"BIOMASS, CARBON STOCK AND CARBON SEQUESTRATION POTENTIAL IN *Acacia nilotica*-PADDY BASED TRADITIONAL AGROFORESTRY SYSTEM"

M. Sc. (Forestry) Thesis

by

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INDIRA GANDHI KRISHI VISHWAVIDYALAYA
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“BIOMASS, CARBON STOCK AND CARBON SEQUESTRATION POTENTIAL IN *Acacia nilotica*-PADDY BASED TRADITIONAL AGROFORESTRY SYSTEM”

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Veijaneng Haokip

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science

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CERTIFICATE-I

This is to certify that the thesis entitled **"Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry System"** submitted in partial fulfillment of the requirements for the degree of **Master of Forestry** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur is a record of the bonafide research work carried out by **Ms. Veijaneng Haokip** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

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

Date: 22/07/2016

Chairman
Advisory Committee

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CERTIFICATE – II

This is to certify that the thesis entitled "**Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry System**" Submitted by **Ms. Veijaneng Haokip** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Forestry** in the Department of Forestry has been approved by the external examiner and Student's Advisory Committee after oral examination.

03/08/16

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Date: 03/08/16

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Faculty Dean ____________________

Director of Instructions ____________________

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%	Per cent
&	And
<	Less than
=	Equal to
>	More than
^{0}C	Degree centigrade
A	Abundance
A/F	Abundance/Frequency
BA	Basal Area
C.G.	Chhattisgarh
CBH	Circumference at breast height
Cm	Centimeter
Cd	Simpson’s index
D	Density
DBH	Diameter at breast height
et al	And others/co-workers
Fig.	Figure
GBH	Girth at breast height
GIS	Geographical Information System
Ha	hectare
ha^{-1}	Per hectare
t ha^{-1}	tons per hectare
ht	Height
i.e.	that is
viz.	namely
e.g.	for example
m ha	million hectare
Kg ha^{-1}	kilogram per hectare
m	meter

g	gram
AGB	Above Ground Biomass
BGB	Below Ground Biomass
NPP	Net Primary Productivity
C	Carbon
CO_2	Carbon dioxide
Mg	mega gram = 10^6 gram
MoEF	Ministry of Environment and Forest
R.B.A.	Relative Basal Area
R.D.	Relative Density
R.F.	Relative Frequency
IVI	Importance Value Index
FSI	Forest Survey of India
UNEP	United Nation Environment programme
IPCC	Inter-governmental Panel on Climate change
FAO	Food and Agricultural Organization
No.	Number
g m^{-2}	gram per square meter
AGBD	above ground biomass density
PMDF	primary mixed deciduous forest
SMDF	secondary mixed deciduous forests
BAR	biomass accumulation ratio
TAGB	total above ground dry biomass
GPP	gross primary production
ANPP	above-ground net primary production
APR	above-ground plant respiration
TBCF	total below-ground carbon flux
NEP	net ecosystem production
MAP	mean annual precipitation
μ g g^{-1}	micro-gram per gram
MAT	mean annual temperature

TDF	tropical dry forests
S.E.	Standard error
d	species richness
Cd	Concentration of dominance
ha^{-1} yr^{-1}	per hectare per year
BNP	Belowground net production
P	Phosphorus
K	Potassium
N	Nitrogen
m^2	Square meter
CD	Critical differences
SOM	Soil organic matter
GHG	Green House Gases
Pg	Petagram (1Pg = 10^{15} grams)
SOC	Soil organic carbon
Tg	Tera gram (1Tg = 10^{12} grams)
KP	Kyoto Protocol
CDM	Clean Development Mechanism
CER	Certified emission reductions
CSP	Carbon Sequestration Potential
SCS	Soil Carbon Sequestration
MBC	Microbial Biomass carbon

THESIS ABSTRACT

Title of the Thesis	:	Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry System
Full name of the Student	:	VEIJANENG HAOKIP
Major Subject	:	FORESTRY
Major Advisor	:	Dr. Lalji Singh
	:	Department of Forestry
Degree to be awarded	:	Master of Science

Signature of the Student

Signature of Major Advisor

Signature of Head of the Department

Date: 22/07/2016

ABSTRACT

In the present study the attempt has been made to quantify the "Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry system" in tropical environment at Nara village PO Bhan Soj, Raipur district (Chhattisgarh), during the year 2015-2016.

The study was conducted in the field where there is an Agroforestry system comprising of *Acacia nilotica* and Paddy. The variation in soil characteristics, biomass, productivity and carbon sequestration across the sites were quantified. Biomass for all the tree were estimated using allometric equations based on the relationship between girth of tree and dry weight of the components (bole, branch, leaf and root). The carbon storage components was computed as the sum of the products obtained by multiplying dry weights of components with their mean carbon

concentrations. The soil properties (physical and chemical) of the field were also studied at two level of soil depth *viz;* 0-10, 10-20cm. The soil of all the field is characterized by silty loam structure with considerably varying proportions of sand (23 – 28 %), silt (55 – 59 %) and clay (16– 19%).

Bulk density ranged from 1.31 to 1.36 gm^{-3}. The soil p^H was within the range 6.10– 6.90. Total N and C were between 87 – 112 Kg/ha and 0.30 - 0.45 %, respectively. The maximum p^H value was recorded at upper layer (0-10 cm) in all the fields. Available P and K were between 7.23 – 17.56 kg $^{ha-1}$ and 294.56 – 404.32 kg $^{ha-1}$ respectively. The electroconductivity of the soil ranges from 0.19-0.33 dS/m. The water holding capacity of the soil ranges from 26-40%.

In the present study, the total crop biomass were ranged between 3.10-4.93. It was maximum in field 1 and minimum in field 6. The total crop yield ranged between 0.82 and 1.58 tons/ha. It was observed maximum in field no 1 and minimum in field no 6. The Carbon Stock of the soil ranged between 4.92 and 5.8 tons/ha. It was found to be maximum in field no 3 and minimum in field no 6. Carbon stock in tree component was 2.32 tons/ha. The total carbon stored in trees across the agroforestry system was found to be 6.15 tons/ha. Total carbon sequestered by the system was at rate of 3.0% tons/ha.Total net productivity of the tree was 2.6 tons/ha/yr.

This research concluded that *Acacia nilotica*-paddy based traditional agroforestry system have the potential to enhance carbon stock through tree biomass and soil. The magnitude and quality of carbon stock depends on the complex interaction between climate, soil, density, age of plantation, and management practices.

शोध सारांश

अ) शोध शीर्षक – "एकेसिया निलोटिका–धान पर आधारित कृषि वानिकी प्रणाली में बायोमास, केर्बन भण्डारण और कार्बन अवशोषण शक्ति का बध्ययन करना"

ब) छात्रा का नाम – वेजनिंग होपिक

स) प्रमुख्य विषय – वानिकी

द) मुख्य सलाहकार का नाम और पता – डॉ. लालजी सिंह, वानिकी विभाग, कृषि महाविद्यालय, इं.गां.कृ.वि.,रायपुर

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प्रमुख सलाहकार के हस्ताक्षर

दिनांक : 22/07/2016

विभागाध्यक्ष के हस्ताक्षर

सारांश

वर्ष २०१५-१६ के दौरान ऐके सिया निलोटिका – धान पर आधारित पारम्परिक कृषि वानिकी प्रणाली में बायोमास कार्बन का भंडार और कार्बन जब्ती शक्ति के परिणाम जानने के लिए रायपुर जिले के नारा गांव, पो. आ. थान ससोज में किया गया।

इस अध्ययन को ऐसे क्षेत्र में किया गया। जहां एक कृषि वानिकी प्रणाली जिसमें ऐकेसिया निलोटिका और धान शामिल थे। जिसमें मृदा की विशेषताओं में बायोमास में उतपादता में और कार्बन जब्ती की मात्रा में भिन्नता का अध्ययन किया गया था। सभी पेड़ों के बायोमास का आंकलन ऐलोमेट्रिक समीकरण के द्वारा किया गया जो कि पेड़ कि परिधि और घटकों का सूखा वनज जैसे तना, शाखा, पत्ती और जड़ से संबंधित है। कार्बन भण्डारण के घटक की गणना उत्पाद के घटक का सूखा वनज और साथ ही औसत कार्बन सांद्रता के गुणांक को जोड़ने पर प्राप्त हुई है। इस क्षेत्र में मृदा के भौतिक व रासायनिक गण का अध्ययन किया गया था जिसकी गहराई दो स्तर पर पहली ०-१० और दूसरा १०-२० सें.मी. है। सभी

क्षेत्र के मिट्टी की पहचान सिल्ट दोमट संरचना के साथ विभिन्न अनुपात में पाये गये। जैसे रेत (२३-२८ प्रतिशत), सिल्ट (५५-५९ प्रतिशत) और क्ले (१६-१९ प्रतिशत) थी।

देर धनतव की सीमा १.३१ से १.३६ घ प्रति ग्राम थी। और मिट्टी के पी.एच. की सीमा ६.१० से ६.९० तक थी। और कुल नत्रजन और कार्बन की सीमा ८७ से ११२ कि.ग्रा. प्रति हेक्टेयर और ०.३० से ०.४५ प्रतिशत के बीच थीं। सभी क्षेत्र पर अधिकतम पी. एच दृका स्तर ०-१० सें.मी. दर्ज किया गया। उपलब्ध फास्फोरस और पोटाश ७.२३ से १७.५६ कि.ग्रा. प्रति हेक्टेयर और २९४.५६ से ४०४.३२ कि.ग्रा. प्रति हेक्टेयर के बीच पाया गया था। मृदा के विद्युत प्रवाह की सीमा ०.१९ से ०.३३ डी.एस. प्रति मीब्र के बीच थी। मृदा की जल धारण क्षमता की सीमा २६ से ४० प्रतिशत थी।

वर्तमान अध्ययन में कुल फसल का बायोमास की सीमा ३.१० से ४.९३ के बीहच थी। और क्षेत्र–एक में अधिकतमऔर क्षेत्र–दो में न्यूनतम कुल फसल बायोमास पायी गयी। और कुल फसल उपज कीं सीमा ०.८२ और १.५८ टन प्रति हेक्टेयर के बीच थी। और क्षेत्र क्रमशः-१ में अधिकतम और क्षेत्र क्रमांक-६ में न्यूनतम स्तर पर पाया गया था। मृदा के कार्बन भण्डार की सीमा ४.९२ और ५.८ टन प्रति हेक्टेष्र के बीच थी। कृषि वानिकी प्रणाली में पेड़ की कुल कार्बन भण्डारण क्षमता ६.१५ टन प्रति हेक्टेयर थी। प्रणाली के द्वारा कुल करार्बन अवशोषण दर ३.० प्रतिशत है। और पेड़ की कुल नेट उत्पादकता २.६१ टन प्रति वर्ष है।

एकेसिया निलोटिका – धान पर आधारित पारमपरिक कृषि वानिकी प्रणाली के अनुसंधान से यह निष्कर्ष निकला है कि पेड़ (वृक्षों) के बायोमास और मृदा द्वारा कार्बन भण्डारण और उसकी गुणवत्ता जलवायु, मृदा घनत्व, वृक्षारोपण की उम्र और प्रबंधन के जटिल परस्पर क्रिया पर निर्भर है।

CHAPTER-1
INTRODUCTION

Trees are known to maintain soil organic matter and nutrient cycling through the addition of litter and root residues into the soil. Carbon dioxide is naturally captured from the atmosphere through biological, chemical, or physical processes. Estimation of biomass is one of the most important requirements for the study of ecosystem functioning. The amount of biomass present in a particular ecosystem depends upon the kind of species available and also their potential to absorb the Carbon dioxide.

Agricultural lands are believed to be a major potential sink and can absorb large quantities of carbon if trees are introduced and judiciously managed with crops. The tropical forests spread over 13.76 million sq. km area worldwide which accounts for 60% of the global forests (FAO 1988, 2005) and play a key role in global carbon cycle both in terms of Carbon flux and the volume of Carbon stored. The Energy crisis, alarming problem of global warming and the increasing prices of fuel wood, pole, fodder and petroleum products have focused considerable attention towards the production of tree biomass. One of the best and successful strategies to solve the energy crisis is the plantation of fast growing multipurpose tree species (MPTs). Growth and biomass production of trees depend on the genetic potential of species, site characteristics and management practices adopted at various stages. The maximum biomass production is not only related to the availability of plant nutrients besides the fast growth of the species but it is also closely related to the selection of suitable provenance of the suitable species for a particular environment. The tropical forests account for 37% of the total 90% of the world's terrestrial carbon that is stored in forests (Houghton 1996).

In the context of forests, carbon stock refers to the amount of carbon stored in the world's forest ecosystem, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. Scientific concerns regarding tropical deforestation and global climate change have motivated ongoing efforts to quantify the role of forests as terrestrial carbon stores in the global carbon cycle (Brown, 1997; Houghton, 1997; Watson et al., 2000; Clark et al., 2002). An estimated 13 million ha of tropical forest is lost each year due to deforestation (FAO, 1999), emitting 5.6–8.6 Gt of carbon into the atmosphere.

The effectiveness of agro forestry systems in storing carbon depends on both environmental and socio-economic factors. In humid tropics, agro forestry systems have the potential to sequester over 70 Mg/ha in the top 20 cm of the soil. The carbon storage capacity in agro forestry varies across species and geography. Agroforestry has the potential of restoration and maintenance of soil fertility, controls and prevents soil erosion, controls water logging, checks acidification and eutrophication of streams and rivers, increases local biodiversity, decreases pressure on natural forests for fuel and provides fodder for livestock, increasing productivity and also improves the livelihoods of people in both developed and developing countries. It also has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. It also provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. Agroforestry systems offer important opportunities for creating synergies between both adaptation and mitigation actions. Deep and extensive root systems of trees enable them to absorb substantial quantities of nutrients below the rooting zone of crops and transfer them to surface soil (Hartemink et al.1996; Allen et al. 2004).

Tree based land used systems could sequester carbon in soil and vegetation and improve nitrogen cycling within the systems. The potential for agricultural systems to sequester atmospheric carbon dioxide (CO_2) through building levels of soil carbon, has been an area of considerable interest in recent years, in view of set greenhouse gas reduction targets. The goal of agricultural carbon removal is to use the crop and its relation to the carbon cycle to permanently sequester carbon within the soil. Thus, the importance of agroforestry as a land use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to carbon sequestration or climate change (Verma *et al*., 2008). The total carbon sequestration potential of global croplands is about 0.75-1Pg/yr or about 50% of the 1.6-1.8 Pg/yr lost due to deforestation and other agricultural activities. (Murthy et al 2013). Agroforestry is also an attractive option for climate change mitigation as it sequesters carbon in vegetation and soil, produces wood, serving as substitute for similar products that are unsustainably harvested from natural forests, and also contributes to farmer's income (Prasad et al 2012). The role of trees in maintaining and improving soil productivity is considered central to the sustainability of many agroforestry systems.

Important strategies of soil C sequestration include restoration of degraded soils, and adoption of recommended management practices (RMPs) of agricultural and forestry soils. Potential of soil C sequestration in India is estimated at 7 to 10 Tg C/y for restoration of degraded soils and ecosystems, 5 to 7 Tg C/y for erosion control, 6 to 7 Tg C/y for adoption of RMPs on agricultural soils, and 22 to 26 Tg C/y for secondary carbonates. (Lal 2004)

Acacia nilotica (L.) Willd. ex Del commonly known as babul, kikar or Indian gum Arabic tree, has been recognized worldwide as a multipurpose tree (National Academy of Sciences 1980). It is a relatively fast growing, drought resistant multipurpose legume with the ability of biological nitrogen fixation. In addition, its strong tap root system (Toky and Bisht 1992), long growing period of more than 300 days with four peaks of leaf flush (Beniwal et al 1992), it can intensively exploit soil column for nutrients and moisture. This species has high potential for nitrogen fixation (Toky et al. 1994) and enhance the organic matter of the soil which makes it one of the most preferred species in rice bunds. It has a high calorific value of 4950 kcal/kg, making excellent fuel wood and quality charcoal. It burns slow with little smoke when dry. It has a 25% more shock resisting ability than teak. (Bargalli and Bargalli 2009).

