-aged, there were wide variations in diameter ranging (3.1 to 16 cm) in the entire block and 9.3 to 15.4 cm in trees taken as sample. Tree height varied from 3.5 to 5.1 m, which in turn has influenced ground above biomass. Useful biomass (bole + bark + leaf) for firewood ranged from 18.3 to 72.64 kg/tree and overall above ground biomass ranged from 26.50 to 100.74 kg/ tree.

Baisya *et al*. (2009) studied ground above biomass distribution and carbon storage at different DBH and compared between the natural semi evergreen forest and sal plantation in humid tropics of northeast India. They noticed that the ground above biomass in natural forest was found higher in the trees having DBH > 60 cm as compared to plantation forests, which was less. The maximum carbon storage in natural and plantation forest was found in 60-80 cm and 40-60 cm class, respectively.

Jinshui Wu (2010) reported that paddy ecosystems in subtropical China had the ability to sequester organic C in amounts larger than those in other ecosystems. As these landscape units represent the real situations for paddy ecosystems under farmers practices for rice production, data from the study confirm that the trend of continuing organic C sequestration in paddy soils occurred in subtropical China.

Singh (2010) studied the impact of land use on vegetation and soil carbon, net primary productivity and nitrogen budget in tropical dry deciduous forest of Barnawapara Sanctuary and reported that natural forests have high stocks of carbon and carbon sequestration than that of plantation and further concluded that natural forests should not be converted to plantation or other land use until it is not highly degraded.

Singh *et al*. (2011) reported the distribution of carbon in soil profile in agro ecosystems of Indo-Gangetic plain and explore factors, which control this distribution. The soil texture was loam in the upper soil layers but changed to silt loam as the depth increased. Bulk density increased with soil depth, and had a negative relationship with soil organic carbon. A significant positive correlation between SOC and clay content was observed. About 69% of soil organic carbon in the profile was confined to the upper 40 cm soil layer where carbon stocked ranged from

8.5 to 15.2 t C/ha. They estimated that the agricultural soils of Indo-Gangetic plains may contain 12.4-26.6 t/ha of organic carbon in the top 1m soil depth. Since agricultural soils contain significantly lower carbon contain than the soils of the natural forest ecosystem in the same climate zone, management practices such as residue placement and reduced or no tillage are required to enhance carbon sequestration. A mix of agroforestry with crop fields may be an ideal option to enhance C sequestration in soils.

Khurana (2012) suggested that among the global common concerns, climate change has been identified as the most important environmental challenge faced by human beings. Emission of carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and hydrocarbons are identified as greenhouse gases causing warming of earth globally. Of these gases, CO_2 alone accounts for 60 percent share. The most practical way of removing excess carbon from atmosphere and storing it in to a biological system is by absorption of atmospheric CO_2 into the physiological system, plant biomass and finally into the soil. Carbon is thus sequestered into the plants and then the animals. Studies have established that carbon sequestration by trees and forest could provide relatively low cost net emission reduction. Carbon management in forest is therefore one of the most important agenda in India in 21st century in context of greenhouse gases effect and mitigation of global climate changes. Studies indicated that Indian forests share 1083.81 Mt C in the year 1994 to 3907.67 Mt C in the year 1993. Mixed planted forest of exotic and native species could be more efficient in sequestering carbon than the monocultures.

Ullah and Al-Amin (2012) worked on above and below ground carbon stock estimation in natural forest of Bangladesh and reported that the total carbon stock of 25 years the forest was 283.80 t ha^{-1} whereas trees produce 110.94 t ha^{-1}, undergrowth (shrub, herbs and grass) 0.50 t ha^{-1}, litter fall 4.21 t ha^{-1} and soil 168.15 t ha^{-1}, respectively.

Pandey *et al*. (2014) compared estimates of agricultural land loss using satellite data with agricultural census data. Their analysis highlights six key results. First, agricultural land loss is occurring around smaller cities more than around bigger cities. Second, from 2001 to 2010, each state lost less than 1 per cent of its total geographical area due to agriculture to urban expansion. Third, the north eastern states experienced the least amount of agricultural land loss. Fourth, agricultural land loss is largely in states and districts which have a larger number of operational or approved SEZs. Fifth, urban conversion of agricultural land is concentrated in a few districts and states with high rates of economic growth. Sixth, agricultural land loss is predominantly in states with higher agricultural land suitability compared to other states. Although the total area of agricultural land lost to urban expansion has been relatively low, our results show that since 2006, the amount of agricultural land converted has been increasing steadily.

Sharma *et al.* (2015) reported that changing climate is a worry for the nation but the country cannot afford to slow down the developing/developmental activities. Land use activities in irrigated agro-ecosystems have started shifting from traditional agriculture to smart agriculture to meet the country's food requirements and secure livelihood security. However, this shift has been achieved at the cost of natural resources and degradation of environment. There is a need to address the technical, economic, legal and social issues of the adopters because they have to lock their land for long time for CS projects, therefore confidence building measures are essentially required to make them aware/motivate for adoption of trees on their farms for mitigation of greenhouse gases (GHGs) and adaptation against changing climate.

2.4. Carbon sequestration trough agroforestry in urban, peri urban and rural areas.

Nautiyal *et al*. (1998) Tree cover in this system was represented by nine species with total average density of 390 trees ha^{-1}, *Grewia optiva* and *Boehmeria rugulosa* being the most dominant. Sequential agroforestry system involving slash-burn practice and cultivation on unterraced slopes without tillage and manuring was an illicit land use on community lands where forestry land use is desirable as per the government policy. Per ha annual energy input in simultaneous agroforestry system was 305267 MJ compared to 279 MJ in sequential agroforestry and 27047 MJ in home garden.

Maikhuri *et al*. (2000) A number of multipurpose tree species are conserved as scattered trees in settled farms on terraced slopes by the traditional farmers in Central Himalaya, India. Knowledge on growth rates and ecological impacts of these tree species is limited. Ten locally valued multipurpose tree species, viz., *Albizzia lebbek, Alnus nepalensis, Boehmeria rugulosa, Celtis australis, Dalbergia sissoo, Ficus glomerata, Grewia optiva, Prunus cerasoides, Pyrus pashia* and *Sapium sebiferum,* were established as mixed plantations at a degraded community forest land site and an abandoned agricultural land site in a village at 1200 m altitude in District Chamoli, India. Above-ground tree biomass accumulation at the abandoned agricultural land site was 3.9 t $ha^{-1}yr^{-1}$ compared with 1.1 t $ha^{-1}yr^{-1}$ at the degraded forest land site. *B. rugulosa*, *C. australis, F. glomerata*, *G. optiva*, *P.cerasoides* and *S. sebiferum* showed more prominent differences in growth at the two sites compared with *A. lebbek, A. nepalensis, D. sissoo* and *P. pashia*. *A. nepalensis* and *D. sissoo* showed best growth performance at both the sites. A significant improvement in soil physico-chemical characteristics was observed after five years at both of the sites. Carbon sequestration in soil was higher than that in bole biomass.

Sudha and Ravindranath, (2000) investigated the species assemblage in different land-use categories and the changes in vegetation over the recent years in Bengaluru City, India. Forty-six sites of nine different land-use categories were sampled to study species composition, DBH distribution and end-uses of trees. Among the tree owning households (50 per cent) in residential areas, 40 per cent of the houses have >5 trees and 22 per cent of houses have >5 tree species in their compound. Trees in residential areas were sampled and studied according to the economic strata of residents and the age of the area. One hundred and sixty-four species were identified in different residential areas, of which 149 species were recorded within compounds and 87 species were avenue trees.

David and Daniel, (2001) estimated that urban trees in the coterminous USA currently store 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million tC/yr ($460 million/year). Carbon storage within cities ranges from 1.2 million tC in New York, NY, to 19,300 tC in Jersey City, NJ. Regions with the greatest proportion of urban land are the Northeast (8.5 per cent) and the southeast (7.1 per cent). The national average urban forest carbon storage density is 25.1 tC/ha, compared with 53.5 tC/ha in forest stands. These data can be used to help assess the actual and potential role of urban forests in reducing atmospheric carbon dioxide, a dominant greenhouse gas.

Akbari, (2002) reported that urban shade trees offer significant benefits in reducing building air-conditioning demand and improving urban air quality by reducing smog. The savings associated with these benefits vary by climate region and can be up to $200 per tree. Their calculations suggest that urban trees play a major role in sequestering CO_2 and thereby delay global warming. A tree planted in Los Angeles avoids the combustion of 18 kg of carbon annually, even though it sequesters only 4.5–11 kg. In this sense, one shade tree in Los Angeles is equivalent to three to five forest trees.

Alain Albrecht and Serigne, (2003). Estimated potential carbon sequestration of agro forestry system is between 12 and 228 Mg ha−1 with a median value of 95 Mg ha−1. Therefore, based on the earth's area that is suitable for the practice (585–1215 × 106 ha), 1.1–2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years.

Punnet Dwivedi *et al*. (2009) studied that in developing countries like India, migration of people from rural to urban areas is responsible for ever expanding urban boundaries. This paper highlights the case of Kerwa Forest Area (KFA), located at about 10 km from the city of Bhopal, capital of Madhya Pradesh state. It was found that the KFA is currently facing severe anthropogenic pressure. Parts of the KFA, located close to the settlements, were found more disturbed than the parts which were located far from the settlements. In spite of disturbances, KFA is a habitat for many threatened and endangered tree species. KFA also plays a critical role of a carbon sink with a total storage of about 19.5 thousand tons of aboveground carbon

David *et al*. (2010) quantified carbon sequestration by urban trees in the United States to examine the magnitude and role of urban forests in relation to climate change. Urban trees field data from 28 cities and 6 states were used to determine the average carbon density per unit of tree cover. Urban tree carbon storage density average 7.69 kg C m^{-2} of tree cover and stores carbon 0.28 kg C m^{-2} tree cover per annual.