In the State of Chhattisgarh, rice (*Oryza sativa*) is the main crop and is cultivated on about 3.5 mha area, which comes approximately 81% area of agricultural land in the rice season. This crop is grown mostly under rain fed conditions (about 85%) and about 8–10% of the rice area comes under huge bunds. Generally, new bunds (having 1.5 m width and height around the paddy fields) are used for growing upland crops for one or two years (Bargalli etal 2009). Subsequently, these bunds are left fallow and are inhabited by naturally growing tree species.

Acacia nilotica grows naturally in bunds at irregular spacing . Few of the important examples of tree which are naturally growing on bunds and boundaries in the traditional agroforestry system are *Acacia nilotica*, *Terminalia tomentosa*, *Albizia procera*, *Butea monosperma* and *Tectona grandis* (Bargalli etal 2009).

The beneficial influences of tree-based cropping systems on increasing soil organic matter, improving soil fertility build-up and restoring soil physical conditions are well recognized. Improvement in water-holding capacity and soil structure along with several fold increase of nitrogen and organic carbon content in the soil under trees than fallow has already been reported. As an old traditional practice, farmers do not follow canopy management of the trees; rather they cut and sell trees that are more than 20 years old. Crop yields are reported to increase when trees are cut or coppiced in agroforestry. There is considerable interest to increase the carbon storage capacity of terrestrial vegetation through land-use practices such as afforestation, reforestation, and natural regeneration of forests, silvicultural systems and agroforestry (Murthy et al, 2013). The present research work focused to explore the potentiality of the Biomass, carbon stock and carbon sequestration in *Acacia nilotica*-Paddy based Traditional Agroforestry system.

The study entitled "Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry System" was carried out with the following objectives:

1. Estimating the biomass of *Acacia nilotica*-paddy based agroforestry system.
2. Quantification of the carbon stock potential of *Acacia nilotica*-paddy based agroforestry system**.**
3. Estimation of the carbon sequestration potential of *Acacia nilotica*-paddy based agroforestry system.

CHAPTER-II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the work on **"Biomass, Carbon Stock and Carbon Sequestration Potential in *Acacia nilotica*-Paddy Based Traditional Agroforestry System".** The literature is broadly reviewed under the following major aspects.

2.1 Biomass pattern, Net Primary Productivity (NPP), and *Acacia nilotica*-Paddy based Traditional Agroforestry system

2.2 Carbon storage pattern and carbon sequestration,

2.3 Soil and nutrient.

2.1 Biomass pattern, and Net primary Productivity (NPP) and Acacia nilotica paddy based traditional agroforestry system

Biomass constitutes a primary data needed for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems (Chaturvedi and Singh, 1987; Tiwari, 1994). On the other hand, the estimation of woody biomass is also necessary for determining the storage and flux of biological materials in an ecosystem (Anderson, 1970). The quantity of tree biomass per unit land area forms the primary data needed to understand the flow of materials and water through forest ecosystems (Swank and Schreuder, 1974).

The biomass estimations in forests are conventionally made by the use of species specific allometric equations and component wise viz., stem, branch, foliage and root biomass are estimated in both tree and shrub layer (Misra, 1968; Odum, 1983; Rai, 1984). In this approach, the availability of species-specific local regression equations is essential for precisely estimating the forest biomass.

Brown *et al.* (1989) reported a strategy for estimating total aboveground biomass of tropical forests. They developed regression equations to estimate aboveground biomass of individual trees as a function of diameter at breast height, total height, wood density, and Holdridge life zone (sensu Holdridge 1967). The regressions are applied to some 5,300 trees from 43 independent sample plots, and 101 stand tables from large-scale forest inventories in four countries, to estimate commercial and total aboveground biomass per unit area by forest type, and to estimate expansion factors defined as the ratio of aboveground to commercial biomass. The quadratic stand diameter (QSD, i.e., the diameter of a tree of average basal area) in a given forest stand influences the magnitude of the expansion factor. Stands of small trees have large expansion factors (up to 6.4), and as QSD increases, the expansion factor decreases to a constant value (about 1.75). Estimates of tropical forest biomass based on small destructive samples continue to be high relative to estimates based on volume data.

Srivastava *et al*. (1989) have determined the soil biomass C, N and P for a native forest site, an unmined deforested site and an age-series of adjacent coal mine spoils. Biomass C ranged from 209-867 μg g-1, biomass N from 20-75 μg g-1 and biomass P from 7-29 μg g-1. Biomass C, N and P were linearly related to each other. Biomass C was also related to the root biomass

Singh and Singh (1991) studied the species composition, plant biomass and net primary productivity on three sites of a dry tropical forest The forest was characterized by small structure with 38−10.4 m^2 ha^{-1} tree and 3 1−7 8 m^2 ha^{-1}shrub basal cover .Species diversity was highest for the mid-slope site while the concentration of dominance was greatest for the hill-top stand Total standing crop of vegetation averaged 6698 t ha^{-1} with 4670 t ha^{-1} in the tree layer, 13.97 t ha^{-1} in the shrub layer, 0.35 t ha^{-1} in the herb layer, 2 83 t ha^{-1} in the litter layer and 3 13 t ha^{-1} in fine roots Of the total annual litter fall (4 88−6.71 t ha^{-1}), 69% was accounted for by leaves and 31% by non-leaf matter .Net primary production (NPP) ranged between 113 and 192 t ha^{-1} $year^{-1}$, to which the contributions of trees, shrubs and herbs averaged 72, 22 and 6%, respectively. Contribution of roots to NPP was substantial and ranged from 29 to 53 t ha^{-1} $year^{-1}$ A total of 83% of vegetation carbon was stored in the above-ground plant parts while the above-ground NPP was responsible for 72% of the total carbon input into the system. The contribution of foliage, herbaceous vegetation and fine roots to carbon turn over was disproportionately larger compared to their share in the total standing crop.

Singh and Singh (1991) studied the species composition and diversity index in mixed dry deciduous forests of Vindhyan region. The basal cover of vegetation varied from 3.8 to 10.4 m^2/ha for trees and 3.1 to 7.8 m^2/ha for shrubs. Shannon and Weiner index and concentration of dominance ranged between 1.93 to 2.18 and 0.18 to 0.38, respectively. The beta diversity was 3.1.

Singh and Singh (1993) concluded that the short live components in a dry tropical forest ecosystem in India (tree foliage, fine root and herbaceous plants) are important for biomass production and nutrient cycling. Short lived components contribute 62% to the dry matter production, while long lived components (tree boles, branches and coarse roots) make up only 38%. The contribution of short-lived components to the total uptake of different nutrients was also high (18-30% of tree foliage, 26-34% for fine roots and 6-19% for herbs). The results indicated that the short lived components play a significant role in the functioning of dry tropical forests.

Viswananth *et al.* (1998) reported that among the various traditional agroforestry models in Chhattisgarh, maintaining *Acacia nilotica* trees as scattered trees inside crop fields at high densities (100-125 trees /ha) on a 10-12 year rotation is very popular. The effect of Babul trees on associated rice crop growth, yield and soil physico-chemical properties was monitored in field plots located in Bilaspur district during 1993-94 period. The observation indicated that crop parameters excepting grain yield were not significantly affected by trees. Grain yield was reduced to the extent of 28-30% immediately below canopy of trees and gradually increased away from spread of crown. The O.M % and available 'N' was significantly affected by tree growth and recorded 48% and 16% higher than control plots. The leaf area index(LAI) values recorded for Babul trees in the experimental plots ranged from 0.98 to 1.83 and was negatively correlated to light available below canopy. Timely root and crown pruning was well as thinning practices are suggested to ensure higher crop yields.

Pandey *et al.* (1999) have reported the effect of *Acacia nilotica* tree (> 12 yr) on the growth and yield of rice (*Oryza sativa*) evaluated in 29 stands in a traditional agroforestry system in a sub-humid tropical region. The tree crown reduced the intensity of light by 8.5 times at 2m and 1.6% at 8m distance from the tree base. The intensity of light was positively correlated to distance.

Pandey *et al. (*1999) reported that *Acacia nilotica* (L.) Willd. ex Del is an important multipurpose tree of traditional agroforestry system in the central belt of the Indian sub-continent. The tree is reported to reduce crop yields under its canopy. However, information is lacking on the spatial variation in soil physical characters, nutrient pool sizes and their availability to crops under its canopy. The study reports influence of three tree canopy positions, viz. mid canopy, canopy edge and canopy gap, of *Acacia nilotica* (≥ 12 years) on texture, organic C, total and mineral N and P, and soil pH, in 0 to 10, 10 to 20 and 20 to 30 cm depth of the soil at ten sites in a traditional agroforestry system. Sand particles declined by 10% and 9% whereas clay particles increased by 14% and 10% under mid canopy and canopy edge, respectively, compared to that under canopy gap. Clay particles did not decline significantly with soil depth under all canopy positions. Proportion of silt particles was not influenced by the canopy position. Soil organic C, total N, total P, mineral N (NO3 – -N and NH4 + -N) and P were greater under mid canopy and canopy edge positions compared to canopy gap. Soil organic C and N pool sizes were maximum in 0 to 10 cm and declined with the depth of soil. Total and mineral P contents were nearly uniform across the depths. C/N ratio tended to increase with the soil depth.

Dhillon *et al.* (1984) reported the Effects of *Dalbergia sissoo* and *Acacia nilotica* planted in E.-W. and N.-S. directions on yields of wheat and rice grown on the S.E. or W. aspects of the tree rows. There was less reduction in wheat yield on the S. aspect than on other aspects and more loss in paddy yield on the W. aspect than on other aspects. *A. nilotica* caused more reduction in yield than *Dalbergia sissoo*

Viswanath *et al*. (2000) studied the functional characteristics of the system which were collected through participatory rural appraisal involving intensive interactions with farmers in the region during six years, and through a structured-questionnaire survey in 25 villages, involving a total of 200 farm families. The farms had an average of 20 babul trees, ranging in age from <1 to 12 years, per hectare in upland rice fields, the tree-stand density being greater on smaller than on larger farms (>8 ha). Over a ten year rotation period, the trees provide a variety of products such as fuel wood (30 kg/tree), brushwood for fencing (4 kg/tree), small timber for farm implements and furniture (0.2 cu.m), and non-timber products such as gum and seeds. The babul + rice system was estimated to have a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten-year period, though at a low level of income. Babul trees account for nearly 10% of the annual farm income of smallholder farmers (<2 ha).

Haripriya (2000) estimated the forest biomass from volume inventories of forests. The above ground biomass for tropical forests ranged from 14 to 210 Mg ha-1, with a mean of 67.4 Mg ha-1.

Bargali *et al.* (2004) studied and reported that in and age series (6 to 20 years old; total 10 age groups) effects of Acacia nilotica trees on growth and yield of gram crop was evaluated in a traditional agroforestry system in sub-humid region of Chhattisgarh state.The crown diameter and DBH of trees increased with increasing age of trees. The growth and productivity parameters were taken in three directions and at distances (1,3 and 5m from the tree base).The impact of tree was maximum at 1m distance from the tree trunk which significantly declined with increasing the distance indicating that greater the distance lesser the effect of the tree.

Swamy and Puri (2005) studied on Biomass production and C-sequestration of *Gmelina arborea* in plantation and agroforestry system in India and stated that tree based land use systems make a valuable contribution to sequester carbon and improve productivity and nutrient cycling within the systems.

Murali *et al.* (2005) studied biomass estimation equation for tropical deciduous and evergreen forests and developed linear and non-linear regression equations for estimation of biomass of tropical forests along with estimates of goodness of fit and percentage of errors. Basal area and height of trees were found to give high goodness of fit and low percentage of errors for deciduous forests. They found that generally the coefficient of determination (r2) was low for evergreen forests. The coefficient of determination was high and estimate of error was low for deciduous forests. They concluded that the biomass estimation equations for deciduous forests were precise and therefore useful for field application.

Hikmat (2005) quantify the biomass and carbon storage of three virgin jungle reserves in Peninsular Malaysia and reported that total biomass and carbon were from 352.66-606.32 t ha-1 and 176.33-303.16 t C ha-1, respectively

Kumar (2006) stated that Rising population pressure and urbanization, coupled with land degradation, soil salinization, and global warming are causing food insufficiency in large parts of Asia. Agroforestry, or woody perennial-based mixed species production systems, has the potential to arrest land degradation and improve site productivity through interactions among trees, soil, crops, and livestock, and thus restore part, if not all, of the degraded lands. Many such practices are sited on the small holdings of tropical Asia, characterized by sub-optimal management and subsistence farming conditions. Food production either directly (producing food grains, root crops, fruits, and vegetables) or indirectly (improving soil conditions and thereby promoting under storey crop productivity especially on degraded sites) constitutes the central theme of most smallholder agroforestry practices. Low input use and ecological security are other intrinsic attributes of this unique land use activity. Despite such advantages, agroforestry as a land use option has not attracted much attention from the planners and extension community. Reasons for this include inconsistencies in under storey crop productivity (positive, negative, or neutral effects depending on species, site, and management) and lack of public policy support. Conscious efforts on system management and policy adjustments are therefore imperative to promote agroforestry adoption by the farming community

Singh *et al.* (2008) reported that the Chhattisgarh region is traditionally been known as the "Rice bowl" of the Central India, covering an area of approximately 72940 Sq.Km.This belt has a predominantly agriculture based economy and nearly 81% of the working population is engaged in Agriculture, mainly of the subsistence type. Growing trees in association with agricultural crops has been found to be viable proposition in this area. Scattered or dispersed trees in cropland is a widespread traditional practice in the semi-arid tropics (SAT). Phytosociological parameters of above tree species were studied. Different crop parameters like shoot number, shoot biomass and grain yield were also studied. They revealed that crop growing in vicinity to trees had lesser shoot number, shoot biomass and grain yield than the crops at distant. Above crops parameters declined with proximity to trees. Correlation studies showed that crop characters studied had significant and positive correlation with each other. All the distances evaluated, differed drastically in terms of crop parameters from each other.

Deb *et al* (2008) worked on ecological analysis in the eastern Himalaya and reported that the total density of the tropical forest was 658 plants/ha, the basal area 85.55 m^2/ha and the diversity of tree layer was 1.39.

Josheph *et al*. (2008) worked on distribution of plant communities of southern India and reported that dry deciduous forest having the 64 tree species, 348 stand density/ha, 22.3 basal area/ha, 3.9 Shannon index value and 0.95 Simpson index value respectively whereas moist deciduous forest having lower value except the basal area and Shannon index value.

Baisya *et al.* (2009) studied above ground biomass distribution and carbon storage in different DBH and compared the natural semi evergreen forest and Sal plantation in the humid tropics of NE India. They found that the above ground biomass in natural forest was higher in the trees having DBH > 60 cm as compared to plantation forests.

Ambagahaduwa *et. al.* (2009) estimated the above ground biomass production in a 25 year-old *Pinus caribaea* plantation. Using these site-specific formulae derive from empirical data, the above ground biomass of the 25 year-old *P. caribaea* stand was found to be 194 t/ha. A second estimation of 136 t/ha for the above ground biomass was obtained using standard formulae. Of the live standing crop, the stem represented 60%, the branches 17%, leaves 13%, cones 3% and dead branches 7%. This pine stand had 695 pine trees/ha, a mean diameter at breast height (dbh) of 20.1cm, a mean height of 20.7 m and mean basal area of 23.6 m_2/ha. The estimated above ground biomass showed that the *P. caribaea* plantation studied is a good sink for sequestered carbon. Based on a metaanalysis of literature data on *P. caribaea* in the tropics, it was found that a *P. caribaea* plantation up to an age of 25 years attains maximum above ground biomass when it reached *ca.* 22 years.

Xiaoping and Miles (2009) studied and stated that live tree biomass estimates are essential for carbon accounting, bio energy feasibility studies, and other analyses. Several models are currently used for estimating tree biomass. Each of these incorporates different calculation methods that may significantly impact the estimates of total aboveground tree biomass, merchantable biomass, and carbon pools. In addition to differences in allometric equations, the various methods are most suitable for particular geographic scales of analysis.

Bargali and Bargali (2009) showed the botany, distribution, ecology, uses of the plant *Acacia nilotica* and its effect on soil and crops. They attempt to compile and document information on different aspect of *A. nilotica* and its potential use in land reclamation.

Bargali *et al*. (2009) studied in an age series of *Acacia nilotica* (L.) Willd. ex Del (6–28 years old)-based traditional agroforestry system in the sub-humid region of Chhattisgarh. They studied the effects of this tree on different rice (*Oryza sativa*) crop parameters (plant density, plant height, effective tillers, total aboveground biomass and grain yield) under natural conditions (without any management practices in trees) and under tree management conditions (cutting of 10% of basal tree branches) were evaluated. The growth and productivity parameters were taken in three directions and at four distances (1, 3, 5 and 7 m from the tree base). The impact of the tree on the crop was maximum at 1 m distance from the tree trunk. The data were also compared with different crop parameters in the open field (beyond the reach of the tree canopy). With increase in tree age, crown diameter and diameter at breast height (DBH), rice productivity reduced from 4.7 (under 9- yr-old tree) to 28.8% (under 28-yr-old tree). Whereas under 6-yr-old tree, there was an increase (4%) in grain yield. With increase in tree canopy size the plant density and effective tillers also reduced. Per cent yield reduction showed significant positive correlation with tree age, crown diameter and DBH. After the removal of 10% of basal tree branches (in 12–28-yr-old trees), the crown diameter of trees was reduced (0.81– 3.77%), plant density (0.05–1%), effective tillers (1.19– 5.8%) and grain yield (1.52–2.92%) increased significantly and plant height decreased (0.09–1.32%) over the unmanaged (without cutting the tree branches) condition.

Baishya *et al*. (2009) reported Tree aboveground biomass (AGB) distribution and carbon storage in different DBH (diameter at breast height) classes. Comparison were made between natural semi-evergreen forest and sal plantation forest in the humid tropical region of northeast India. The natural forest had lower AGB (323.9 Mg ha^{-1}) than the plantation forest (406.4 Mg ha^{-1}). About 49% of the AGB was present in > 60 cm dbh trees in the natural forest against 24% in the plantation forest. The carbon storage was highest in 60-80 cm and 40-60 cm dbh classes in the natural forest and plantation forest, respectively. The differential AGB and carbon distribution pattern has been related to past disturbance history and age of the forests. Although both the forests had potential for Carbon Sequestration due to presence of large number of trees belonging to small dbh classes, the plantation forest had an edge over the natural forest because of better silvicultural practices.

Singh *et al*. (2009) investigated the impact of land use change on species structure, biomass and carbon storage in tropical dry deciduous forest and converted forest and found that the total biomass in natural forest was 192.933 Mg ha^{-1} and 95.64 Mg ha-1 in 32 years old converted forest. The total above ground biomass in different forest plots ranged from 71.94 to 162.91 Mg ha^{-1} with highest in natural forest and lowest in 23 years old converted forest. The below ground biomass varied from 13.97 to 30.02 Mg ha^{-1} following the similar trend as in case of above ground biomass.

Tyagi *et al*. (2009) studied the biomass and productivity in an age series of *Dalbergia sissoo* plantations in sodic lands of Sultanpur district of Eastern Uttar Pradesh, India. The contribution of leaves, bark and bole to the above ground biomass increased with the increase in age, while twigs and branches showed a reverse trend. The total biomass was between 388.52 kg ha-1 in 3 years to 50927.13 kg ha-1 in 9 years old plantations.

Kauffman *et al*. (2009) estimated carbon pool and biomass dynamics associated with deforestation, land use and agricultural abandonment in the neotropics. The total aboveground biomass is highly variable among neotropical ecosystems ranging from < 5 to > 600 Mg/ha and aboveground C pools would comprise 48% of this total.

Hertel *et al*. (2009) reported the mean total biomass of the stands of Indonesia was 303 Mg ha^{-1} (or 128 Mg C ha^{-1}), with the largest biomass fraction being recorded for the above ground components (286 Mg ha^{-1}) with 11.2 and 5.6 Mg ha^{-1} of coarse and fine root biomass. The total above and below ground net primary production was estimated at 15.2 Mg ha^{-1} yr^{-1} (or 6.7 Mg C ha^{-1} yr^{-1}) with 14% of this stand total being invested below ground and 86% representing above ground net primary production.

Chaturvedi *et al.* (2010) stated that forest biomass are required for understanding several ecological processes such as nutrient cycling and carbon sequestration. Comparasion was made regarding the biomass estimates of seven tropical tree species measured on the basis of two methods: (i) allometric equations relating destructively measured tree biomass and the circumference at breast height (CBH), and (ii) non-destructive equation having wood specific gravity (ρ) in the estimator. There were strong correlations between the two methods for all tree species.

Swamy *et al*. (2010) studied that biomass, litter fall and net primary productivity (NPP) of tropical evergreen forests of Western Ghats, India and observed that total stand biomass ranged from 440 to 571 Mg ha^{-1}, of which trees contributed 90.2-92.2% and remaining 8.8-9.8% were contributed by shrubs and herbs. The standing litter ranged from 3.5 to 4.2 Mg ha^{-1} and litter production from 4.0 to 5.7 Mg ha^{-1} yr^{-1}. The average NPP was 23.7 Mg ha^{-1} yr^{-1}, of which 64.7% was contributed by trees, 13.6% by shrubs, 2.7% herbs and 19.1% by litter, Turnover rate and turnover time ranged from 0.93 to 0.95 yr-1 and 1.05 to 1.08 yrs, respectively

Nizalapur *et al*. (2010) estimated the aboveground biomass in Indian tropical forest using multi frequency DLR-ESAR data. The results obtained with DLR-ESAR airborne data in C, L and P bands over the parts of Gujarat, India. They reported that with increase in the biomass levels, backscattering coefficient also increases and C bands ESAR data is capable of predicting biomass up to 70 Mg/ha, L bands up to 150 Mg/ha and P band up to 200 Mg/ha.

Singh *et al*. (2011) quantified the biomass of subtropical forest of North India and reported to be ranged from 292.8-386.2 Mg ha^{-1} among the sites. The contribution of different components in total biomass was 28% by stem, 58% by branches, 3% by leaf and 11% by root

Navar (2011) worked on the spatial distribution of aboveground biomass in tropical forests of Mexico and reported the mean aboveground biomass stock of these forests is 2.77 Pg.

Singh *et al*. (2011) studied the biomass and net primary productivity (NPP) of rehabilitated subtropical forest in India and estimated that the net production of rehabilitated forest was 25 Mg ha-l yr-1.

Dhanai et al. (2013) reported the Worldwide recognition of Acacia nilotica commonly known as babul, Kikar or Indian gum arabic tree as an important multipurpose tree. Aqueous extracts of fresh leaf, bark and pod of *Acacia nilotica* were tested for potential effects on Wheat (*Triticum aestivum*). Aqueous extract of *A. nilotica* was prepared by soaking 200 gm of powder in 1000 ml distilled water (20%) as per standard method. It was diluted to 5%, 10%, 15%, 20% concentration. The experiment was conducted in sterilized petri dishes for seed germination and growth parameters. The results on seed germination and shoot-root length indicated that the inhibitory effect was proportionate to the concentration of the extracts. Seed germination and shoot-root length of wheat was found to be significant and aqueous effect increased with increasing in the concentration of aqueous fresh leaf, pod and bark extract from 5 to 20 per cent. Inhibitory effect was much pronounced on shoot length rather than root length. The maximum inhibitory effect among the various parts of *Acacia nilotica* was observed for pod extract.

Kittur and bargali (2013) reported that the upliftment of ecosystem sustainability can be further improved through right policies that promote agroforestry which can increase carbon sequestration in agro-ecosystems, thereby providing climate change mitigation assistances. Thus, agroforestry if properly developed, have the potential to improve socio-economically more sustainable and make the landscape more better.

Madguni and Singh. (2013) reported that Forest is one of the important sources of fuel wood and has been meeting energy requirement of most the rural poor. Due to continued depletion of forest cover and density, the sustainability of fuel wood is questioned. The ever increasing demand and poor return of the forest has to be catered with innovative technology and judicious use of fuel wood.

Biomass can be converted into useful energy by way of thermal, chemical and biochemical conversion, depending on the composition of the fuel and the desired energy carrier product. However woody biomass is still in the early stages of energy production.

Devagiri *et al*. (2013) assessed the above ground biomass and carbon pool in different vegetation types of Karnataka using spectral modeling. Field measured AGB ranged between 7.25 to 287.047 t-dry wt/ha across different vegetation types in the region.

Joshi *et al*. (2013) measured the tree biomass and carbon stock of central Himalaya's mixed forest in India and reported that the total tree biomass of the area ranged between 9.47-62.54 t ha^{-1} in all aspect of the forests, while the total carbon stock were ranged from 4.73-31.27 t ha-1 across the study sites.

Arora *et al.* (2014) assessed the Growth, biomass, carbon storage, and carbon sequestration potential along an age series in *Populus deltoides* plantations . The growth rate of diameter at breast height and height was higher in trees of 4 to 7 years and 2 to 5 years, respectively. The total aboveground biomass (AGB) increased with age and reached its maximum (180.2 Mg ha–1) at 11 years of age. Mean carbon concentration in aboveground components varied from 39.7% to 51.7%. Allometric equations were developed to estimate biomass and biomass carbon in different tree components, which had adjusted R squares greater than 94%. Aboveground carbon stocks in *P. deltoids* increased from 0.5 Mg ha–1 at 1 year to 90.1 Mg ha–1 at 11 years. The carbon sequestration rate (i.e. carbon sequestrated in wood products and by the substitution of biomass for coal) in mature plantations (7–11 years) varied from 5.8 to 6.5 Mg C ha–1 per year. Soil carbon stocks increased with age (1–11 years) from 61.2 to 66.8 Mg ha–1 and decreased with soil depth. Soil carbon stock in different ages of plantations varied from 63.9 to 83.8 Mg ha–1 at 0–30 cm depth, 57.5 to 60.1 Mg ha–1 at 30–60 cm depth, and 55.5 to 59.7 Mg ha–1 at 60–90 cm depth. The amount of total carbon stock (AGB and soil) increased from 64.4 Mg ha–1 at 1 year to 173.9 Mg ha–1 at 11 years. This study recommends *P. deltoides* planting as a viable option for sustainable production and carbon mitigation.

2.2 Carbon Storage Pattern and Carbon Sequestration.

Nelson *et al*. (1999) estimates the sequestering of carbon by secondary forests which occupy almost half the deforested area of the Brazilian Amazon. There was the use of accurate allometric relationships for non-destructive measurement of standing biomass and by an evaluation of the suitability of existing equations for application in secondary forest. Species-species and mixed-species regressions for estimating total above-ground dry weight (DW) were therefore developed using eight abundant secondary forest tree species in the central Amazon. Using only DBH as the input variable, the species-species equations estimated DW of individual trees with an average error of 10-15%. For the mixed-species equations, developed using 132 trees from seven of the eight species (excluding Cecropia), average error in estimating DW of individual trees was 19.8% using only DBH and 15.0% using DBH plus species density of the wood (SD).

Kaur *et al.* (2002) studied the tree-based land-use systems and reported that it could sequester carbon in soil and vegetation and improve nutrient cycling within the systems. The total carbon storage in the trees + grass systems was 1.18 to 18.55 Mg C ha^{-1} and carbon input in net primary production varied between 0.98 to 6.50 Mg C ha^{-1} yr^{-1}. Carbon flux and net primary productivity increased significantly due to integration of trees with grasses. Compared to ‘grass-only’ systems, soil organic matter, biological productivity and carbon storage were greater in the silvipastoral systems. Of the total Nitrogen uptake by the plants, 4 to 21 per cent was retained in the perennial tree components. Nitrogen cycling in the soil-plant system was found to be efficient.

Chave *et al.* (2005) reported that tropical forests hold large stores of carbon, yet uncertainty remains regarding their quantitative contribution to the global carbon cycle. One approach to quantifying carbon biomass stores consists in inferring changes from long-term forest inventory plots. Regression models are used to convert inventory data into an estimate of aboveground biomass (AGB). Proportional relationships between aboveground biomass and the product of wood density, trunk cross-sectional area, and total height are constructed. The most important predictors of AGB of a tree were, in decreasing order of importance, its trunk diameter, wood specific gravity, total height, and forest type (dry, moist, or wet). Overestimates prevailed, giving a bias of 0.5–6.5% when errors were averaged across all stands. Regression models can be used reliably to predict aboveground tree biomass across a broad range of tropical forests. Because they are based on an unprecedented dataset, these models should improve the quality of tropical biomass estimates, and bring consensus about the contribution of the tropical forest biome and tropical deforestation to the global carbon cycle.

Glenday (2006) reported that Forestry based carbon emissions offset projects have potential to both mitigate climate change and foster sustainable forest management. Degraded African tropical forests could sequester large amounts of additional carbon, but the lack of empirical data limits the feasibility of initiating carbon offset projects in many threatened forests. This study examines the potential to increase carbon stocks in the Kakamega National Forest of western Kenya, a threatened biodiversity hotspot and Kenya's only remaining rainforest. Carbon density values for indigenous forest and plantations were estimated based on forest inventory data from 95 randomized plots distributed throughout the forest. Total ecosystem carbon was estimated using allometric equations for tree biomass, destructive techniques for litter and herbaceous vegetation biomass, and Dumas combustion and spectroscopy for soils. Land cover maps for 1975, 1986, and 2000 were used to estimate both current carbon stocks and the influence of past land use changes. Mean carbon density in indigenous forest was 330 - 65 Mg C/ha, greater than that of the forest's hardwood plantations (280 - 77 Mg C/ha) and significantly greater that of softwood plantations (250 -77 Mg C/ha). The distribution of carbon densities within the indigenous forest and the variation between plantation types suggest management practices could feasibly increase Kakamega's carbon stock. Deforestation between 1975 and 1986 and limited reforestation from 1986 to 2000 have resulted in a net loss of 0.4–0.6 Tg C

Asako Takimoto (2007) studied and reported that the tree-based systems retains more C in the systems both above- and below-ground than tree-less land-use systems. By joining the C credit market, the landowners could sell the C sequestered in their agroforestry systems.