Mark and Jon Pasher, (2012) Urban trees provide numerous ecosystem goods and services by providing shade, habitat for wildlife, removal of air pollutants and the removal and storage of atmospheric CO_2. Carbon removal services provided by

Canadian urban trees have previously been assessed using an IPCC 2006 guidelines approach based on the percentage of urban area covered by tree canopy (UTC) for the 2012 time period . Based on the urban area boundary layers for 1991 and 2011, Canada's urban areas grew by an estimated 6% for this time period. Most of this growth occurred through conversion of agricultural and forested lands to urban. At the national scale the UTC for 1990 was estimated to be 27.6%, as compared to the 2012 UTC estimate of 26.1%, the difference between estimates for the two time periods fell within the uncertainty range. Carbon removal estimates based on the UTC estimates were also very similar for the two dates with 660.2 kt C removed in 1990 and 662.8 kt C removed in 2012.

Nowak *et al*. (2013) reported that urban tree field data from 28 cities in 6 states were used to determine the average carbon density per unit of tree cover. These data were applied to state wide urban tree cover measurements to determine total urban forest carbon storage and annual sequestration by state and at nation level.

John Connors *et al*. (2014) explicated a range of published and grey literature over the last three decades has underlined the importance of urban and peri-urban agriculture and forestry (UPAF) in cities of developing regions. The focus in the published literature is on livelihoods, poverty reduction and ecosystem services at multiple city scales. Cities of developing regions, particularly in Africa, are searching for ways of addressing the unavoidable impacts of climate change and UPAF has demonstrated scalable adaptation and mitigation potential. The study examines the extent to which literature conveys any evidence for UPAF playing a role in mediating the effects of climate/environmental change.

Sandhya Kiran and Shah Kinnary, (2015) findings in urban area suggest that 73.59 tons of CO_2 is removed by trees planted on roadsides of Vadodara city, which represents 22 per cent of the City's estimated total CO_2 production. Total CO_2 emission at major roads was found around 159.47 tonnes because of more number of automobiles as it is the third most-populated city in the Indian state of Gujarat. Results are restricted to the CO_2 that is sequestered by trees planted only on roadsides excluding other carbon sinks. It is therefore evident that tree planting on roadside and urban forestry is an effective method of offsetting CO_2 from human sources.

Parihaar *et al*. (2015) studied the indigenous agroforestry system with energy and economic efficiency of the landscape. This village includes 110 families with a human population of 631. Simultaneous agroforestry system was the main land use system being operated in the village. A total of fifteen tree species and twenty-two crop species were reported from the study area. Among tree component, *Mangifera indica*, *Tectona grandis* and *Populas sp* were the most dominant species. In agroforestry system annual energy input was 81 905 MJ/ha.

Erik Velasco *et al*. (2016) suggested that urban forests may represent an important carbon reservoir. However, the potential to directly remove carbon dioxide from the atmosphere by urban vegetation is still poorly supported by scientific evidence. Studies carried in in mid-latitude cities Singapore and Mexico City suggest that the carbon uptake by urban vegetation is small compared to the magnitude of the anthropogenic emissions; the CO2 flux data from two residential neighbour hoods of Singapore and Mexico City were analyzed. Results suggest that (sub) tropical vegetation may either act as an emission source or sink depending on the species and characteristics of the trees and the amount and conditions of pervious surfaces for soil respiration. The biogenic component (vegetation and soil) was found to be a sink of 1 Mg km^{-2} day^{-1} of CO_2 in Mexico City, but an emission source of 0.8 Mg day^{-1} km^{-2} of CO_2 in Singapore. The biogenic contribution to the total CO_2 flux represents -1.4 per cent and 4.4 per cent at both sites, respectively.

Matti Kuittinen *et al*. (2016) the study was carried out in seven different urban housing areas in the Finnish city of Espoo to ascertain the extent to which site efficiency affects to the ecosystem services if the full life-cycle GHG emissions of these areas are taken into account. The results show that the impact of CO_2 uptake through carbon sinks in growing plants and the uptake of soil organic carbon vary greatly. Its share of all emissions varied from a marginal value of 1.2 per cent to a more considerable value of 11.9 per cent.

Niyas *et al*. (2016) investigated the changes in the structural and functional attributes of selected urban and peri-urban home gardens of Kerala *viz*. Thrissur Municipal Corporation and Manjeri Municipality. The peri-urban homegardens (Manjeri) represented a total of 76 plant species with a distribution predominantly of fruit tree species (20), timber species (10) and medicinal plants (10). Home gardens in the Thrissur corporation region (urban) however showed lower diversity and stocking with a total of 51 tree species mostly represented by fruit tree species (15) and ornamental plants (17). The peri-urban home gardens regardless of the size showed better plant diversity and abundance with Simpson's dominance index and Shannon Index values at ranges of 0.73 to 0.84 and 2.72 to 3.37 respectively. The urban home gardens showed considerable reduction in species diversity with Simpson's dominance index and Shannon Index values ranging from 0.34 to 0.51 and from 1.53 to 2.03 respectively.

Haoluan Wang and Feng Qiu, (2017) study helps to fill this gap in the literature by investigating the drivers of forest-to-agriculture conversion in one of the largest metropolitan areas and its surrounding peri-urban regions in Canada, focusing on the effect of farmland losses to development. Agricultural land losses are an important driver for deforestation, and the magnitude of impact increases as the availability of forest-cover increases; population growth hinders the process of deforestation; high road density encourages forestland conversion to agriculture. Future policy-design shall find it helpful to incorporate the agricultural land expansion onto forestland due to land development when evaluating the social, economic, and environmental consequences of urbanization.

III MATERIAL AND METHODS

In this chapter, various material and methodologies were used to assess the bund measurements, and other related aspects are presented.

3.1 Selection of study area

Study on agroforestry was carried out in two parts, one in Bengaluru district, Karnataka state, two transects in the North and South direction from center of the Bengaluru was made. Each transect area was bifurcated into rural, peri-urban and urban region based on the population density, and the study was conducted. In another part of the study some areas of Tumakuru district adjacent to Bengaluru with similar climatic conditions is also selected for the present study. Following are the villages which fall under this location namely; Gunnagere, Idguru, Kempasagara, Sompura, Ammanagatta. In these two study sites farmers are classified into 43 small farmers (< 2 acres), 47 medium farmers (2-5 acres) and 25 large farmers (>5 acres) based on their land holdings. The length and width of all the bund is measured in these farmlands and expressed in meters per acre. The tree diversity and carbon stock in the trees present on bund were assessed in these areas.

3.2Measurment of bund area in the farmers field

The length and width of bund was measured using 50 meter measuring tape and expressed in meters. Total number of bund is counted and trees present only on bunds are counted.

3.2.1 Observations recorded

- Measurement of bund area: The bund area in each farm is measured in terms of length and the width of each bund and boundary of the farm and added to get the total length and width, which is expressed as bund length per unit acre land area.The height of the bund is not measured and hence bund area is expressed in m^2 and not in m^3, because the primary interest is to quantify the land available for tree planting. The bund length refers to length of both bunds within and boundary of an acre area.
- Tree species present on the bund area and the spacing of the trees on the bund is also recorded.

- The details of the land holdings such as name of the farmer, village and geographical location is collected.

3.2.2 Methodology for measuring the bund

The length of bund per acre of land was calculated using the equation:

$$\text{Mean bund length (m)} = \frac{\text{Sum total length of all bunds}}{\text{Number of bunds}}$$

The width of bund per acre of land was calculated using the equation:

$$\text{Average width of the bund (m)} = \frac{\text{Sum total width of all bunds}}{\text{Number of bunds}}$$

Area occupied by bund

It is calculated by multiplying the length of bund by its base width.

$$\text{Bund area} = \text{bund length} \times \text{bund width}$$

3.3. Tree diversity

Tree species present on bund was identified to species level as per taxonomic classification (Mulia *et al*. 2010) and is used for deriving the species diversity.

3.3.1. Alpha Diversity Index

Diversity index is expressed using Shannon Alpha Diversity index Method. The typical values generally varied between 0.80 and 3 in most of the ecological studies, the index is rarely greater than 4. Diversity indices provide more information about community composition than simply species richness (i.e., the number of species present). It also takes the relative abundances of different species into account. The formula used for deriving Shannon diversity index is as follows.

$$\mathbf{H = -\sum (P_i \times \ln P_i)}$$

Where,

P_i is proportion of S made up of the i^{th} species

For a well-sampled community, we can estimate this proportion as $P_i = n_i/N$.

n_i is the number of individuals in species i.