Singh and Sharma (2007) reported that Poplar (*Populus deltoides* Bartr.) based agroforestry systems are economically viable and more sustainable than many other crop rotations prevalent in northern India. Growth {girth at breast height (GBH) and height} and productivity (volume) of clone G-48 of poplar spaced at 5 x 4 m, soil organic carbon (OC), and concentration of available macronutrients (N, P and K) and micronutrients (Zn, Fe, Mn and Cu) in surface soil (0-15 cm depth) were determined at an interval of six months starting from April 2002 till October 2003 in one and four year old (in January 2002) 16 poplar plantations on farmers' fields in Ludhiana, Punjab. The observations were taken from plantations having fodder {sorghum (Sorghum bicolor)/pearlmillet (*Pennisetum americanum*) in summer}-wheat (*Triticum aestivum*) (in winter) rotation throughout the poplar age and those having sugarcane (*Sachharum officinarum*) initially during two years and fodder-wheat rotation thereafter. The GBH, height and volume of younger plantations intercropped with fodder wheat rotation were 15.6, 17.2 and 46.7%, respectively higher than that of plantations intercropped with sugarcane. Growth increment of poplar was markedly higher during April to October than October to April. Soil OC was significantly greater in older (6.83 g kg-1) than the younger (5.35 g kg-1) plantations.

Ramachandran *et al.* (2007) reported the need for a carbon databank as addressed by him in the context of mitigating climatic changes. As a pilot study, carbon stock in a natural forest area of Kolli hills, part of the Eastern Ghats of Tamil Nadu, India has been estimated using geospatial technology. The total biomass, both above and below ground, is calculated and the total carbon stock estimated. Likewise, the sequestered soil organic carbon is also estimated. The biomass carbon estimated is 2.74 Tg and the soil carbon is 3.48 Tg. The lesser soil organic carbon indicates that the forest area is severely affected by degradation due to various need-based forestry practices and anthropogenic disturbances. A national-level carbon databank is envisaged for all types of forest in India to study the temporal change and Carbon Sequestration potential for better management of forests.

Condit (2008) reported the best scientific methods available for estimating carbon stocks in forests and in the vegetation left behind after forest is cleared.

Most of the biomass in a forest is in trees, and the focus of methods for estimating biomass is measuring the above-ground portion of trees.

Baisya *et al*. (2009) studied above ground biomass distribution and carbon storage in different DBH and compared the natural semi evergreen forest and Sal plantation in the humid tropics of NE India. They found that the above ground biomass in natural forest was higher in the trees having DBH > 60 cm as compared to plantation forests.

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.

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 *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 dept increased. Bulk density increased with soil dept, 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.

Rizvi *et al.* (2011) reported that Poplar (*Populus deltoides*) has gained considerable importance in agroforestry plantations of western Uttar Pradesh, Uttarakhand, Haryana, Punjab, and Jammu and Kashmir due to its deciduous nature, fast growth, short rotation and high industrial requirement. Poplar based agroforestry systems are prevalent among farmers of Saharanpur (UP) and Yamunanagar (Haryana) districts of northwestern India. These systems are not only remunerative to the farmers, but also play an important role in the assimilation of atmospheric carbon dioxide in the form of biomass carbon stocks. An assessment of carbon storage vis-à-vis CO2 assimilation by poplar plantations in agroforestry has been made for these two districts. Contribution of poplar plantations to carbon storage was found to be 27– 32 t ha^{-1} in boundary system, whereas it was 66– 83 t ha^{-1} in agrisilviculture system at a rotation period of 7 years in the two districts. Thus, poplar plantations make important contributions towards atmospheric CO_2 assimilation and hence play a significant role in the mitigation of atmospheric accumulation of greenhouse gases.

Chaturvedi *et al.* (2011) studied the carbon density and accumulation in woody species of tropical dry forest in India and reported that across the sites, the mean aboveground stem carbon density was 87 t c ha-^{1} with the greatest value of 151 t C ha^{-1} at the Hathinala and the lowest value of 15.6 t C ha^{-1} at the Kotwa site. Across the sites, about 12% of the carbon per unit ground area was accumulated by leguminous species and remaining 88% by the non-leguminous species. The average stem biomass across the plots (336 t ha^{-1}) was the highest under Hathinala and the lowest for the Kotwa site (34.7 t ha-^{1}).

Prasad *et al.* (2012) reported that increasing concentration of greenhouse gases in the atmosphere and the adverse effects associated with climate change have necessitated the need for identification of systems with high carbon sink as a mitigation strategy. Tree-based systems with short rotation species either as farm forestry or agroforestry systems have the potential to sequester carbon in a short period. Leucaena and eucalyptus-based systems, mostly planted at closer spacing, are widely distributed in several districts of Andhra Pradesh, India. Their objectives is to analyze the carbon storage of two land-use systems (farm forestry and agroforestry) with two short rotation tree species, viz. leucaena and eucalyptus, and to evaluate their carbon sequestration potential in degraded lands. The carbon stock of leucaena farm forestry system was 62 Mg/ha, whereas in eucalyptus farm forestry system, it was 34 Mg/ha for a rotation of 4 years. Biomass and carbon accumulation were relatively higher in farm forestry systems and the rate of accumulation was highest during the third year.

Nair, P.K.R. (2012) reported the terms such as global warming, climate-change, and carbon sequestration that used to sound as technical until about a decade ago have now become common parlance in everyday life. While this rapid-and widespread use of the terms signifies their relevance and importance, it has also resulted in the use of the terms ambiguously, erroneously and sometimes out-of-context. It is therefore important that the concepts and significant of the terms explained right at the outset, and it is done using the IPPC (Intergovernmental panel on climate change) and UNFCCC (United Nations Framework Convention on Climate Change) guidelines.

Wani *et al.* (2012) studied an overview of estimates on C sequestration potential of varied forestry land use systems in India for country level and site-specific assessments.

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 green house gases causing warming of earth globally. Of these gases, CO2 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 CO2 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 green house gases effect and mitigation of global climate changes. Studies indicated that Indian forests share 1,083.81 MtC in the year 1994 to 3,907.67 MtC 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 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

Murthy *et al*. (2013) have reported that forestry is one of the important means to reduce CO2 emissions as well as enhancing carbon sinks. Forests are a large sink of carbon and their role in carbon cycles is well recognized. They discussed the role of agroforestry systems in carbon mitigation. Agroforestry provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. Agroforestry systems offer important opportunities of creating synergies between both adaptation and mitigation actions. Agroforestry systems have the potential to provide significant mitigation options but they require proper management that influences the amount of carbon sequestered. The role of agroforestry practices in climate change mitigation in India can be realized to its full potential by overcoming various technical, financial and institutional barriers.

Nowak *et al.* (2013) studied the Carbon Storage and sequestration by urban trees in the United States and they estimated the total tree carbon storage in U.S. urban areas and it was found to be 643 million tones and annual sequestration was estimated to be 25.6 million tones.

Wicke *et al.* (2013) studies the greenhouse gas balance and the economic performance (i.e. net present value (NPV) and production costs) of agroforestry and forestry systems on salt-affected soils (biosaline (agro) forestry) based on three case studies in South Asia. The economic impact of trading carbon credits generated by biosaline (agro) forestry is also assessed as a potential additional source of income.

Swamy and Mishra (2014) reported that the anthropogenic activities are alarmingly increasing the concentrations of CO2 in the atmosphere leading to the climate change. Agriculture ecosystem especially tropical agriculture is most vulnerable to climate change posing a serious threat on food, nutritional security and livelihoods of poor farming communities. Agroforestry technologies indeed offer viable opportunity to mitigating the atmospheric accumulation of CO_2 and other Greenhouse gases, and potential for transforming to resilient farming systems and further help smallholder farmers of many tropical countries like India for adapting to climate change. However, the magnitude of C sequestration in many agroforestry systems is still unknown, which primarily depends on the choice of tree species and managerial practices. The relates to the project on *Gmelina arborea*, *Populus deltoides* and *Ceiba pentandra* based agroforestry systems evaluated for C storage potentials in sub-humid tropics Chhattisgarh, India. At 5 years age, total biomass varied from 12.9 Mg ha^{-1} to 25.1 Mg ha^{-1} in *C. pentandra*, while 9.9 Mg ha^{-1} to 21.4 Mg ha^{-1} in *G. arborea*.

Yadav *et al.* (2015) estimate the standing biomass and carbon buildup in the fruit tree based agrihorticulture farming systems of Himalaya, India. Aboveground biomass, carbon stock and carbon stock equivalent carbon dioxide (CO2) varied from 10.8 to 37.8 Mg $ha^{–1}$, 4.8 to 17.0 Mg $ha^{–1}$, 17.6 to 62.3 Mg $ha^{–1}$, respectively. The significantly (<0.05) higher biomass (37.8 Mg $ha^{–1}$), carbon stock (17 Mg ha–1) and carbon stock equivalent CO2 (62.3 Mg $ha^{–1}$) was recorded in the pear + wheat and the lowest was observed in wheat monocropping. The highest rate of biomass, carbon and CO_2 accumulation was found in pear + wheat (12.0, 5.3, 19.6 Mg $ha^{–1}$ year–1) followed by apricot + wheat (11.5, 5.2, 18.9, Mg $ha^{–1}$ $year^{–1}$) and varied with diverse fruit tree species. Fruit tree biomass showed a significant and positive relationship with total biomass, total carbon and total CO2 mitigation. Revised : 17.05.2015

Chauhan *et al.* (2015) did assessment on Six years poplar plantations for productivity, carbon storage and economics in comparison to sole cropping. Wheat grain yield was significantly higher in control plots (4.55 t/ha) than boundary plantation (3.28 t/ha) and block plantation (2.03 t/ha). Similar trend was recorded for straw yield (6.61 t/ha in control plots, 4.83 t/ha in boundary plantation and 3.5 t/ha in block plantation. The boundary plantation produced higher DBH (24.23 cm) than the block plantation (19.71 cm). The crown spread itself followed the same trend but both the planting methods had almost similar plant height. However, the total tree biomass was higher with block plantation (96.31 t/ha) than boundary plantation (30.14 t/ha) but per tree biomass was more in boundary plantation than block plantation. The total carbon storage was higher in block planting method (55.43 t/ha) than in boundary plantation (32.70 t/ha) and lowest total carbon storage in sole cropping system (31.20 t/ha). Agro forestry systems likely had a greater capacity to sequester C in the long-term than the annual cropping systems because of their diverse configurations. The economic benefits were also higher in block plantation than boundary and sole cropping of rice-wheat (B : C ratio of 3.30, 1.90 and 1.61, respectively).: 20.09.201.

Upadhyay (2016) reported the recently released Fifth Assessment Report by IPCC that presents another set of strong and conclusive evidence for a changed climate due to anthropogenic factors. His reports also presents, with various degrees of certainty (or uncertainty), wider impact of climate change at global and regional levels on agriculture. Because of its inherent climate sensitive nature the impact of changed climate is direct and most obvious on agro-ecosystems and, due to its disruptive influence on agricultural production systems, it is a major cause of social vulnerability. Undoubtedly, sustaining agricultural production under changed climatic scenario is going to be daunting task, particularly under rainfed conditions where crop production already suffers from multiple biotic and abiotic stresses. The other important negative effect of climate change due to worsening weather conditions is deteriorating nutritional and market value of produce. The only realistic option to alleviate the impact of climate change and sustain agricultural production is to develop adaptation strategies at local level after assessing the nature and extent of vulnerability of different agricultural production systems.

Nelson *et al.* reported the sequestering of carbon by secondary forests, which occupy almost half the deforested area of the Brazilian Amazon . It will be improved by the use of accurate allometric relationships for non-destructive measurement of standing biomass and by an evaluation of the suitability of existing equations for application in secondary forest. Species-specific and mixed-species regressions for estimating total above-ground dry weight (DW) wereS therefore developed using eight abundant secondary forest tree species in the central Amazon. Using only DBH as the input variable, the species-specific equations estimated DW of individual trees with an average error of 10±15%. For the mixed-species equations, developed using 132 trees from seven of the eight species (excluding Cecropia), average error in estimating DW of individual trees was 19.8% using only DBH and 15.0% using DBH plus species density of the wood (SD). Average SD for each species can be substituted without increasing the error of the estimate. Adding total tree height (H) as an input variable provided only a slight reduction

2.3 Soil and nutrient.

Singh and Singh (2002) studied the changes in soil properties and foliage nutrient composition in different age classes of *Eucalyptus camaldulensis* plantation. Height and diameter at breast height (dbh) of the stand ranged from 9.2 to 25.7 m and 9.4 to 21.5 cm respectively, depending on the age of the stand. Foliage nutrients were in order Ca>N>K> Mg > P and differed considerably between different ages. Foliage N and P increased until Y12 and decreased afterwards. Soil organic matter and nitrogen (NH_4-N + NO_3-N) were significantly higher in the 0-15 cm layer compared with the 15-30 cm layer. Soil nutrients were significantly higher in the plantation area compared with the non-planted control plot. Soil pH, PO_4-P, Ca, Mg and K concentrations decreased with stand age whereas SOM, NH_4-N, NO3-N, Cu, Zn and Mn increased. The study thus suggested that plantations require fertiliser application and/or thinning after 12 years to manage the problem of nutrient depletion.

Pandey *et al.* (2003) reported the effect of residual Nitrogen on the yield of Rice crop after removal of *Acacia nilotica* (L) wild.ex. Del.tree in a traditional agroforestry system in Central India. Twenty four homogenous rice fields were selected .These were divided into six sets of four fields each. From these sets, trees had been removed 1-5 years and 7 years respectively before the beginning of the study. There was only one tree stump in each fields. Rice crop and soil were sampled at 1-7m and 20m distances from the tree stump. Distance of 20m was treated as control. Maximum 53% of the residual Nitrogen was released quickly for the first rice cropping season following the tree removal and remaining 37%

gradually, until the fifth cropping season. Yield of the rice crop was higher by 73%, across the distances, for the first cropping season, 52% for the second, 45% for the third, 41% for the fourth and 26% for the fifth cropping season, compared to the control. The crop yield, soil organic carbon and total soil Nitrogen increased upto 5m from the tree stump in the first cropping season. Soil organic carbon and total soil Nitrogen declined with passage of time following the tree removal, where as C/N ratio increased.