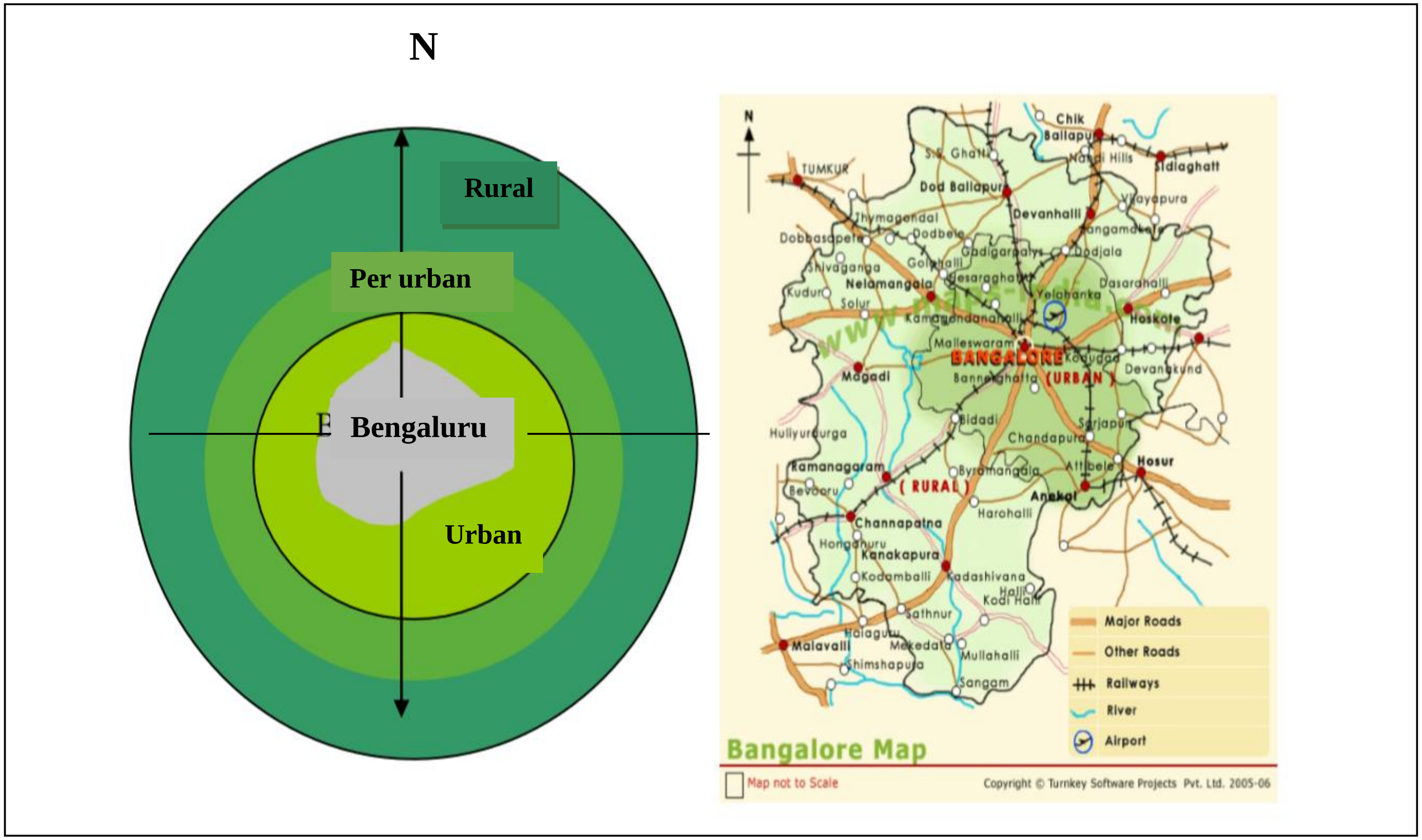

Plate 1: A schematic representation of sampling design (Left) and the map corresponding to the inner two layers of it (Right).

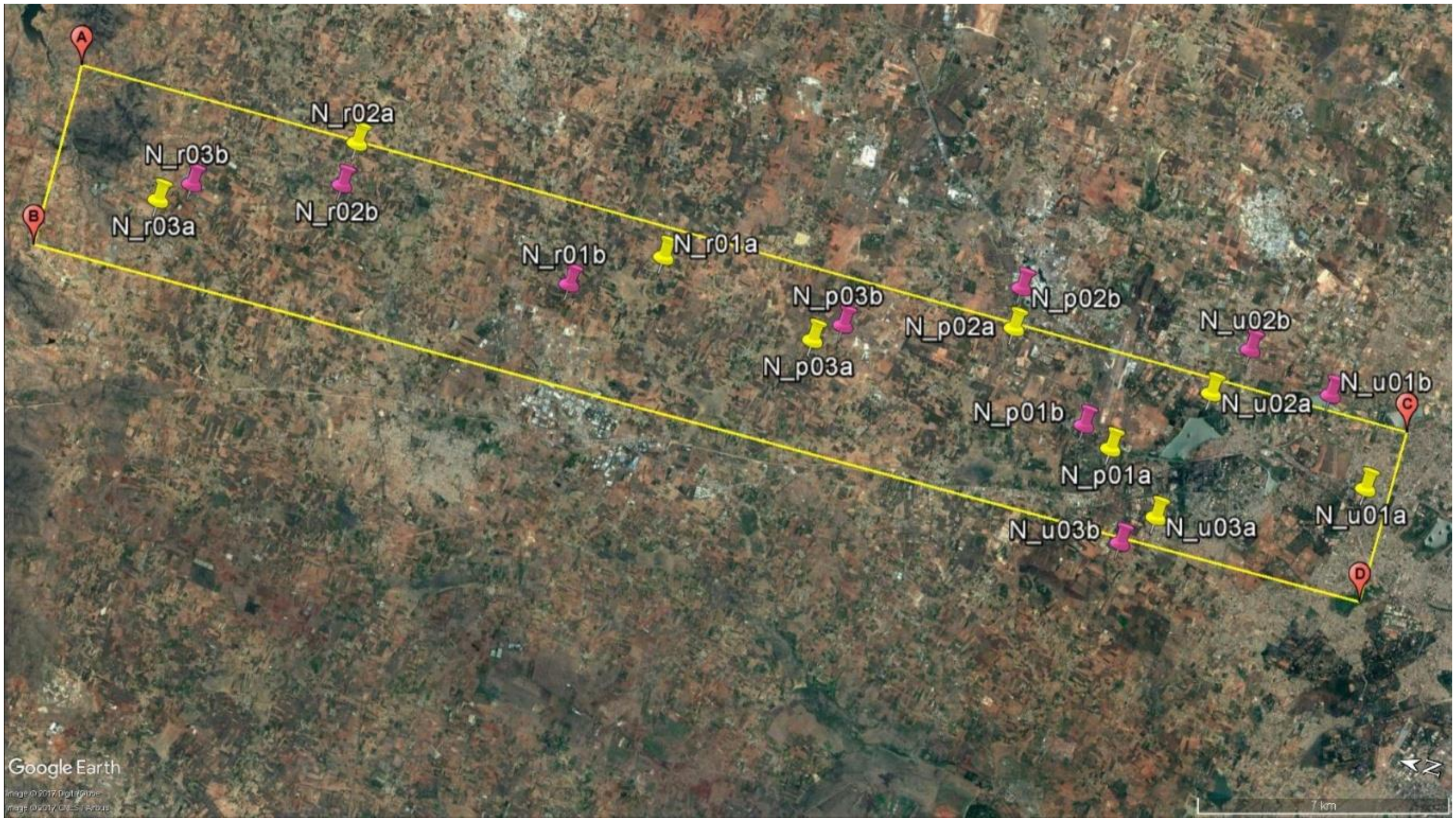

Plate 2: Study sites in the North transect rural (N_r), peri urban (N_p) and urban (N_u) areas.

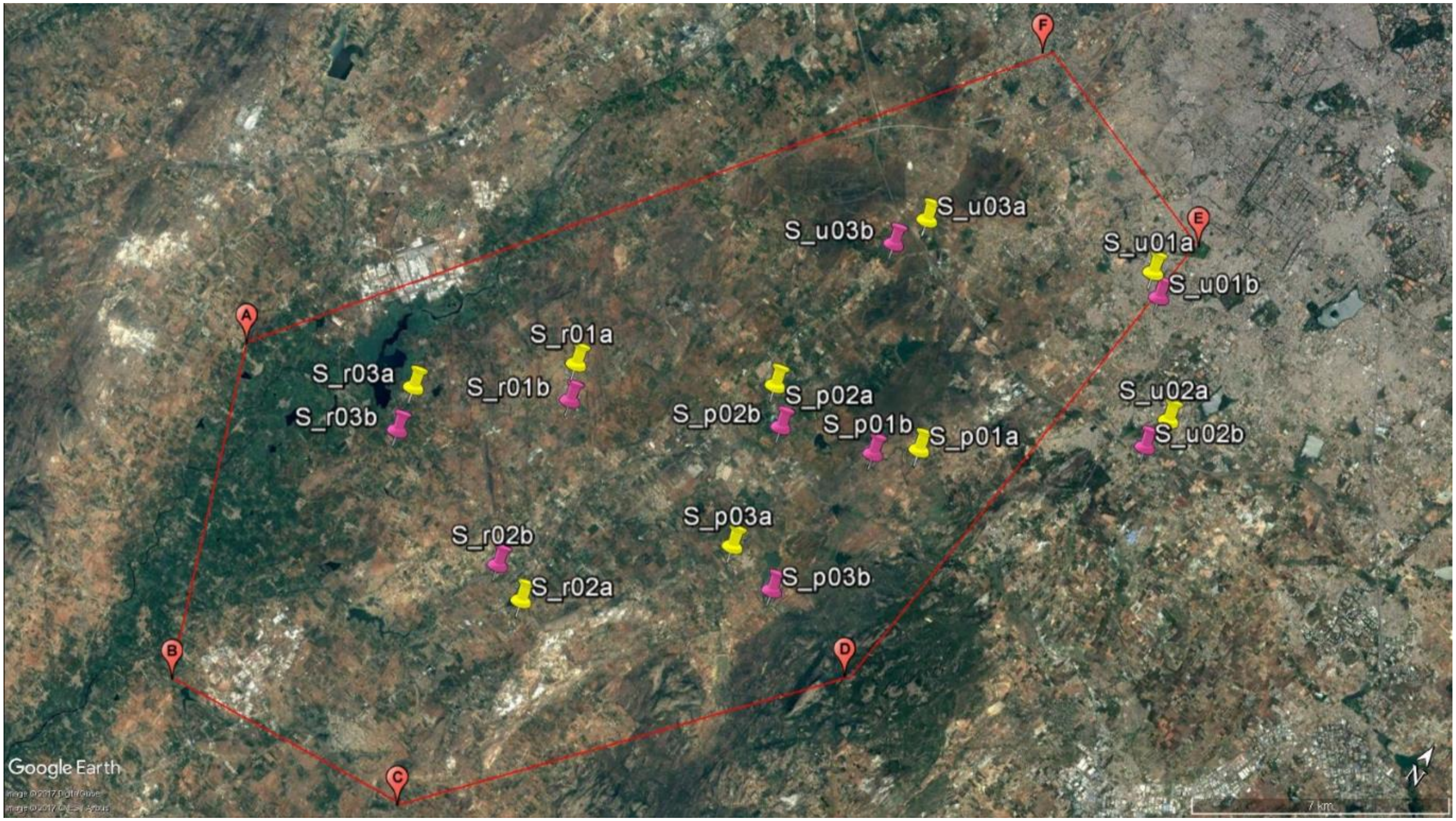

Plate 3: Study sites in the South transect rural (S_r), peri urban (S_p) and urban (S_u) areas.

N is the total number of individual species in the community.

Since by definition the P_iS will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why we take the inverse of the sum.

3.3.2. Beta Diversity Index

Jaccard β diversity represents the differences in species composition among sites (Here size refers to small, medium and large farm size). The variation in species composition between areas of diversity and the easiest way to assess it is by using similarity coefficients between pairs of sites. The values vary between 0-1 and the values indicate the extent of dis-similarity between the ecosystems.

$$C_j = j/(a+b-j)$$

Where,

j is the number of species found in both the sites.

a is the number of species in site A.

b is the numbers of species found in site B.

3.4 Tree density

Density is simply the number of trees per unit area on the bund and is generally reported as the number of trees per hectare (1 hectare = 2.47 acres). There will be 10,000 m^2 per hectare, so once the number of trees per plot is determined it can be converted it to this unit. Here number of trees present on bund in each farm category is noted and density is calculated.

3.5. Carbon sequestration assessment

Carbon stock in the standing trees was assessed by deriving the volume of the stem using tree height and stem diameter. The carbon content in the biomass is calculated assuming that 45% of the total biomass is carbon.

The standard protocol is as follows, the relevant total biomass values from total collected tree samples and multiply each by its wood density. This will give the estimates of the total carbon contained in trees of each stratum (tones C/ species), the total carbon contained in each stratum (tones C/ stratum), and the total carbon (in tones).

3.5.1. Girth and height of the tree

The girth of the tree is measured using measuring tape graduated to measure a minimum of one mm. The height of tree is measured with the help of Blume Leiss altimeter. The Blume Leiss altimeter is uses trigonometric principle. The device measures the angle of elevation between the operator and measured points. Tree heights can directly be read from the device depending on fixed distances of 15m, 20m, 30m and 40m. For mountainous areas slope correction factors can directly be read from the device depending on the slope.

3.5.1.1. Using Blume Leiss Altimeter to determine tree height

- Select a distance, preferably 15, 20, 30, or 40 meters away from the tree, where the required point on the tree (tree tip) can be seen. Measure the selected horizontal distance from the base of the tree.
- Release the pointer by pressing the button on the side of the instrument.
- Sight at the required point on the tree, wait for a moment for the pointer to settle then pull trigger.
- Read the height directly from the appropriate scale if you are 15, 20, 30, or 40 meters away from the tree. If you were unable to find a position at one of these distances:
  - If the horizontal distance is a simple fraction of one of the scale distances (e.g. 10 m is half of 20 m), read from the scale distance and multiply by the appropriate fraction.
  - Read from the percent scale and multiply this percentage by the horizontal distance measured in step 1.
- Site to the base of the tree and repeat steps 2 - 4.
- Combine the heights from steps 4 and 5 to determine total tree height
  - Add the 2 heights together if you looked up to the required point in step 3 and down to the base of the tree in step 5.

- Subtract the height to the base of the tree from the height to the required point if you are on sloping ground and had to look up to both the required point and the base of the tree.

3.5.2. Volume of the tree:

To calculate of volume of tree volume of a cylinder were used. Here trunk is assumed cylindrical in shape.

$$\textbf{VOLUME} = \pi r^2 h$$

Where r is radius of the stem and h is height of the tree. r is derived from the following relationship.

$$C = 2\pi r \text{ or } r = C/2\pi$$

3.5.3. Biomass of tree

After determining the total volume of the tree it is multiplied with the density of specific tree species to derive the biomass.

Biomass (kg) = volume × density of the species

3.5.4. Carbon content of the biomass

In general the carbon content of the biomass present in different parts of the plant such as leaf, stem and other parts varies between 40-50 per cent of the biomass. On an average 45 per cent of the ground above biomass is considered as carbon content (Singh, 1991).

Carbon content (kg) = Standing biomass × 0.45.

3.5.4.1. CO_2 content of the biomass

The CO_2 in the atmosphere is assimilated by trees in the process of photosynthesis. In order to derive the amount of CO_2 converted into carbon in the biomass, the molecular weight of carbon and oxygen is used as follows. Atomic weight of carbon is 12 and oxygen is 16

$CO_2 = (12 + (16×2))/12 = 44/12 = 3.67$.

Thus one molecule of carbon=3.67 molecules of CO_2 or 1 ton of carbon = 3.67 ton of CO_2.

3.6. Statistical Analysis

The analysis of the subject to data of variance obtained from various component of the study where ever it is relevant in analysis using different statistical tools. The level of significance used in F-test was at $p = 0.05$ and further, to know the difference between the means post hoc test was performed using Duncan test at level of 0.05 by using SPSS (Statistical Package for Social Science, version 2010)

IV RESULTS AND DISCUSSION

The results and discussions of the experiment conducted to evaluate the bund area and its tree composition in agriculture lands across the rural, peri-urban and urban regions of Bengaluru, and is compared with the rural area of the adjacent district of Tumakuru, which has similar rainfall and climatic conditions but do not have the pressure of urbanization.

Urbanization across the globe is increasing at a rapid rate. In India about 40% of the population is in urban area and is likely to increase further in the years to come. Global urban population increase is much more than this. The urbanization brings about changes in the land use patterns and primarily the arable land is converted into constructed areas thereby reducing the land cover on vegetation. This is happening largely because rural population depend on agriculture for their livelihood and large area of agriculture in India is rainfall dependant. Rainfed agriculture has huge uncertainties in terms of both rainfall distribution, duration and time, which in turn will have a strong bearing on the crop productivity. This situation is likely to be further aggravated due to changing climate across the world. Due to climate change there will be many more adverse effects and therefore this is one of the major challenges the world is currently need to address without further delay. Conversion of agriculture land to other urban related uses will reduce the green cover thereby reducing the sinks of atmospheric carbon and adding to the owes of climate change. One of the cost effective and environment friendly approaches to ameliorate climate change is to increase the vegetation cover, especially tree cover. Since the land availability is a major constraint, utilization of bunds and boundaries can help in increasing tree cover to a certain extent. However, there is no much information on availability of land area in the form of bund and boundaries and its composition. With this background, current study is an effort to quantify the bund and boundaries in Bengaluru across the rural urban transition zones in comparison with the rural area of adjacent taluka of Tumakuru that falls in the same agro-climatic zone.

As described in the methodology, Bengaluru is divided into north and south transects (regions) because the conditions as well as crops cultivated are different in these two regions. This is because of changes in the rainfall and associated change in the climatic conditions and natural resources, mainly the water.

4.1. Bund area and distribution

Average length of bund varied significantly among the study areas (Table 4.1.1). The average length of bund was highest under rural area (247.03m/ac) followed by peri urban (212.44m/ac) and urban (177.33m/ac) in north transect. The bund width ranged from 1.41 m/ac to 1.51 m/ac but did not vary significantly among the rural, peri-uban and urban areas.

Average length of bund varied significantly among the farmers with small, medium and large size land holdings (Table 4.1.1). The average length of bund area was highest under small farm category (260.22m/ac) followed by large (202m/ac) and medium (174m/ac) in north transect. The bund width ranged from 1.33 to 1.59m/ac. Average width of bund did not vary significantly among the land holdings of different size. The average width of bund was highest among medium size farm holding (1.59m/ac) followed by small (1.42m/ac) and large (1.33m/ac) in north transect. In case of bund area it is highest in rural area (352.22 m^2) followed by peri urban (331.65m^2) and is least in urban area (251.83m^2). Similarly, among the different land size holdings it was highest among small farmers (369.2 m^2) followed by medium (276.66 m^2) and large size farmers (268.66 m^2).