Chhabra *et al.* (2003) attempted to estimate soil organic carbon pool in Indian forests. In this study, a database of published measurements (with depth) of soil organic carbon (C) containing information on location , soil type, texture, estimated bulk density, and forest type in Indian forests was prepared. It was used for estimating soil organic C densities for various forest types for two depth classes (0-50 and 50- 100 cm). The mean soil organic C density estimates for top 50 cm based on 175 observations ranged from 37.5t / ha_{-1} in tropical dry deciduous to 92.1 t / ha_{-1} in littoral swamp forest. The mean soil organic C density estimates based on 136 observations ranged from 70 t / ha_{-1} in tropical dry deciduous forest to 162 t / ha_{-1} in montane temperate forest for top 1m soil depth. The estimated soil organic C densities were combined with remote sensing based recent forest area inventory (64.20 Mha) by Forest Survey of India to arrive at estimates of soil organic C pool by major forest types of India. The total organic C pools in Indian forests have been estimated as 4.13 Pg C in top 50 cm and 6.81 Pg C in top 1 m soil depth. These estimates may be taken valid for 1980-1982 period on which the remote sensing based forest area assessment was made by FSI. The historic loss in forest soil organic C pool (1880-1981) in top 1 m soil depth has been estimated as 4.13 PgC. The estimated soil organic C densities by forest types can form input in models for estimating net C release from forests by deforestation as well as in estimation of historic loss in soil organic C pool in Indian forests

Singh and Kashyap (2007) studied the variations in soil N-mineralization and nitrification in seasonally dry tropical forest and savanna ecosystems in Vindhyan region, India.The annual N-mineralization and nitrification rates were highest at Hathinala moist forest site having maximum moisture content, organic-C, N and

Studies conducted by Paoli *et al.* (2008) on the relationship between soil fertility and aboveground biomass in lowland tropical forests have yielded conflicting results, reporting positive, negative and no effect of soil nutrients on aboveground biomass. He quantified the impact of soil variation on the stand structure of mature Bornean forest throughout the lowland watershed (8–196 m a.s.l.) with uniform climate and heterogeneous soils. Categorical and bivariate methods were used to quantify the effects of (1) parent material varying in nutrient content (alluvium > sedimentary > granite) and (2) 27 soil parameters on tree density, size distribution, results, reporting positive, negative and no effect of soil nutrients on aboveground biomass. He quantified the impact of soil variation on the stand structure of mature Bornean forest throughout the lowland watershed (8–196 m a.s.l.) with uniform climate and heterogeneous soils. Categorical and bivariate methods were used to quantify the effects of (1) parent material varying in nutrient content (alluvium > sedimentary > granite) and (2) 27 soil parameters on tree density, size distribution basal area and aboveground biomass. Trees >=10 cm (diameter at breast height, dbh) were enumerated in 30 (0.16 ha) plots (sample area = 4.8 ha). Six soil samples (0–20 cm) per plot were analyzed for physiochemical properties. Aboveground biomass was estimated using allometric equations. Across all plots, stem density averaged 521 + 13 stems ha^{-1}, basal area 39.6 + 1.4 m^2 ha^{-1} and aboveground biomass 518 + 28 Mg ha^{-1} (mean + SE). Adjusted forest-wide aboveground biomass to account for apparent overestimation of large tree density (based on 69 0.3-ha transects; sample area = 20.7 ha) was 430 + 25 Mg ha^{-1}. Stand structure did not vary significantly among substrates, but it did show a clear trend toward larger stature on nutrient-rich alluvium, with a higher density and larger maximum size of emergent trees. Across all plots, surface soil phosphorus (P), potassium, magnesium and percentage sand content were significantly related to stem density and/or aboveground biomass ($R_{Pearson}$ = 0.368–0.416). In multiple linear regression, extractable P and percentage sand combined explained 31% of the aboveground biomass variance. Regression analyses on size classes showed that the abundance of emergent trees >120 cm dbh was positively related to soil P and exchangeable bases, whereas trees 60–90 cm dbh were negatively related to these factors. Soil fertility thus had a significant effect on both total aboveground biomass and its distribution among size classes.

Dinakaran and Krishnayya (2010) carried out the study showing a variation in soil organic carbon (SOC) and litter decomposition across different vegetal covers. Tropical vegetal covers occupied by teak, bamboos and mixed species were used for the study. SOC was analyzed in the soil up to a depth of 1.25 m at different intervals. Physical fractionation was done in the collected soil samples. Respiration was measured in the soils of three types in summer, monsoon and winter. Litter-bag experiment was carried out to understand the process of decomposition in three types of litter at three depths, viz. top, 25cm and 50 cm. SOC values from the three different types of vegetal cover showed significant differences. The annual fall of leaf-litter was maximum in mixed vegetal cover followed by teak and bamboo. Litter-bag experiment showed that the litter got decomposed within a year on storage. Higher soil respiration in all the three vegetal covers supports faster rates of decomposition. The decomposition was faster in bags kept at the top layers of the soil compared to the ones in the deeper layers. There was an increase in SOC of samples from the litter-bag study, indicating that tropical soils can absorb additional carbon. Physical fractionation of SOC showed uniformity in the proportions of mobile and recalcitrant pools across soil profiles of the three vegetal covers. A proton NMR study carried out to understand the chemical nature of SOC revealed complete absence of carboxyl group, whose presence is generally reported in the SOC of temperate soils. The groups observed were alkyl, *0*-alkyl and aromatic. Fluctuations were seen in the proportion of alkyl groups. Uniformity seen in the chemical composition of SOC from the proton NMR study revealed that barring initial steps, decomposition of organic matter would follow more or less the same path in tropical soils, irrespective of differences in plant litter.

Yao *et al.* (2010) studied the effects of land use types on soil organic carbon and nitrogen dynamics in Mid-West Côte d'Ivoire. Results showed that total soil organic carbon content decreased significantly (p=0.007) from natural forest to mixed crop systems. The average values were around 2.58 % in natural forest, 1.99 % in multispecies tree plantations, 1.69 %, in teak to 1.48 % in cocoa plantations and 1.29 % in mixed-crop fields. Significantly lower soil pH was observed in cocoa plantations, mixed-crop fields and mixed-tree plantations as 5.98, 6.9 and 6.7, respectively, as compared to natural forest and teak plantations (7.3), ($p<0.0001$). Total soil N, organic C and C: N ratios were significantly influenced by land use ($p=0.0012$; 0.007 and 0.0136, respectively). Higher mineralizable C and N levels were observed in natural forest, mixed-tree and teak plantations, with significant differences between main land use types (CMIN, $p=0.0084$; NMIN, <0.0001). The study also shows a highly significant and positive correlation between clay and soil organic C, as well as total N contents ($r^2=0.637$; $p<0.0001$). Land use impact on soil organic C and total N were also significant across the different land use types .N-mineralization and nitrification rates differ significantly across the sites and seasons. These rates were significantly correlated with soil moisture and mineral-N contents. The result suggested that variations in rates of N-mineralization and nitrification in the dry tropical ecosystems are related to differences in soil moisture content, nutrient status and vegetational cover in combination with other environmental factors

CHAPTER – III
MATERIALS AND METHODS

A study on **"Biomass, Carbon Stock and Carbon Sequestration Potential of *Acacia nilotica* Paddy Based Traditional Agroforestry System"** was carried out at Nara village, Bhan Soj Post office, Raipur (Chhattisgarh) during the year 2015-2016. The details of the study site, climate, soils, and other features of area along with the methodologies used are described below:

3.1The Study area

The study was conducted in Nara Village which is located in the Raipur District Post office Bhan Soj.The area is located in the Arang Block division which is situated at the altitude of 278 m above sea level in the state of Chhatisgarh.The type of Irrigation is Rain fed.

3.1.1 Climate

The climate of study area is dry humid tropical comprised of three seasons viz. rainy, winter and summer. The rainy season commences from the mid-June to October. The winter season, which commences from the beginning of November and last till the end of February. The summer commences from the beginning of March. It is quite prolonged and lasts till monsoon sets in. The monthly weather data from August 2015 to June 2016 is given as Appendix A

3.1.2 Rainfall

The average annual rainfall in the study area ranges from 1200-1350 mm. It gradually decreases from south east direction to North West direction. About 80 percent of the rainfall in the study area is received from south west monsoon during June to September. The highest amount of rainfall occurs in July. Number of rainy days varies from 90-100 days

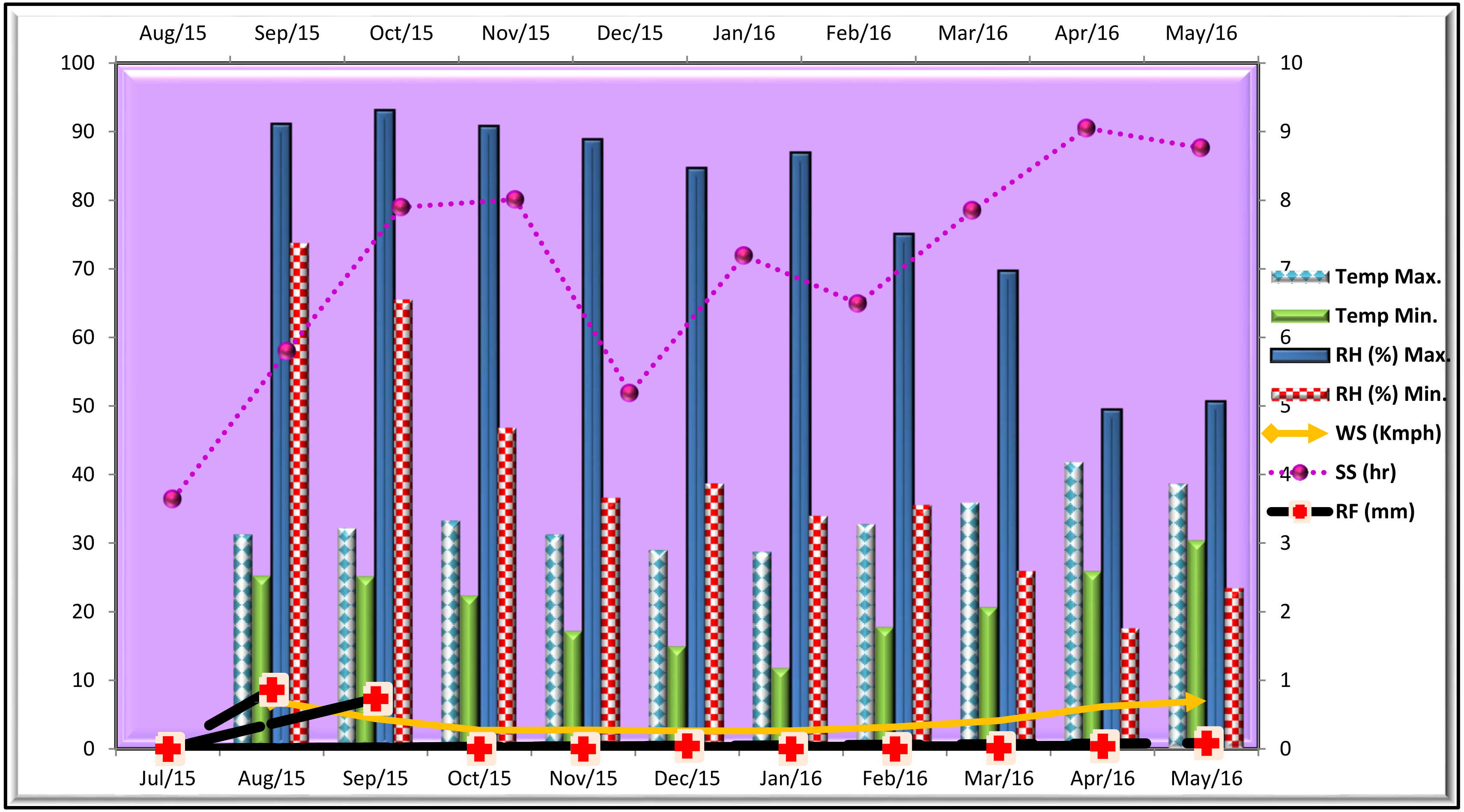

Fig 3.1 Meteorological data from the months of August 2015 to May 2016

3.1.3 Soils

The type of soil of the study area is Inceptisols which is locally also known as Matasi.This soils are considered to be immature soil with poor soil profile features having lighter texture and shallow to moderate depth. They are low in organic matter and available nutrients, which support mainly grasslands and degraded forests. These soils are commonly found in the Eastern and Southern aspects

3.1.4 Temperature

The mean monthly maximum temperature varies from 27.3° C in January to 41.8° C in May and mean monthly minimum temperature varies from 12.7° C in December to 27.3° C in May. The mean annual maximum and minimum temperatures of study area are 33.1° C and 20.5° C, respectively.

3.1.5 Humidity

Relative humidity of study area increases with the onset of south-west monsoon and it generally becomes more than 80% in July. In the post monsoon and winter season the relative humidity lies between 50-65% in the morning (6:00 to 12:00 hrs.) and 30-40% in the afternoon (12:00 to 16:00 hrs.). Relative humidity is lowest during summer and drops below 30 percent in the afternoon in April and May.

3.2 Methodology

The study sites has a total area of 1.54 acre divided into 6 plots which is bund base agroforestry system i.e. there is a presence of *Acacia nilotica* trees on the bund of rice field. In total there are 19 trees scattered naturally in the fields.

3.2.1. Girth at breast height (GBH)

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

3.2.2 Measurement of Biomass.

3.2.2.1 Crop biomass

For the measurement of crop biomass, quadrat size of 0.25 sq metre was used. The quadrat is randomly placed in 10 places in all the field. For the measurement of Paddy crop, 10 sample plots of 0.25 m^2 were laid randomly in

Plate 1-A view of Study area

each Plot/field. Crops of each Quadrat was harvested and kept in marked Envelopes. Samples were brought to the laboratory and fresh weight were taken. Further samples were separated in grains yield and Crop residue biomass. Each biomass value was reported on oven dry weight basis. Crop samples were taken at its peak growth/biomass stage. Biomass was further converted in ton/ha.

3.2.2.2 Tree biomass:

For the measurement of tree biomass, allometric equations relating tree circumference to biomass developed earlier by Singh and Mishra (1979) (Appendix B) were used. Computation protocol as described by Singh and Singh (1991) was followed. In brief tree individuals were categorized into girth classes.The mean GBH (Girth at breast height) value for a girth class was used in the regression equation to get an estimate of biomass (by component) for that girth class. Then this value was multiplied by the density of trees in that girth class. The girth values were summed to obtain the biomass estimate for the site.

The relationship between girth of a tree and dry weight of a component is given by equation:

$$\textbf{Log Y = a + b log X}$$

Where,

Y = dry weight (kg) of component (bole, branch, leaf and root)

X = girth (cm) at 1.37 m height

a and b = allometric constants.

Girth of all the individuals of tree species at the beginning and ending of the study is given in Table 3.1 and Girth classes ranging from 20 cm to 160 cm is given Table 3.2.

Table 3.1 GBH (Girth at Breast Height) of *Acacia nilotica* in study area

Serial Number	Girth at breast Height (GBH) measured on 8th August 2015	Girth at breast Height (GBH) measured on 15th June 2016
1	66	69
2	94	98
3	95	100
4	59	62
5	129	133
6	150	155
7	112	114
8	60	63
9	118	121
10	80	84
11	100	105
12	94	98
13	27	30
14	35	38
15	74	77
16	25	29
17	65	67
18	30	34
19	75	79

Table 3.2 Girth classes for *Acacia nilotica*

S.No	Diameter classes (in cm.)
1	>20-≤40
2	>40-≤60
3	>60-≤80
4	>80-≤100
5	>100-≤120
6	>120-≤140
7	>140-≤160

3.2.3 Estimation of Net Primary Productivity:

The net primary production of the *Acacia nilotica* was measured using girth increments and biomass data following Singh and Singh (1991). The method is briefly described below.

In August 2015, all the tree individuals observed on the sites were marked and their girth were measured and the girth of the same individuals were remeasured after ten months in June 2016. Mean annual girth increment for each girth class was calculated. Using the allometric equations following Singh and Mishra (1979) the girth class and subsequently stand biomass for bole, branch, foliage and coarse roots were calculated separately from girth measurements. The girth class and subsequently biomass of stem, branch, leaves and roots in each diameter class for each species were calculated and separated from girth measurements on August 2015 (B1); June 2016 (B2). The net biomass accumulation for ten months (B2-B1). The estimation of total net primary productivity for the species was calculated by summing the NPP of trees (by components obtained form allometric equations).Further the NPP data was converted on per year basis. As paddy crop being annual assuming ≤ 1 year turnover rate crop biomass, it was considered equal to Net Production in present study.

3.2.4 Estimation of carbon stock and carbon sequestration

Carbon stock in tree components viz bole, branch, foliage, coarse roots were determined by multiplying respectively with 43.5, 45.67, 46.67, and 35.73 with their respective biomass values following Singh (2010). For determining carbon storage in crop 50% plant parts was considered as carbon. Hence, it was multiplied with crop biomass. For determination of Carbon Sequestration C concentrations of respective tree components were multiplied with Net Primary Productivity of respective components. For determination of carbon sequestration by crop carbon concentration viz considering turnover rate of ≤ 1 year crop biomass were considered equal to crop productivity and further crop productivity were multiplied with 50% will give Carbon Sequestration

3.2.5 Estimation of carbon stock in soil:

The 10 soil samples were randomly collected from all the sites at two depths viz. 0-10 cm and 10-20 cm depths. The amount of carbon in soil (0-10 and 10-20 cm) was determined from bulk density, soil volume and carbon values.