The average length of farm bund was highest under rural areas (247.03m/ac) followed by peri-urban (212.44m/ac) and urban (177.33m/ac) in south transect (Table 4.1.2). However, it did not vary significantly. The bund width ranged from 1.58 to 1.81 m/acre. Average width also did not vary significantly among the different study areas. The average length of farm bund was highest under small farm category (258.89 m/ac) followed by medium (202.67 m/ac) and large (199 m/ac) in south transect, but the differences were not statistically different. The bund width ranged from 1.46 m/acre to 1.80m/acre. The average width of farm bund was highest under large farm category (1.80 m/ac) followed by medium (1.72 m/ac) and small (1.46m/ac).

Among the three zone in south transect highest land area occupied by bund was fund in rural area (428.97m^2) followed by peri urban area (350.76m^2) and least was seen in the urban area (321.6m^2). Similarly among the land holding categories highest area occupied by bunds was found among small holdings (377.84 m^2) followed by large (358.2 m^2) and large size holdings (348.59 m^2).

Table 4.1.1. The bund details among the land transition zones and the farmer size categories in Northern transect of Bengaluru.

Land transmission zones/ Land holding categories	Bund length(m)	Bund width(m)	Bund area(m^2)
Rural	247.03(b)	1.42(a)	352.22
Peri urban	212.44(a)	1.51(a)	331.65
Urban	177.33(a)	1.41(a)	251.83
S.Em±2377.67F Table=7.30		**S.Em±0.109 F Table=0.276**	
Small	260.22(a)	1.42(a)	369.2
Medium	174(b)	1.59(a)	276.66
Large	202(b)	1.33(a)	268.66
S.Em±2377.67 F Table=4.59		**S.Em±0.109 F Table=1.37**	

Note : value indicated with same alphabet are not significantly different.

Table 4.1.2. The bund details among the land transition zones and the farmer size categories in Southern transect of Bengaluru.

Land transmission zones/ Land holding categories	Bund length(m)	Bund width(m)	Bund area(m^2)
Rural	237.11(a)	1.81(a)	428.97
Peri urban	222.11(a)	1.58(a)	350.76
Urban	201.33(a)	1.60(a)	321.6
S.Em±5017.20 F Table=2.02		**SEm±0.202 F Table=0.702**	
Small	258.89(a)	1.46(a)	377.84
Medium	202.67(a)	1.72(a)	348.59
Large	199(a)	1.80(a)	358.2
SEm±5017.20 F Table=0.379		**SEm±0.202 F Table=1.41**	

Note : value indicated with same alphabet are not significantly different.

Table 4.1.3. Bund details of different land holding categories of rural area of Tumakuru

Land holding categories	Bund length(m)	Bund width(m)	Bund area / acre(m^2)
Small	301 (a)	1.44 (a)	435
Medium	212 (b)	1.52 (a)	321
Large	195 (b)	1.34 (a)	257
SEm±7.96067; F Table=24.643 (Bund length) **SEm±0.03668; F Table=2.456 (Bund width)**			

The bund length ranged from 195 to 301 m/acre, with a mean of 242 m/acre (Table 4.1.3). The length of bund varied significantly among the land holding categories, it was highest under small land holdings (301 m) followed by medium (212 m) and large (195 m). The bund width ranged from a minimum of 1.34 m to maximum of 1.52 m, with a mean value of 1.42 m. Average width of bund did not vary significantly among the different size land holdings category. Total land area occupied by bunds was found to highest among small farmers and it was least in large farmers.

It is interesting to note that the bund length and the total land area occupied by bunds remained more in rural areas of both Bengaluru and Tumakuru compared to peri-urban and urban region. Further, among the farmers with different land holdings, small farmers had more area in their bunds compared to large farmers. These trends were similar in rural area of Tumakuru also, where small farmers had more land area occupied by bunds compared to medium and large land holdings. It is important to note that the bund width did not differ among any of the categories (rural to urban and small to larger land holdings) studied, suggesting that the bund width is same among all the farming community irrespective of size of the holding as well as urbanization. From the results, it is also clear that the area occupied by bund and boundaries was more among the rural and small farmers compared to large, peri-urban, and urban area, which is largely due to variation in the bund length. This suggests that the efficiency of land use is more as we move away from rural area towards the urban regions and among the large farmers compared to farmers with small holdings. This also implies that the area available on bunds is more in rural area compared to urban area and with small farmers compared to large farmers. Therefore, under existing situation there are more trees seen on the bunds of small large farmers, while the possibility of increasing tree cover is more in large farmers bunds because the spacing followed by large farmers is more compared to medium and small farmers (Table 4.7.23, 4.7.24 and 4.7.25).

4.2. Tree diversity

After assessing the bund size the composition of the bunds in terms of perennial trees present on the bunds was studied. There were eight tree species found in the rural north transect belonging to seven different families. The total number of trees found in the study area were 172 of which 86 were found in small farm category, followed by medium farm category (52) and it was least among large farmers (34) in the north transact of Bengaluru district. (Table 4.2.4).

Among the 86 trees in small farmer category, highest number of trees were of *Tectona grandis* (63) followed by *Eucalyptus spp* (15), *Azadirachta indica* (5), and least number was seen in *Acacia nilotica* (2), *Grevillea robusta* (1). Similarly in medium farmer category out of 52 trees, highest number of trees were of *Eucalyptus spp.* (13), followed by *Azadirachta indica* (15), *Tectona grandis* (11),*Melia dubia*(11) and least was seen in *Artocarpus heterophyllus*(1), *Grevillea robusta* (1). In case of large farmers category a total of 34 trees were found and highest number of trees was *Tectona grandis* (82), followed by *Eucalyptus spp.* (35), *Azadirachta indica* (31), *Melia dubia* (15), and least numbers of trees are in *Grevillea robusta* (4), *Acacia nilotica* (2), *Pongamia pinnata* (2), *Artocarpus heterophyllus* (1) and all the 8 tree species were found among the large farmers (Table 4.2.4).

The trends were similar in peri-urban region to that of rural area. Out of 113 trees in small farmer category, highest number of trees were found in *Tectona grandis* (35) followed by *Azadirachta indica* (23), *Eucalyptus spp*(19), *Melia dubia*(15), *Grevillea robusta* (10) and least number of trees were *Swietenia mahagani (L.)* jacb.(5), *Pongamia pinnata* (4) and *Mangifera indica* (2). Similarly among the medium farmer category out of 55 trees, highest number of trees were *Eucalyptus spp* (17), followed by *Tectona grandis* (16), *Acacia nilotica* (13), *Tamarindus indica* (5),

Table 4.2.4. Tree species density and distribution on bunds in rural areas of North transect of Bengaluru district among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small (3)	Medium (3)	Large (3)	
1	*Artocarpus heterophyllus*	Moraceae	0	1	0	1
2	*Azadirachta indica*	Meliaceae	5	15	11	31
3	*Eucalyptus spp*	Myrtaceae	15	13	7	35
4	*Grevillea robusta*	Proteaceae	1	1	2	4
5	*Melia dubia*	Meliaceae	0	11	4	15
6	*Pongamia pinnata*	Fabaceae	0	0	2	2
7	*Tectona grandis*	Lamiaceae	63	11	8	82
8	*Acacia nilotica*	Fabaceae	2	0	0	2
	Total		86	52	34	172

Table 4.2.5. Tree species density and distribution on bunds in peri-urban areas of North transect among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small (3)	Medium (3)	Large (3)	
1	*Azadirachta indica*	Meliaceae	23	0	17	40
2	*Eucalyptus spp*	Myrtaceae	19	17	18	54
3	*Grevillea robusta*	Proteaceae	10	0	0	10
4	*Mangifera indica*	Anacardiaciae	2	0	0	2
5	*Meliadubia*	Meliaceae	15	0	0	15
6	*Pongamia pinnata*	Fabaceae	4	0	14	18
7	*Swietenia mahagani*	Meliaceae	5	4	0	9
8	*Tamarindus indica*	Fabaceae	0	5	2	7
9	*Tectona grandis*	Lamiaceae	35	16	0	51
10	*Acacia nilotica*	Fabaceae	0	13	0	13
	Total		113	55	51	219

Swietenia mahagani (4). In case of large farmers category out of 51 trees highest number of trees was *Eucalyptus spp* (18), followed by *Azadirachta indica* (17), *Pongamia pinnata* (14) and *Tamarindus indica* (2) recorded highest population (Table 4.2.5).

In the urban area tree number remained same among all the three land holding categories but the species composition varied (Table 4.2.6). Out of 56 trees among small farmer category, highest number of trees were *Azadirachta indica* (22) and *Tectona grandis* (10).Similarly in medium farmer category out of 56 trees, highest number of trees were *Eucalyptus spp* (27) and *Melia dubia* (13). In case of large farmers category a total of 57 trees were *Tectona grandis* (34) followed by *Pongamia pinnata* (8).

It was noticed that the total number of trees in urban areas was less (169) compared to rural and peri-urban areas (Table 4.2.6). Although the number of trees present in urban areas found to be less, the number of species found were more (12) compared to rural and peri urban areas of north transact.

Out of 44 trees in small farmer category, highest number of trees were *Melia dubia* (10) followed by *Azadirachta indica* (7) and *Tamarindus indica* (6) (Table4.2.7). Similarly in medium farmer category out of 43 trees, highest number of trees were *Melia dubia* (10) and *Tectona grandis* (10). In case of large farmers category out of 40 trees, highest number was seen in *Azadirachta indica* (15) and *Tectona grandis* (9).

South transect rural has less number of trees (127) compared to north transect rural (Table 4.2.7). It was noticed that there was no much difference in total number of trees in three different farmer category small (44), medium (43) and large (40). From these three zones more number of trees were found to be in *Melia dubia* 36.

Total number of trees on bunds in peri-urban was found to be more compared to rural area in the south transects (Table 4.2.8). Out of 66 trees in small farmer category, highest number of trees were *Azadirachta indica* (24) followed by *Eucalyptus spp* (18) and *Tectona grandis* (11). Similarly, in medium farmers' category out of 51 trees, highest number of trees were *Azadirachta indica* (30), *Tectona grandis* (8) and *Delonix regia* (6). In case of large farmers category a total of 57 trees, highest was found to be in *Azadirachta indica* (22) and *Eucalyptus spp*(10).

Table 4.2.6. Tree species density and distribution on bunds in urban areas of North transect among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small(3)	Medium(3)	Large(3)	
1	*Albizia lebbeck*	Fabaceae	0	1	1	2
2	*Artocarpus heterophyllus*	Moraceae	0	1	0	1
3	*Azadirachta indica*	Meliaceae	22	3	6	31
4	*Eucalyptus spp*	Myrtaceae	1	27	0	28
5	*Ficus bengalensis*	Moraceae	0	0	1	1
6	*Grevillea robusta*	Proteaceae	7	3	6	16
7	*Mangifera indica*	Anacardiaciae	9	2	0	11
8	*Melia dubia*	Meliaceae	4	13	0	17
9	*Pongamia pinnata*	Fabaceae	3	2	8	13
10	*Samanea saman*	Fabaceae	0	1	0	1
11	*Tectona grandis*	Lamiaceae	10	3	34	47
12	*Acacia nilotica*	Fabaceae	0	0	1	1
	Total		56	56	57	169

Table 4.2.7. Tree species density and distribution on bunds in rural areas of South transect among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small(3)	Medium(3)	Large(3)	
1	*Albizia lebbeck*	Fabaceae	5	0	0	5
2	*Artocarpus heterophyllus*	Moraceae	1	0	0	1
3	*Azadirachta indica*	Meliaceae	7	8	15	30
4	*Eucalyptus spp*	Myrtaceae	0	0	7	7
5	*Ficus religiosa*	Moraceae	4	0	0	4
6	*Melia dubia*	Meliaceae	10	20	6	36
7	*Moringa oleifera*	Moringaceae	4	0	0	4
8	*Phyllanthus emblica*	Phyllanthaceae	2	0	0	2
9	*Pongamia pinnata*	Fabaceae	3	5	3	11
10	*Santalum album*	Santalaceae	1	0	0	1
11	*Syzygium cumini*	Myrtaceae	1	0	0	1
12	*Tamarindus indica*	Fabaceae	6	0	0	6
13	*Tectona grandis*	Lamiaceae	0	10	9	19
	Total		44	43	40	127

Table 4.2.8. Tree species density and distribution on bunds in peri urban areas of South transect among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small(3)	Medium(3)	Large(3)	
1	*Albizia lebbeck*	Fabaceae	5	0	0	5
2	*Artocarpus heterophyllus*	Moraceae	5	2	0	7
3	*Azadirachta indica*	Meliaceae	24	30	22	76
4	*Delonix regia*	Fabaceae	0	6	0	6
5	*Eucalyptus spp*	Myrtaceae	18	0	10	28
6	*Ficus religiosa*	Moraceae	0	5	0	5
7	*Grevillea robusta*	Proteaceae	3	0	5	8
8	*Mangifera indica*	Anacardiaciae	0	0	5	5
9	*Tectona grandis*	Lamiaceae	11	8	5	24
	Total		66	51	47	164

Total number of trees in urban region was highest compared to rural and peri-urban categories (Table 4.2.9). Out of 41trees in small farmer category, highest number of trees were *Michelia champaca* (12) and *Tectona grandis* (10). Similarly in medium farmer category out of 63 trees, highest number of trees were *Azadirachta indica* (40) and *Peltophorum pterocarpum* (11). In case of large farmers category out of 70 trees highest number of trees were *Azadirachta indica* (32) and *Tectona grandis* (22).

Out of 191 trees in small farmers category, highest number of trees were *Tectona grandis* (68), followed by *Azadirachta indica* (48) and less number of trees was *Syzygium cumini* (1), *Tamarindus indica* (1), *Ficus religiosa* (5) (Table 4.2.10). Similarly in the medium farmers category out of the total 181 trees highest number of trees were found in *Tectona grandis* (48), followed by *Melia dubia* (40) and*Azadirachta indica* (24). The least number of trees were *Tamarindus indica*

(1),*Saraca asoca* (1), *Peltophorum pterocarpum* (1). In case of large farmers category total of 120 trees came from 18 out of 24 different trees species, among which 67 trees were of *Tectona grandis* and 17 trees belonged to *Melia dubia.*

The type of species as well as the density of species across the farmers category varied. Among the three farmers category studied more number of species was found in small followed by medium but it was least among large farmers. Most dominant species was *Tectona grandis* followed by *Azadirachta indica* and *Melia dubia* among all farmers.

Table 4.2.9. Tree species density and distribution on bunds in urban areas of South transect among different size land holdings.

Sl No.	Name of the species	Family	Number of Individuals			Total
			Small (3)	Medium (3)	Large (3)	
1	*Artocarpus heterophyllus*	Moraceae	0	2	0	2
2	*Azadirachta indica*	Meliaceae	8	40	32	80
3	*Eucalyptus spp*	Myrtaceae	5	0	0	5
4	*Ficus religiosa*	Moraceae	4	0	0	4
5	*Grevillea robusta*	Proteaceae	0	5	4	9
6	*Mangifera indica*	Anacardiaciae	2	5	3	10
7	*Michelia champaca*	Magniliaceae	12	0	0	12
8	*Peltophorum pterocarpum*	Fabaceae	0	11	0	11
9	*Samanea saman*	Fabaceae	0	0	2	2
10	*Swietenia mahagani*	Meliaceae	0	0	4	4
11	*Tamarindus indica*	Fabaceae	0	0	3	3
12	*Tectona grandis*	Lamiaceae	10	0	22	32
	Total		41	63	70	174

Table 4.2.10. Tree species density and distribution on bunds in rural Tumakuru among different size land holdings.

Sl. No	Name of the species	Family	Number of individual			Total
			Small (n=37)	Medium (n=38)	Large (n=25)	
1	*Acacia auriculiformis*	Fabaceae	12	9	2	23
2	*Aegle marmelos*	Rutaceae	1	1	1	3
3	*Albizia lebbeck*	Fabaceae	0	0	1	1
4	*Artocarpus heterophyllus*	Moraceae	6	2	1	9
5	*Azadirachta indica*	Meliaceae	48	24	14	86
6	*Eucalyptus spp*	Myrtaceae	8	5	3	16
7	*Ficus benghalensis*	Moraceae	5	14	1	20
8	*Ficus racemose*	Moraceae	2	5	0	7
9	*Ficus religiosa*	Moraceae	0	1	0	1
10	*Gliricidia sepium*	Fabaceae	0	0	1	1
11	*Grevillea robusta*	Proteaceae	15	12	2	29
12	*Leucaenaleuco cephala*	Fabaceae	0	0	1	1
13	*Mangifera indica*	Anacardiaciae	2	1	2	5
14	*Melia dubia*	Meliaceae	13	40	17	70
15	*Moringa oleifera*	Moringaceae	2	0	1	3
16	*Peltophorum pterocarpum*	Fabaceae	0	1	0	1
17	*Phyllanthus emblica*	Phyllanthaceae	1	0	0	1
18	*Polyalthia longifoila*	Annonaceae	1	0	0	1
19	*Pongamia pinnata*	Fabaceae	2	16	3	21
20	*Psidium guajava*	Myrtaceae	1	0	1	2
21	*Saraca asoca*	Fabaceae	2	1	0	3
22	*Syzygium cumini*	Myrtaceae	1	0	1	2
23	*Tamarindus indica*	Fabaceae	1	1	1	3
24	*Tectona grandis*	Lamiaceae	68	48	67	183
	Total		191	181	120	492

4.3. Shannon alpha diversity index

Shannon alpha diversity index was calculated for the small, medium and large farmer category of north transect to know the distribution pattern of the tree species present in three different landscapes (Table 4.3.11). The index values varied from 0.83 in smallholdings in rural area to 1.79 in smallholdings of peri urban area. The diversity values depend on both number of individuals' presents as well as the number of species. In north transect highest Shannon diversity was recorded in peri urban landscape followed by urban and rural.

Table 4.3.11. Shannon alpha diversity index among three different land holding sizes in the north transect.

Sl. No	Land holdings	Rural	Peri-urban	Urban
1	Small	0.83	1.79	1.64
2	Medium	1.51	1.47	1.61
3	Large	1.61	1.21	1.27

The diversity values in the south transect varied from 1.48 to 2.10 in rural region among small farmers, 1.39 to 1.59 among peri-urban and 1.10 to 1.65 in urban region (Table 4.3.12).

Table 4.3.12. Shannon alpha diversity index among three different land holding size in the south transect

Sl. No	Land holdings	Rural	Peri-urban	Urban
1	Small	2.10	1.55	1.65
2	Medium	1.25	1.20	1.10
3	Large	1.48	1.39	1.42

In south transect highest Shannon diversity was recorded in rural landscape among small land holding farmers and it was least among the urban followed by peri-urban regions. This was due to higher number of species recorded in urban medium size land holding farmers, suggesting, species richness is more in rural areas.