Plate 2- Quantification of crop in study area

Plate 3 A near view of Paddy

Plate 4 View of the tree marked

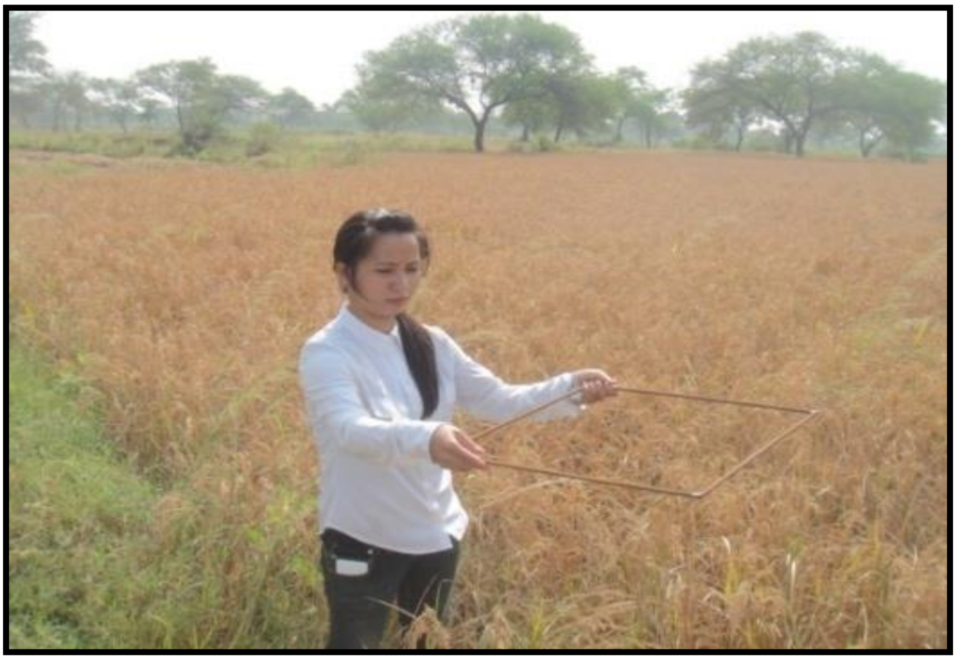

Plate 5 front view of the quadrat

Plate 6 A view while collecting Soil sample

3.2.6 Chemical analysis of soil

3.2.6.1 Soil sampling

Soil samples were collected randomly from 10 locations in each field at 0-10 cm and 10-20 cm depths. Samples were mixed thoroughly and large pieces of plant material were hand picked. Soils were sieved through a 2mm mesh screen. Samples were divided in two parts, one part has air dried which other was kept field moist. Field moist samples were used for the analysis of N and P. Rest of the analysis was carried our on air dried soil.

3.2.6.2 Nutrient analysis

The soil samples were collected from 0-10 cm and 10-20 cm soil depth in the month of April. The data on total nitrogen, organic carbon, available phosphorus, p^H, EC, and available potassium were analyzed through t-test assuming equal variances. The soil samples for estimation of the nutrient status were collected from both the depth in summer season.

The collected samples were chemically analysed in the laboratoary. Soil p^H was measured with glass electrode (soil:water ratio1:2), after stirring for 30 minutes as described by Piper (1967).

Particle size distribution (texture) was analysed by Pipette method (Piper,1950). Bulk density was determined by measuring the weight of dry soil of a unit volume to a depth of 0-10 cm and 10-20 cm. Water holding capacity (WHC) was determined using perforated circular brass boxes.(Piper, 1950). Organic carbon of the soil was determined by Walkley and Black's method. Total nitrogen was determined by Kelplus (Pelican equipment) based on micro Kjeldhal principle. The total phosphorus was determined after HClO4 digestion (Jackson, 1958). Potassium was determined by flame photometer method (Jackson 1958).

3.2.7 Statistical analysis

The data on physico-chemical properties of soil i.e. bulk density, total soil carbon, total nitrogen, available phosphorus and available potassium was analyzed through t test.The differences between treatment means of all parameters were tested for their significance at 5% or 1% levels following Snedecor and Cochran (1967)

CHAPTER- IV
RESULT AND DISCUSSION

The results on “Biomass, Carbon Stock and Carbon Sequestration potential in *Acacia nilotica* Paddy Based Traditional Agroforestry Systems are described in this chapter. The findings are presented in Sixth parts to facilitate the interpretation of results in accordance with topics. First part deals with the results on Physico-Chemical properties of soil, second part deals with crop biomass and its parameters, the third part deals with tree biomass, the fourth part deals with estimation of carbon storage pattern in *Acacia nilotica* paddy based agroforestry systems, fifth part deals with total carbon stock of soil, crop and tree and and the sixth part deals with estimation of carbon sequestration potential in soil, crop and tree in the tropical environment at Nara village of Raipur. Results on different aspects in each part are described below:-

4.1 Physico- Chemical properties of soil

The Soil of the study area was characterized by silty loam in texture with considerably varying proportions of sand, silt and clay given in Table 4.1, Fig 4.1, 4.3. The soil p^H was in the range of 6.40 – 6.90 at the soil depth 0-10 cm while the same was 6.10-6.50 cm at the soil depth 10-20 cm given in Table 4.2, Fig 4.1**.**

Table 4.1 Soil Texture of the study area at 0-10 cm and 10-20 cm depth

a) Sand(%)	F1	F2	F3	F4	F5	F6
0-10cm	27±0.35	28±0.56	25±0.26	28±0.45	27±0.43	26±0.32
10-20cm	23^a±0.55	25^a±0.46	23^a±0.43	26^a±0.46	24^a±0.25	23^a±0.23
b) Silt(%)						
0-10cm	55±0.36	56±0.34	56±0.33	55±0.32	58±0.42	57±0.36
10-20cm	58±0.41	57±0.21	58±0.32	57±0.41	59±0.25	59±0.23
c) Clay(%)						
0-10cm	18±0.35	16±0.45	19±0.45	17±0.39	15±0.42	17±0.37
0-20cm	19±0.45	18±0.37	19±0.36	17±0.32	17±0.35	18±0.39
Class	Silty loam	Silty loam	Silty loam	Silty loam	Silty loam	Silty loam

Note: F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

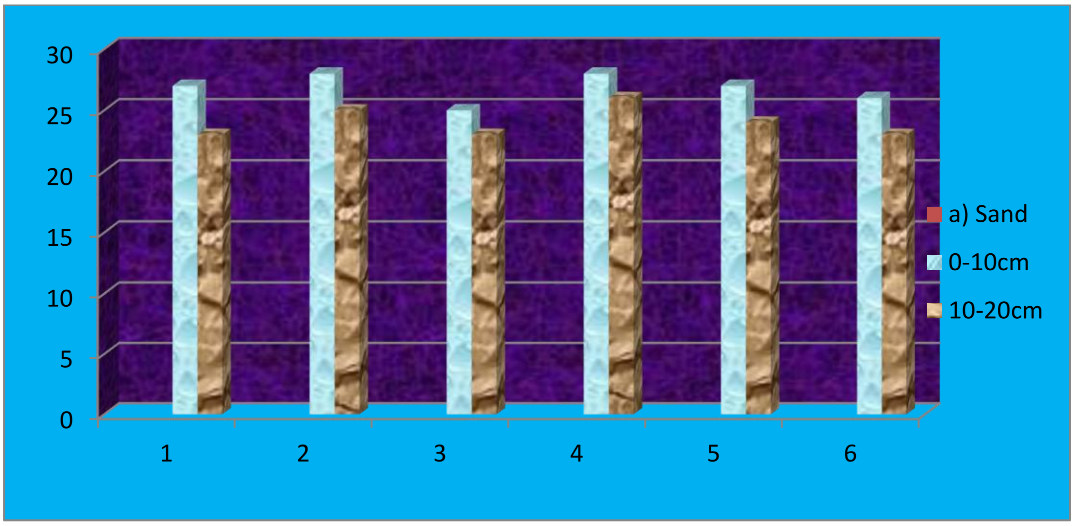

Fig 4.1 Sand content in soils of depth 0-10cm and 10-20cm

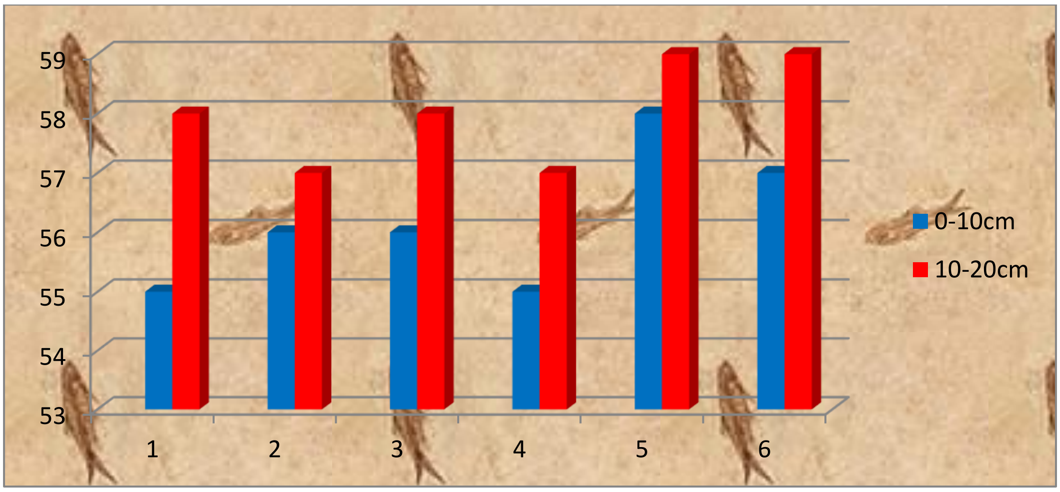

Fig 4.2 Silt constituents in soils of depth 0-10cm and 10-20cm

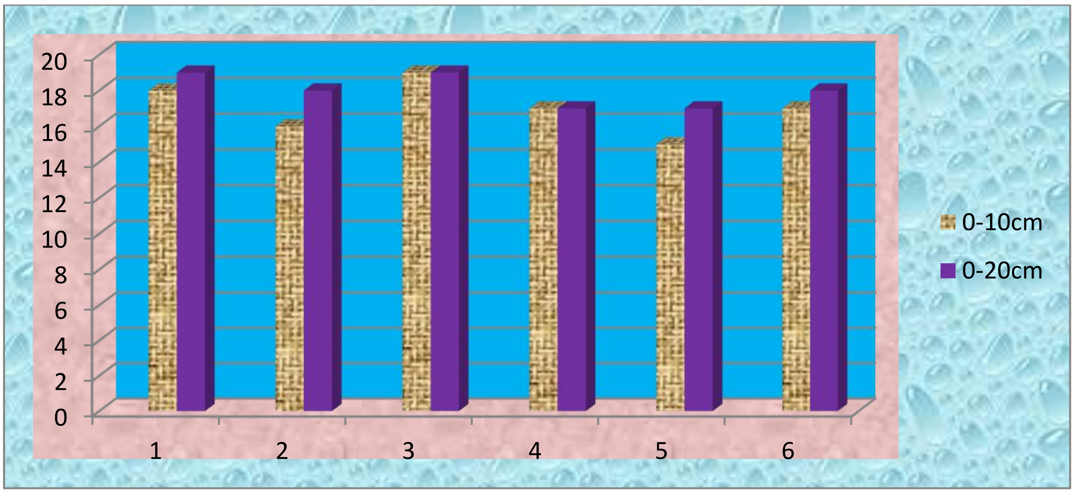

Fig 4.3 Clay content of soils of soil depth 0-10cm and 10-20cm

4.1.1 Organic carbon

Organic carbon was found to be within the range of 0.37% to 0.45% for soil depth 0-10 cm and in the range of 0.30% to 0.39% for soil depth 10-20 cm for different field under study. (Table 4.2). Swamy and Puri (2005) findings revealed that soil organic carbon from all sites decreased generally with the increasing depth from the surface soil to the lower layer soil. Similar observations were also observed in the present study. Samra and Singh also observed an increase in soil organic carbon status of surface soil by 0.39 to 0.52% under *Acacia nilotica+Sacchram munja* and 0.44 to 0.55% under *Acacia nilotica+Eulaliopsis binata* after 5 years. The present finding is also comparable with the research.

The mean organic carbon content of the of the soil in 0-10cm and 10-20cm depth was 0.40% and 0.33% respectively. It was observed that, with increase in depth, the organic carbon content decreases in all the fields under study. The t-test, assuming equal variances, indicated significant variation in organic content of the soil for different depths for all the fields under study at p<0.05.

Table 4.2 Organic carbon content of the field at 0-10 cm and 10-20 cm depth

OC(%)	F1	F2	F3	F4	F5	F6
0-10cm	$0.41^{b}\pm0.02$	$0.40^{b}\pm0.04$	$0.45^{b}\pm0.08$	$0.39^{b}\pm0.05$	$0.38^{b}\pm0.08$	$0.37^{b}\pm0.07$
10-20cm	$0.30^{a}\pm0.01$	$0.35^{a}\pm0.06$	$0.39^{a}\pm0.05$	$0.34^{a}\pm0.06$	$0.30^{a}\pm0.09$	$0.31^{a}\pm0.05$

Note: a) The superscripts indicate the significance of difference between the physic-Chemical properties for different levels of soil depths at p<0.05.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

C) OC(%) = ORGANIC CARBON

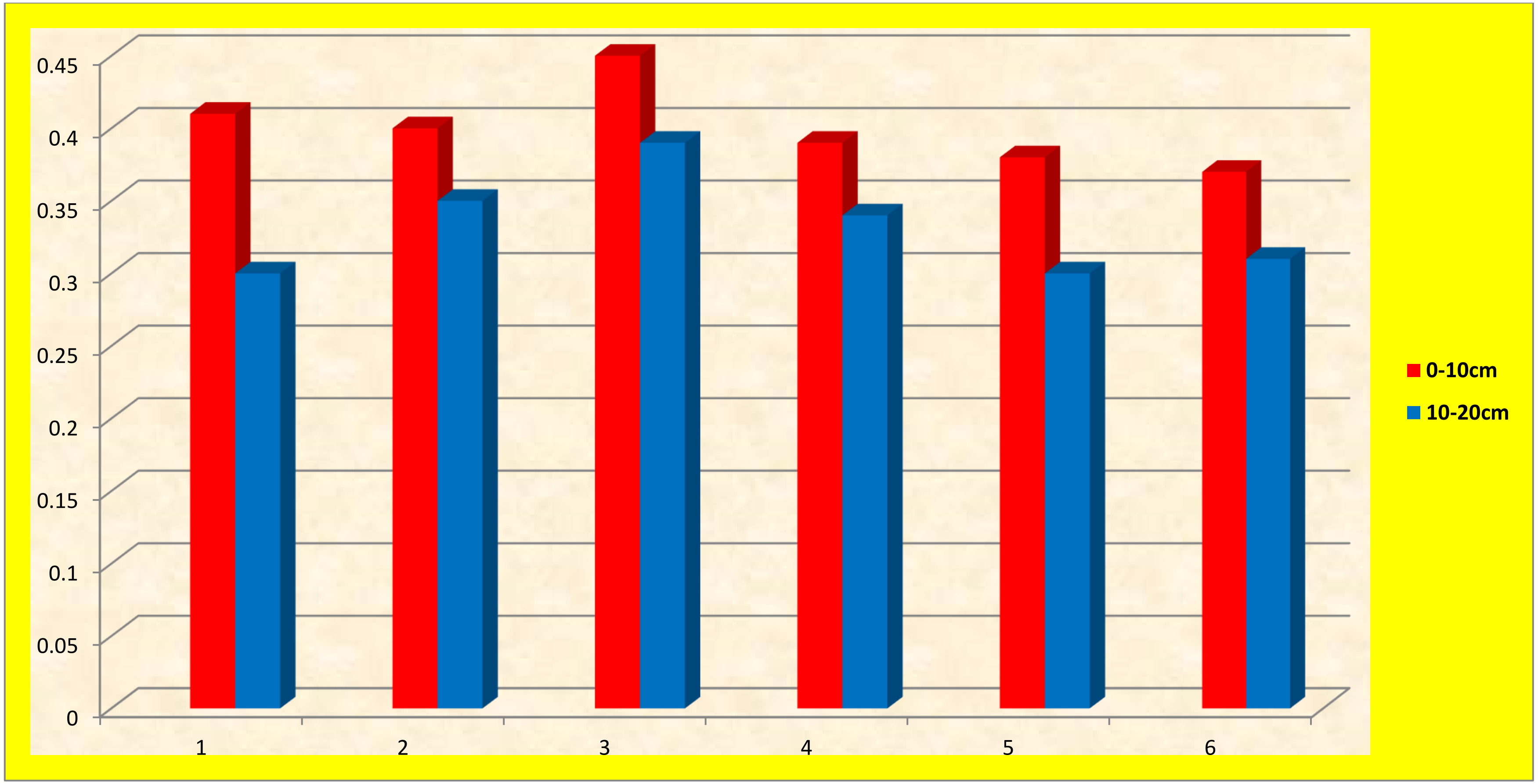

Fig 4.4 Organic carbon content of the soil of depth 0-10cm and 10-20cm

4.1.2 Bulk Density

Bulk density of the soil ranges from 1.29 to 1.36 g cm^{-3} (Table 4.3). The highest bulk density was observed in field no 4 of depth 10-20 cm (1.36g cm^{-3}) and the lowest was observed in field number 3 of depth 0-10 cm (1.29 g cm^{-3}). Increase in bulk density with increasing soil depth is also reported by Affule *et al.* (2004).

4.1.3 Water holding capacity

The water holding capacity of the soil was found to be ranging from 26% to 42% with maximum water holding capacity observed in field no 5 of depth 0-10 cm (42%) (Table 4.4) and the least was observed in field no 3 of dept 10-20 cm (26%). Hence, it was found that the water holding capacity decreases with increasing in the depth. The t-test assuming equal variances indicates that the variation in water holding capacity of the soil due to variation in soil depth were statistically significant ($p<0.05$).

Table 4.3 Bulk density of the soil at 0-10 cm and 10-20 cm depth.

Bulk Density	F1	F2	F3	F4	F5	F6
0-10cm	$1.34^{b}\pm0.78$	$1.31^{b}\pm0.67$	$1.29^{b}\pm0.69$	$1.34^{b}\pm0.55$	$1.31^{b}\pm0.45$	$1.33^{b}\pm0.36$
10-20cm	$1.35^{a}\pm0.87$	$1.32^{a}\pm0.74$	$1.30^{a}\pm0.71$	$1.36^{a}\pm0.65$	$1.33^{a}\pm0.57$	$1.35^{a}\pm0.44$

Note: a) The superscripts indicate the significance of difference between the physical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

Table 4.4 Water holding capacity of the soil at 0-10 cm and 10-20 cm depth

Waterholding capacity(%)	F1	F2	F3	F4	F5	F6
0-10 cm	40^{b}±0.55	36^{b}±0.59	29^{b}±0.69	35.67^{b}±0.67	42^{b}±0.75	37^{b}±0.67
10-20 cm	36.09^{a}±0.60	32^{a}±0.64	26^{a}±0.68	30^{a}±0.76	38^{a}±0.84	32^{a}±0.77

Note: a)The superscripts indicate the significance of difference between the physical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

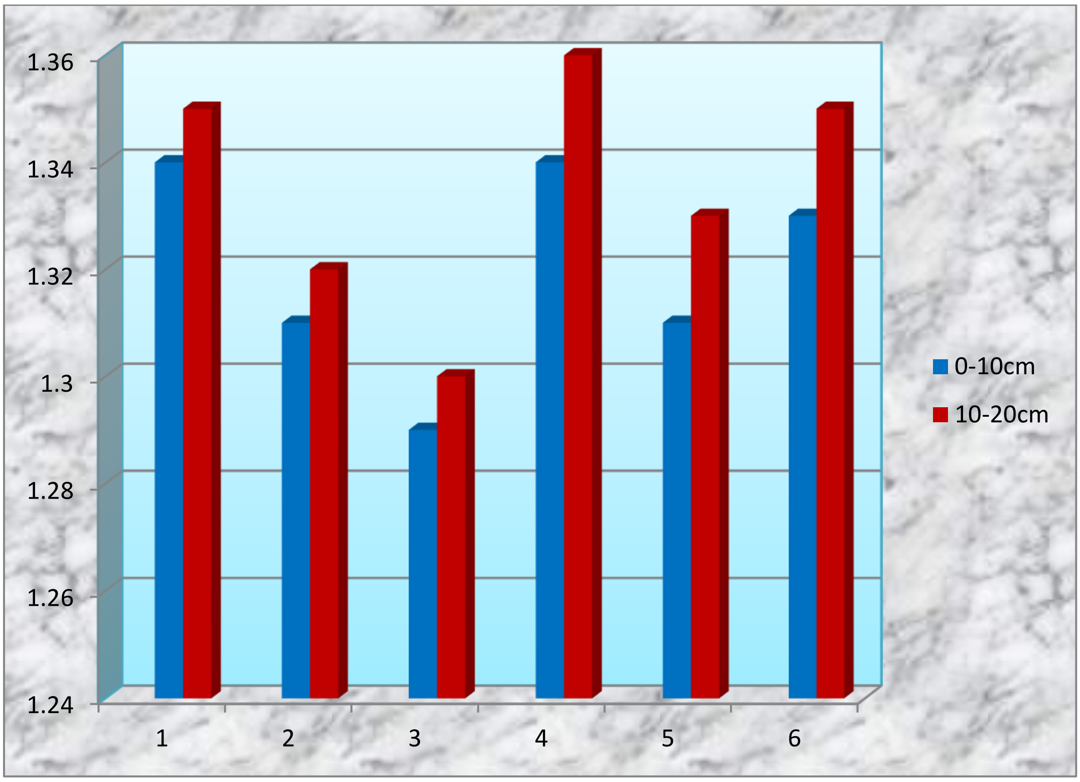

Fig 4.5 Bulk density of soil of the soil of depth 0-10cm and 10-20cm

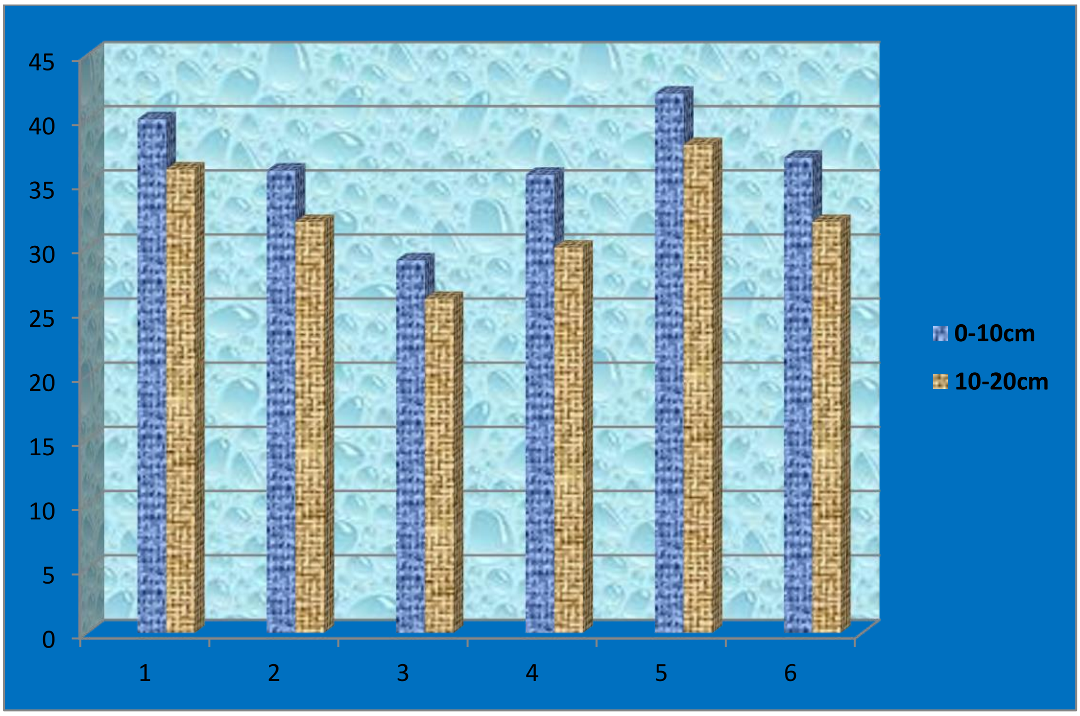

Fig 4.6 Water holding capacity of the soil of depth 0-10cm and 10-20cm

4.1.4 p^H

It was observed that, with increase in depth, the p^H decreases in all the fields under study. The t-test, assuming equal variances, indicated significant variation in p^H of the soil for different depths for all the fields under study at $p<0.05$.

Table 4.5 p^H of the soil at 0-10 cm and 10-20 cm depths

Properties	F1	F2	F3	F4	F5	F6
0-10cm	6.40^b	6.90^b	6.80^b	6.70^b	6.90^b	6.50^b
10-20cm	6.10^a	6.50^a	6.50^a	6.30^a	6.50^a	6.20^a

Note: a) The superscripts indicate the significance of difference between the physico-chemical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

4.1.5 Electroconductivity

In all the field, it is clearly observed that electro conductivity is higher in the surface, 0-10 cm depth and lower in 10-20 cm depth (Table 4.6). The electroconductivity was lowest in field no 6 of depth 10-20cm (0.21 dS/m) and highest in field number 1 of depth 0-10cm (0.33 dS/m). Hence, it is concluded that the surface soil has more electroconductivity. The t-test assuming equal variances indicates that the water holding capacity of the soil due to variation in soil depth were statistically significant ($p<0.05$).

Table 4.6 Electroconductivity of soil at 0-10 cm and 10-20 cm depth.

Electroconductivity (dS/m)	F1	F2	F3	F4	F5	F6
0-10cm	0.33^b±0.34	0.28^b±0.22	0.31^b±0.36	0.24^b±0.36	0.26^b±0.43	0.20^b±0.55
10-20cm	0.27^a±0.32	0.24^a±0.29	0.25^a±0.32	0.19^a±0.39	0.21^a±0.38	0.16^a±0.45

Note: a) The superscripts indicate the significance of difference between the physico-chemical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

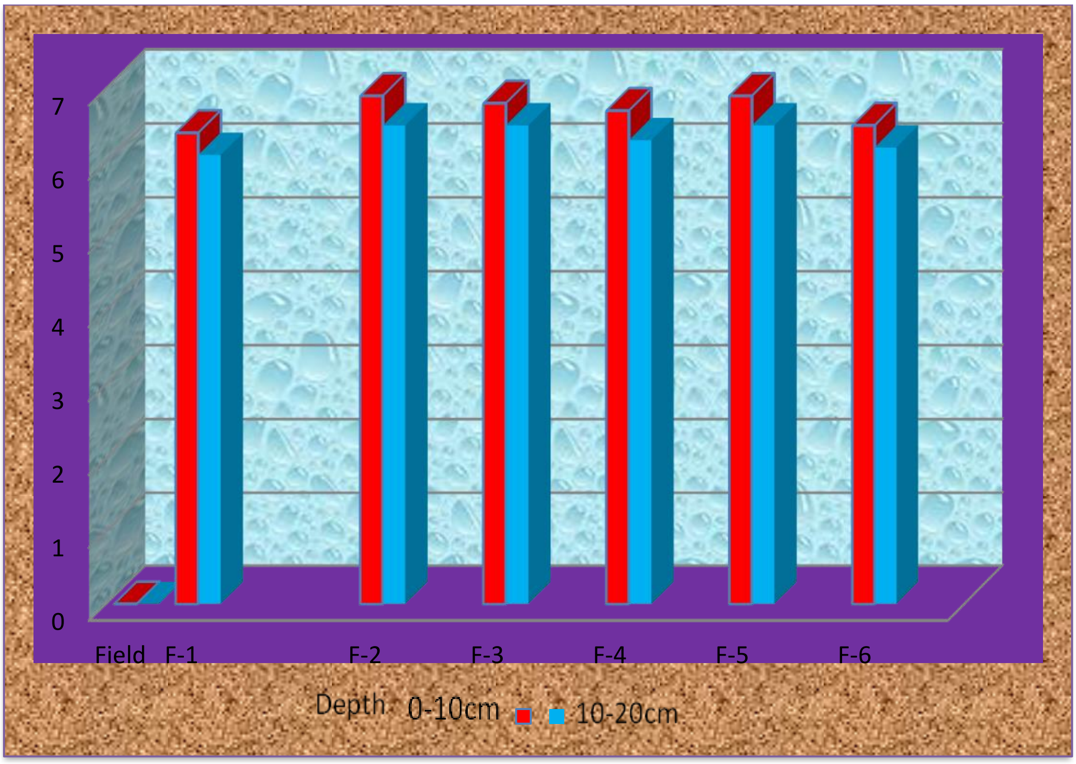

Fig 4.7 p^H content of the field of 0-10cm and 10-20cm depth

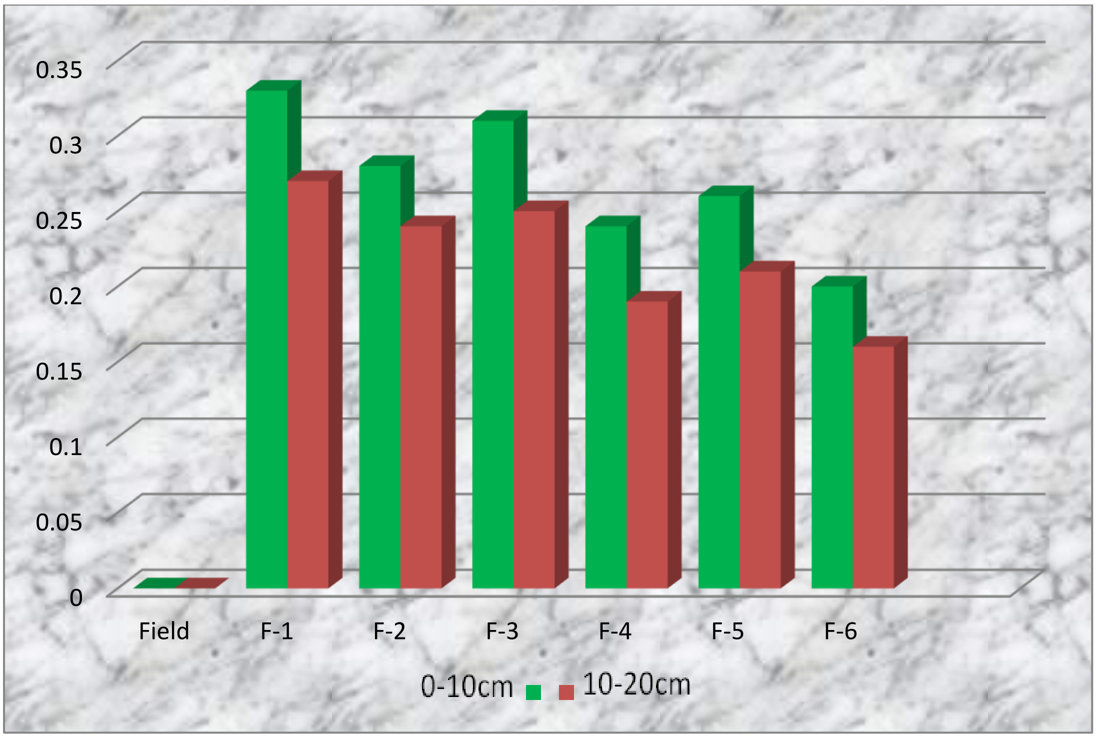

Fig 4.8 Electroconductivity of the soil of depth 0-10cm and 10-20cm

4.1.6 Nitrogen (N)

Nitrogen content of soils is given in Table 4.7, 4.9. In the present study, the available nitrogen was found more in the upper soil surface. The highest available nitrogen was found at field no 2 with 112.44 Kg/ha at 0-10cm. Swamy and Puri (2005) reported that available nitrogen decreased with increased in soil depth.