Diversity in rural parts of Tumakuru is higher as seen in case of Bengaluru. Maximum values were recorded in medium size farmers followed by small and large farmers respectively (Table 4.3.13).

Table 4.3.13. Shannon alpha diversity index rural Tumakuru.

Sl. No	Land holdings	Diversity index
1	Small	2.01
2	Medium	2.11
3	Large	1.65

4.4. Jaccard beta diversity index

Jaccard beta diversity index help in assessing and comparing the diversity between two ecosystems. Jaccard beta diversity index in rural areas where small and medium farmer category were found to be 0.22 meaning and about 22 percent similarity between these two categories while a value of 0.37 between large and small farm category indicates about 37 percent similar species or 63 percent of the species are unique to these two landscapes. Similarly, between the large and medium farm category 50 percent species were unique to these two ecosystems (Table 4.4.14). In peri urban area where small and medium farmer category tree species has 8.3 percent similarity while large and medium farmer category indicates about 20 percent similar species or 80 percent of the species are unique to these two category. Similarly, between the large and medium farm category 72 percent species were unique to these two category. In urban north transect where small and medium farmer category were found to be 0.30 which suggest that about 30 percent similarity between these two category while a value of 0.08 between large and medium farm category or 92 percent of the species are unique to these two category. Similarly, between the large and medium farm category 94 percent species were unique to these two category.

Jacquard β-diversity index that indicates the uniqueness of species in a given landscape (Maza *et al*., 2002).

Table 4.4.14. Jaccard beta diversity index along the rural- urban transition among the three-size land holdings in North transect of Bengaluru.

Land holdings	Small	Medium	Large
Rural			
Small	---	---	---
Medium	0.22	---	---
Large	0.37	0.5	---
Peri urban			
Small	---	---	---
Medium	0.08	---	---
Large	0.2	0.12	---
Urban			
Small	---	---	---
Medium	0.30	---	---
Large	0.08	0.06	---

Table 4.4.15. Jaccard beta diversity index along the rural- urban transition among the three-size land holdings in South transect of Bengaluru.

Land holdings	Small	Medium	Large
Rural			
Small	---	---	---
Medium	0.07	---	---
Large	0.45	0.5	---
Peri urban			
Small	---	---	---
Medium	0.1	---	---
Large	0.37	0.42	---
Urban			
Small	---	---	---
Medium	0.1	---	---
Large	0.18	0.2	---

Jaccard beta diversity index in rural south transect where small and medium farmer category were found to be 0.07 which suggest that about 7.1 percent similarity between these two category while a value of 0.45 between large and medium farm category indicates about 45 percent similar species or 55 percent of the species are unique to these two category. Similarly, between the large and medium farm category 50 percent species were unique to these two category (Table 4.4.15). In peri urban area where small and medium farmer category tree species has 10 percent similarity while a value of 0.37 between large and medium farm category indicates about 63 percent of the species are unique to these two category. Similarly, between the large and medium farm category 58 percent species were unique to these two category.In urban area where small and medium farmer category 10 percent similarity between these two categories while a value of 0.18 between large and medium farm category indicates about 18 percent similar species. Similarly, between the large and medium farm category 80 percent species were unique to these two category.

Jaccard beta diversity index of small and medium were found to be 0.52, which suggest that there, is about 52 percent similarity between these two landscapes while a value of 0.47 between medium and small farmers category indicates about 47 percent similar species or 53 percent of the species are unique to these two land holding groups. Similarly, between the large and medium 79 per cent species were unique (Table 4.4.16).

Table 4.4.16. Jaccard beta diversity index among the three size land holdings in rural Tumakuru.

Land holdings	Small	Medium	Large
Small	---	---	---
Medium	0.52	---	---
Large	0.47	0.21	---

4.5. Carbon stocks in standing trees among different areas

Higher amount of carbon stock was observed in peri urban zone (29 tones) followed by rural zone (23 tones) and least carbon stock was recorded in urban zone (21 tones) (Table 4.5.17). From these entire three land transition zone a total of 73 tons of carbon is stored in standing biomass of trees which is equal to 269 tons of carbon dioxide sequestered from atmosphere.

Higher amount of carbon stock was observed in peri urban zone (78 tones) followed by urban zone (54 tones) and least carbon stock was recorded in rural zone (32 tones) (Table 4.5.18). From these entire three ecosystems a total of 164 tons of carbon is stored in standing biomass of trees which is equal to 604 tons of carbon dioxide sequestered from atmosphere over years.

Table 4.5.17. Carbon stock in standing trees of north transect along the rural urban transition.

	Carbon stock (tons)	Co_2(tons)
Rural	23	85
Peri-urban	29	106
Urban	21	78
Total	73	269

Table 4.5.18. Carbon stock in standing trees of south transect along the rural urban transition

	Carbon stock (tons)	Co_2(tons)
Rural	32	117
Peri-urban	78	287
Urban	54	200
Total	164	604

The amount of carbon sequestered by trees and there by the total amount of CO_2 removed from the atmosphere is derived from the total biomass accumulated by the trees as explained in the methodology. A total of 73 tons of carbon which is equivalent to 269 tons of CO_2 is absorbed because of the trees maintained on the bunds in north transect. Out of the total carbon sequestered, maximum contribution has come from peri urban followed by trees in the rural and urban zone (Table 4.5.17). This is mainly because of the more number of individuals in the peri urban areas and their larger size. A total of 164 tons of carbon which is equivalent to 604 tons of CO_2 is absorbed because of the tree cover in south transect (4.5.18). It was noticed that more carbon is sequestered in south transect as that of north transect mainly because of more size, height and girth of trees. Out of the total carbon sequestered, maximum contribution has come from peri urban followed by trees in the urban and rural zones (David and David 2010).This suggests that both less density of larger trees or more density of smaller trees can contribute for removing carbon from the atmosphere. Thus from such analysis it is possible to identify suitable tree species to different landscapes based on the space available for tree planting. Apart from storing carbon, the trees on the bunds also help in relegating the wind speeds, trapping dust, assimilating many contaminants, release oxygen into atmosphere and many other ecosystem services. Not all these benefits are quantified in economic terms.

The total carbon stock was estimated from the biomass of standing tree (Table 4.5.19). The amount of carbon sequestered by trees and thereby the amount of CO_2 removed from the atmosphere is derived from the biomass accumulated by the trees as explained in the methodology. The total carbon accumulated from all the trees present on bund is 97tons, out of this maximum contribution is from medium farm category. From this, a total of 352 tons of CO_2 from the atmosphere has been sequestered in to trees. This table gives the amount of carbon sequestered by trees where the existing number of trees that helped in removing carbon present in atmosphere, if the number of trees is increased then it is helpful both to mitigate climate change and sustainable forest management. (Srivastava *et al*. 2007) estimated carbon sequestration and mitigation through conservation strategy and the process of recognizing that the reforestation and afforestation, but the intrinsic part to take along to preserve and conserve biodiversity which also serves the important purpose of acting and storing carbon.

Table 4.5.19. Carbon stock in standing tree rural Tumakuru

Land holdings	**Carbon stock (tons)**	**Co_2(tons)**
Small	35	126
Medium	43	157
Large	19	69
Total	97	352

4.6. Tree density on bunds

The mean average of 28 trees/acre were found on bund area in small farmers category. Total number of trees on bund of small farmer category is 255 where individual trees ranged from 0-37 and from 9 species. On an average 40 trees/acre were recorded on medium farmers category (Table 4.6.20). Total number of trees found were 163, where individual tree population ranged from 0-21 from 13 species. Similarly 17 trees were found per acre of land in large farmers category. Total number of trees on bund of large farmers category is 142 where individual tree ranged from 0-23 from of 13 species.

Table 4.6.20. Trees present on the bunds in the North transect.

	Number of trees /acre		Total number of trees on bund	Number of existing species
	Average	Range		
Small (n=9)	28	(0-37)	255	9
Medium (n=9)	40	(0-21)	163	13
Large (n=9)	17	(0-23)	142	14

Table 4.6.21. Trees present on the bunds in the South transect.

	Number of trees /acre		Total number of trees on bund	Number of existing species
	Average	Range		
Small (n=9)	16	(0-15)	144	16
Medium (n=9)	17	(0-33)	152	10
Large (n=9)	17	(0-26)	155	19

On an average 16 trees were found per acre of land in small farmers category. Total number of trees on bund of small farmers category is 144 where individual trees ranged from0-15 from 16 species. The mean average 17 trees were found per acre of land in medium farmers category (Table 4.6.21). Total number of trees found were 152 where individual tree population ranged from 0-33 from 10 species. Similarly, 17 trees were found per acre of land in large farmers category. Total number of trees on bund of large farmers category is 155 where individual tree species ranged from 0-26 from 19 species.

Therefore, the average number of trees present in bund areas of south transect is less than that of north transect, therefore it shows that there is more space available for planting the tree and can plant more trees compared to north transect. If a regular spacing is maintained then there is a possibility of accommodating more trees on the bund area. Therefore, the need of planting the tree is more in south transect so that the impact of build-up of atmospheric carbon can be reduced to certain extent.

On an average 4 trees were found per acre of land in small farmers category. Total number of trees recorded on bund of small farmers category is 191 from 37 farmers out of 43 studied. Number of individual from each species from 0-26 and there were 19 different tree species. In medium farmers, category also four trees were found per acre. Total number of trees found were 181 and out of 46 medium farmers, studied trees were found in 38 farmers only. Individual tree population ranged from 0-25 and from 16 species. Similarly, 5 trees were found per acre of land in large farmers category. Total number of trees found is 120 from 20 out of 25 studied. Individual tree population ranged from 0-27 from 18 species (Table 4.6.22).

Table 4.6.22. Details of trees present on the bunds in rural Tumakuru.

	Number of trees /acre		Total number of trees on bund	Number of existing species
	Average	Range		
Small (n=43)	4.00 (n=37)	(0-26)	191	19
Medium (n=46)	4.00 (n=38)	(0-25)	181	16
Large (n=25)	5.00 (n=20)	(0-27)	120	18

The average number of trees present in bund areas is very less in these study areas therefore, it shows that there are more available space on bund for planting trees.

4.7. Trees present on actual spacing and hypothetical spacing for adding still more trees.

Here total bund length, spacing and number of trees per acre of land is given (Table 4.7.23). From all three areas of rural, peri urban and urban landscape of north transect the mean average total bund length in farmers' category of small 260m, medium 174 m and large 202 m was recorded. Trees present on bund with existing spacing is noted *i.e*. 28 trees with 9.2 m spacing in small farmers category, 40 trees with 4.3 m spacing in medium farmers category and 17 trees with 11.8 m spacing in large farmers category.

Table 4.7.23. Hypothetical spacing and number of trees possible to accommodate on bunds of different land holdings in north transect.

	Total length of bund(m)	**Number of trees present at current spacing**		**Number of trees possible at spacing/acre**		
		Spacing(m)	**Trees**	3 m	4 m	5 m
Small	260	9.2	28	86	65	52
Medium	174	4.3	40	58	43	29
Large	202	11.8	17	67	50	40

Note: m:meter

Since the number of trees actually present on the bund is less, there is a possibility of increasing trees on bund. The hypothetical spacing and number of trees that can be accommodated on existing bunds are given (Table 4.7.23). In small farmer category of north transect, if the spacing is maintained with 3m there is a possibility of increasing 86 trees on existing bund. Similarly, with 4m spacing 65 trees and 5m spacing 52 trees can be accommodated. In medium farm category if the spacing is maintained with 3 m there is a possibility of increasing 58 trees on existing bund. Similarly, with 4 m spacing 43 trees and 5m spacing 29 trees can be accommodated.

Similarly, in large farm category if the spacing is maintained with 3m there is a possibility of increasing 67 trees on existing bund. Similarly with 4m spacing 50 trees and 5m spacing 40 trees can be accommodated.

Here total bund length, spacing and number of trees per acre of land is given (Table 4.7.24). From all three areas of rural, peri urban and urban landscape of south transect the mean average total bund length in farmers category of small 259m, medium 203 m and large 109 m is recorded. Trees present on bund with existing spacing is noted *i.e.* 16 trees with 16 m spacing in small farmers category, 17 trees with 12 m spacing in medium farmers category and 17 trees with 11m spacing in large farmers category.

Table 4.7.24. Hypothetical spacing and number of trees that is possible to accommodate on bunds of different land holdings in south transect.

	Total length of bund(m)	Number of trees present at current spacing		Number of trees possible at spacing/acre		
		Spacing(m)	Trees	3 m	4 m	5 m
Small	259	16	16	86	64	51
Medium	203	12	17	67	50	40
Large	199	11	17	66	49	39

Note: m:meter

Since the number of trees actually present on the bund of south transect is very less than north transect, there are more possibility of increasing trees on bund compared to north transect. The hypothetical spacing and the possibility of number of trees that can be accommodated on existing bunds are given. In small farmer category of south transect, if the spacing is maintained with 3m there is a possibility of increasing 86 trees on existing bund. Similarly, with 4m spacing 64 trees and 5m spacing 51 trees can be accommodated. In medium farm category if the spacing is maintained with 3 m there is a possibility of increasing 67 trees on existing bund. Similarly, with 4 m spacing 50 trees and 5m spacing 40 trees can be accommodated and in large farm category, if the spacing is maintained with 3m there is a possibility of increasing 66 trees on existing bund. Similarly, with 4 m spacing 49 trees and 5m spacing 39 trees can be accommodated. If the more number of trees are present, more carbon can be sequestered and suitable species that can fetch farmers income (Alain Albrecht and Serigne Kandji, 2003). Agricultural lands are believed to be a major potential sink and could absorb large quantities of carbon if trees are reintroduced to agro-forestry ecosystems and judiciously managed together with crops and/or animals

Here total bund length, spacing and number of trees per acre of land is given (Table 4.7.25). From all three farmer categories the mean average bund length in farmers category of small 301 m, medium 212 m and large 195 m is recorded. Trees present on bund with existing spacing is noted i.e. 4 trees with 75 m spacing in small farmer category, 4 trees with 53 m spacing in medium farmer category and 5 trees with 39 m spacing in large farmer category.

Table 4.7.25. Hypothetical spacing and number of trees that is possible to accommodate on bunds of different land holdings rural Tumakuru

	Total length of bund(m)	**Number of trees present at current spacing**		**Number of trees possible at spacing/acre**				
		Spacing(m)	**Trees**	4 m	5 m	10 m	20m	30m
Small	301	75	4	75	60	30	15	10
Medium	212	53	4	53	42	21	11	7
Large	195	39	5	48	38	19	10	6

Note: m:meter

Since the number of trees actually present on the bund is very less in these study area, there are more possibility of increasing trees on bund. The hypothetical spacing and the possibility of number of trees that can be accommodated on existing bunds are given. In small farmer category, if the spacing is maintained with 4m there is a possibility of increasing 75 trees on existing bund. Similarly with 5m spacing 60 trees,10m spacing 30, 20 m spacing 15 trees and 30m spacing 10 trees can be accommodated. In medium farmer category if the spacing is maintained with 4 m there is a possibility of increasing 53 trees on existing bund. Similarly with 5m spacing 42 trees,10 m spacing 21 trees, 20m spacing 11 trees and 30m spacing 7 trees can be accommodated and in large farmer category if the spacing is maintained with 4m there is a possibility of increasing 48 trees on existing bund. Similarly with 5m spacing 38 trees,10 m spacing 19 trees, 20 m spacing 10 trees and 30 m spacing 6 trees can be accommodated. If the more number of trees are present more carbon can be sequestered and suitable species that can fetch farmers income (Alain Albrecht and Serigne Kandji, 2003). Agricultural lands are believed to be a major potential sink and could absorb large quantities of carbon if trees are reintroduced to agro-forestry ecosystems and judiciously managed together with crops.

Although the possibility of increasing tree cover in rural areas of Tumakuru is higher compared to rural areas of Bengaluru. However, it is also important to understand the reasons.

V SUMMARY

Climate change is one of the major issues that influence the health and the economic growth. Global climate change is predicted to have serious implications especially in tropical countries. Increasing tree cover is considered an ecologically and economically sustainable approach to address the impact of climate change. The trees act as major sink of atmosphere CO_2 and help in trapping pollutants and particulate matter. Land availability being a major constraint, increasing tree cover in agricultural land through agro forestry system is one of the viable options recommended by IPCC.

One of the productive arable land and not used for cultivation is the bunds. Hence, bund is and can be used for planting the trees. Thus bunds in urban, peri urban and rural agriculture land are assessed to understand the bund dimension and tree diversity and density. This study was carried out by measuring the bund length and bund width to know if there is any possibility of increasing tree density in the bunds. Study was done in two transects in the North and South direction the radiates from the center of the Bengaluru district. This was compared with rural areas of the adjacent Tumakuru district. Each transect area was bifurcated into rural, peri urban and urban region based on the population density. Here bund length and width are measured from small, medium and large farmers category. Bund length varied among the small, medium and large farmers category but bund width remained the same. However, bund length was found to be more in rural areas of both Bengaluru and Tumakuru districts compared to urban and peri-urban regions of Bengaluru. This suggests that land is subject to more judicious use in urban area compared to rural parts. It also implies that since bund length is more in rural area more trees can be accommodated in the rural region.

Tree density was found to be more in northern part of Bengaluru compared to southern parts. This is mainly due to differences in the cropping pattern differences in, which depended on the rainfall pattern, climatic conditions and water availability in these regions.

Number of tree species found in the rural parts of Tumakuru was more compared to Bengaluru district. Number of tree species among the rural, peri-urban and urban areas varied from eight in rural to thirteen in the urban areas. However highest number of individuals from most of these regions belongs to *Tectona grandis* and *Azadirachta indica*. This suggests that preference in general among the farming community is more for commercially important, timber yielding teak and medicinally important neem, but also has timber value.

It is interesting to note that the number of trees seen on the bunds in Bengaluru among the small, medium and large farmers in both north and southern regions remained almost same. Considering the total length of the bund and the spacing at which the trees are planted, the possibility of increasing the tree density on the available bunds among the small farmers is relatively more compared to medium and large farmers, while in case of rural area of Tumakuru there is a huge potential to increase the tree density on the bunds as the existing tree density is vary sparse compared to Bengaluru. It is important to note that the trees on the bunds, irrespective of their number or size will contribute ecologically by sequestering the atmospheric carbon. Hence, any addition of trees even if it is a small number will be helpful in ameliorating the climate.

However for enhancing the tree cover further inputs such as suitable tree species and the tree density need to be evaluated in addition to farmers willingness to take up more trees on the bunds.

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