The statistical test indicates that the variation in total available nitrogen content of soil due to site and soil depth was statistically significant ($p<0.05$).

4.1.7 Phosphorus (P)

Available Phosphorus content of soils is given in table 4.8, fig 4.10 was found to be maximum in Field number 3 (17.56 Kg/ha) and minimum in field 1 at 10-20 cm depth (10-20 cm) and it was observed that the available phosphorus decreases with increase in dept . It was found that except in field no 6 the available phosphorus is at par. The t-test assuming equal variances indicates that the variations in available phosphorus due to site and soil depth were statistically significant ($p<0.05$). The interaction of site x soil depth was also significant ($p<0.05$). The variation in available phosphorus content of soil at 0-10 cm and 10-20cm depth of all the field was statistically non-significant

4.1.8 Pottasium (K)

Pottasium content of soil is given in table 4.9 and fig 4.11. The t test assuming equal variances indicates that the variation in available potassium content of soil due to site and soil depth were statistically significant ($p<0.05$). The interaction of site x soil depth was also significant ($p<0.05$). The available potassium content of soil of both soil depth of the site was at par.

Table 4.7 Nitrogen (N) content of the soil at 0-10cm and 10-20cm depths.

Properties	F1	F2	F3	F4	F5	F6
0-10cm	$100.35^{b}\pm0.55$	$112.44^{b}\pm0.54$	$87^{b}\pm0.45$	$112.44^{b}\pm0.56$	$87^{b}\pm0.361$	$100.35^{b}\pm0.38$
10-20cm	$87^{a}\pm0.45$	$100.35^{a}\pm0.57$	$75.26^{a}\pm0.48$	$87^{a}\pm0.75$	$75.26^{a}\pm0.43$	$75.26^{a}\pm0.53$

Note: a) The superscripts indicate the significance of difference between the chemical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

Table 4.8 Phosphorus (P) content of the soil at 0-10cm and 10-20cm depths

Properties	F1	F2	F3	F4	F5	F6
0-10cm	$12.63^{b}\pm0.23$	$12.9^{b}\pm0.37$	$17.56^{b}\pm0.45$	$13.26^{b}\pm0.43$	$12.36^{b}\pm0.38$	$14.07^{b}\pm0.53$
10-20cm	$7.23^{a}\pm0.27$	$7.97^{a}\pm0.38$	$12.72^{a}\pm0.39$	$8.06^{a}\pm0.45$	$8.51^{a}\pm0.38$	$10.57^{a}\pm0.55$

Note: a) The superscripts indicate the significance of difference between the chemical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

Table 4.9 Pottasium (K) content of the soil of depth 0-10cm and 10-20cm

Properties	F1	F2	F3	F4	F5	F6
0-10 cm	$404.32^{b}\pm0.87$	$343.84^{b}\pm0.89$	$351.68^{b}\pm0.75$	$403.2^{b}\pm0.72$	$321.44^{b}\pm0.70$	$427.84^{b}\pm0.81$
10-20 cm	$383.04^{a}\pm0.83$	$316.96^{a}\pm0.79$	$318.08^{a}\pm0.79$	$392^{a}\pm0.78$	$294.56^{a}\pm0.79$	$376.32^{a}\pm0.85$

Note: a) The superscripts indicate the significance of difference between the chemical properties for different levels of soil depths at $p<0.05$.

b) F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

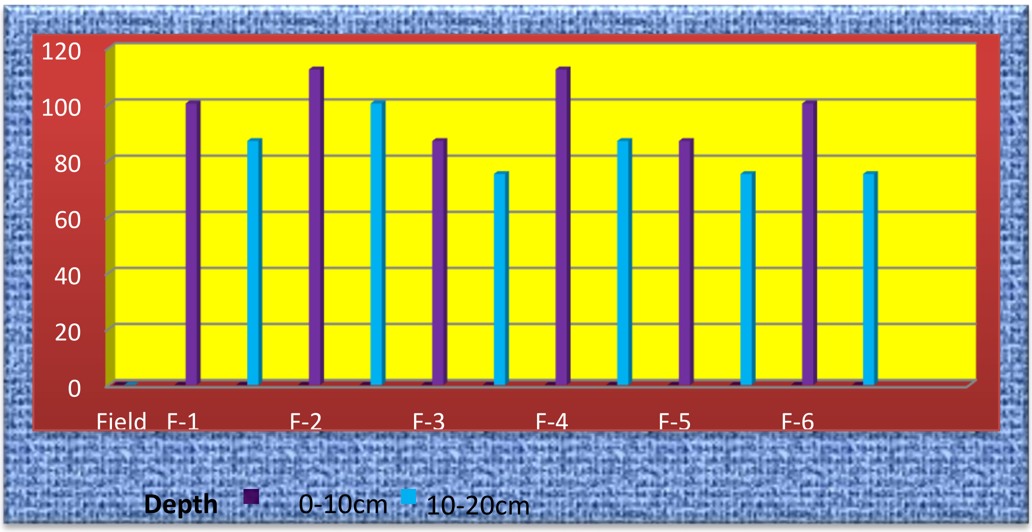

Fig 4.9 Nitrogen content of soils of depth 0-10cm and 10-20cm

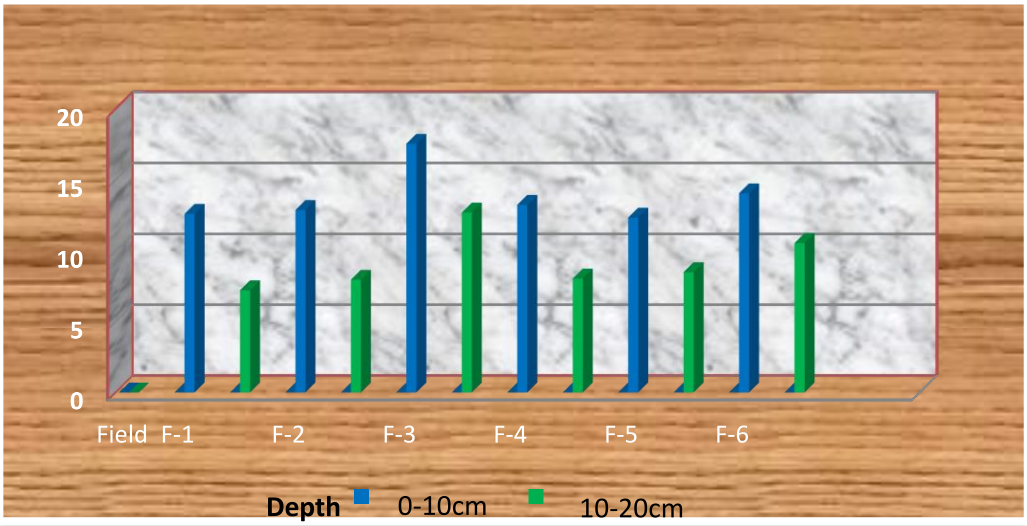

Fig 4.10 Phosphorus content of the soil of depth 0-10cm and 10-20cm

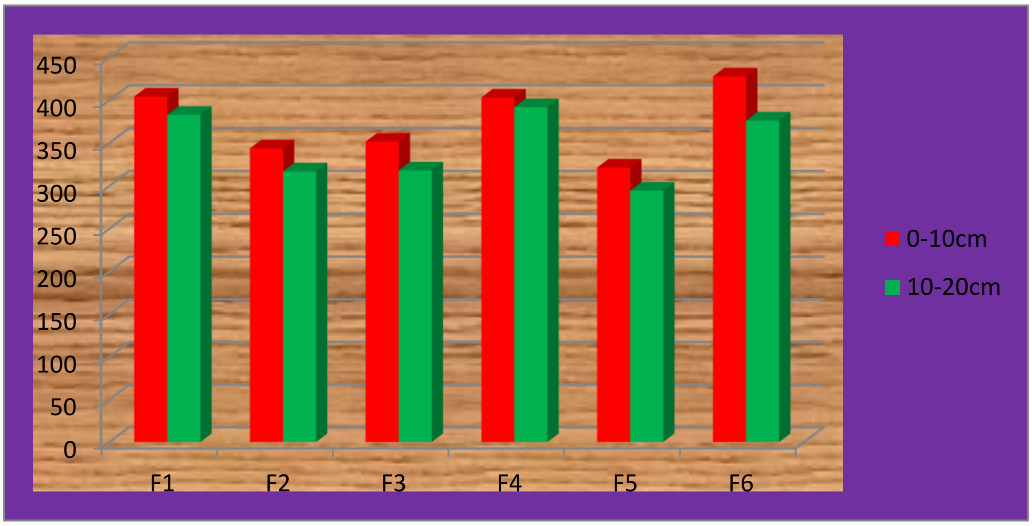

Fig 4.11 Pottasium content of soil at depth 0-10cm and 10-20cm

4.2 Measurement of Biomass

4.2.1 Total Crop biomass

The crop biomass measured in present study for various fields were ranged between 3.10 and 4.93 tons/ha. (Table 4.10). It was observed maximum in field 1 and minimum in field 6 and followed the order F6<F2<F5<F4<F3<F1. The yield of crop biomass obtained for different field through t-test assuming 2 variances were found to be unsignificant

4.2.2 Grains biomass (Yield)

The Crop yield ranged between 0.82 and 1.58 tons/ha, It was observed maximum in field 1 and minimum in field 6. Crop yield biomass followed the order F6<F2<F4<F5<F3<F1. Proportions of given biomass across all the fields ranged between 26-34% and mean grain yield was 32%.

4.2.3 Residue Biomass

The residue biomass ranged between 2.18 and 3.35 ton/ha. It was maximum in field 1 and minimum in field 2. Residue biomass followed the order F2<F6<F5<F4<F3<F1. Proportions of residue biomass to total crop biomass ranges between 66% to 68% and mean residue biomass was 68%.

Table 4.10 Total crop biomass,Crop yield biomass and Crop residue biomass.

Biomass	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6	Average Biomass
Crop Residue Biomass	3.35±0.49	2.18±0.53	2.50±0.43	2.52±0.53	2.38±0.38	2.28±0.20	3.71±0.35
Crop yield biomass	1.58±0.35 (32)	1.01±0.27 (32)	1.27±0.21 (34)	1.17±0.23 (32)	1.24±0.21 (34)	0.82±0.11 (26)	1.18±0.42 (32)
Total crop biomass	4.93±0.84 (68)	3.20±0.80 (68)	3.77±0.64 (66)	3.69±0.76 (68)	3.62±0.59 (66)	3.10±0.31 (74)	2.53±0.38 (68)

Note: Value given in the parenthesis represents % value

4.3 Tree biomass:

The biomass and productivity of the the sites is given in Table 4.11. It was 5.34 tons/ha in bole, 8.53 tons/ha in branch, 0.51 tons/ha in leaf and 2.007 tons/ha in root.Of the total biomass 52% was stored in branch,33% in bole,12% in roots, and only 3% in leaf.

4.4 Net Primary Productivity

Net Primary productivity is given in Table 4.11**.**Net primary productivity of the tree +Crop system showed significant differences due to the tree species.Total Net Primary Productivity of the tree was 2.61 tons/ha/yr, of the total tree net Productivity branch contributed 44%, foliage 25%, bole 22%, and root 8%. The total mean Crop Productivity was 3.71 tons/ha/yr, of this 68% was crop residue and 32% Grain yield. Total Tree+Crop Productivity was 6.32 tons/ha/yr. Of this, contribution of crop was 59% and 41% was contributed by tree.

Table 4.11 Biomass (tons/ha) and Net Primary Productivity (tons/ha/yr) of study site

Component	**Biomass**	**Net Primary Productivity**
Crop		
Residue	2.53	2.53
Grain	1.18	1.18
Total crop	3.71 (18)	3.71 (59)
Tree		
Bole	5.34	0.58 (22)
Branch	8.53	1.16 (44)
Leaf	0.55	0.65 (25)
Root	2.007	0.22 (8)
Total	16.39	2.61 (41)

Note: The value given in Parenthesis represents Percentage (%)

4.5 Carbon stock in Soil, Crops and Trees.

4.5.1 Soil Carbon Stock

Carbon stock is given in table 4.13. The carbon stock of the soil at depth 0-10 cm ranged between 4.92 and 5.8 tons/ha. It was maximum in field no 3 and minimum in field no 6. Mean carbon stock at 0-10 cm depth was 5.27 tons/ha. Gupta *et al* (2009) reported the carbon stock value of 13.3 tons/ha in Poplar based agroforestry system. Patil *et al* also reported the soil carbon stock value range between 8.2 to 9.5 tons/ha in 10 years Paddy cultivated area.So the present findings was found to be comparable.

Carbon stock of the soil for the depth 10-20 cm was in between 3.99 and 5.07 tons/ha being maximum in field no 5. Mean Carbon Stock at 10-20 cm depth was 4.42 tons/ha. Singh et al (2011) reported carbon stock in Indo Gangetic Plains between 8.5 to 9.69 tons/ha.

4.5.2 Carbon Stock in Crop

Carbon stock in crop residue across the field was between 1.09 tons/ha and 1.68 tons/ha. It was maximum in field no 1 and minimum in field no 2. Mean carbon stock of crop residue was 1.26 tons/ha.

Carbon stock in Crop Grains ranged between 0.41 tons/ha and 0.79 tons/ha.Mean Carbon Stock in grain yield was 0.59 tons/ha

Total Carbon in crop across the field was between 1.56 and 2.47 tons/ha. Average carbon stock in Crop was 1.86 tons/ha.

4.5.3 Carbon Stock in Trees.

The carbon stock value for the tree was found to be 6.15 tons/ha distributed in bole (2.32 tons/ha), branch (2.89 tons/ha), leaf (0.23 tons/ha) and root (0.71 tons/ha) (Table 4.14). Carbon stock of the tree was obtained multiplying the biomass with C concentration constant for various components of the tree(Table 4.12). Pragasan and Karthick (2013) reported the carbons stock of *Acacia nilotica* value 11.40 tons/ha.The present findings is comparable.

Table 4.12 Carbon concentration in different components of tree

PARTS	C(%)
BOLE	43.5
BRANCH	45.67
LEAF	46.67
ROOT	35.73

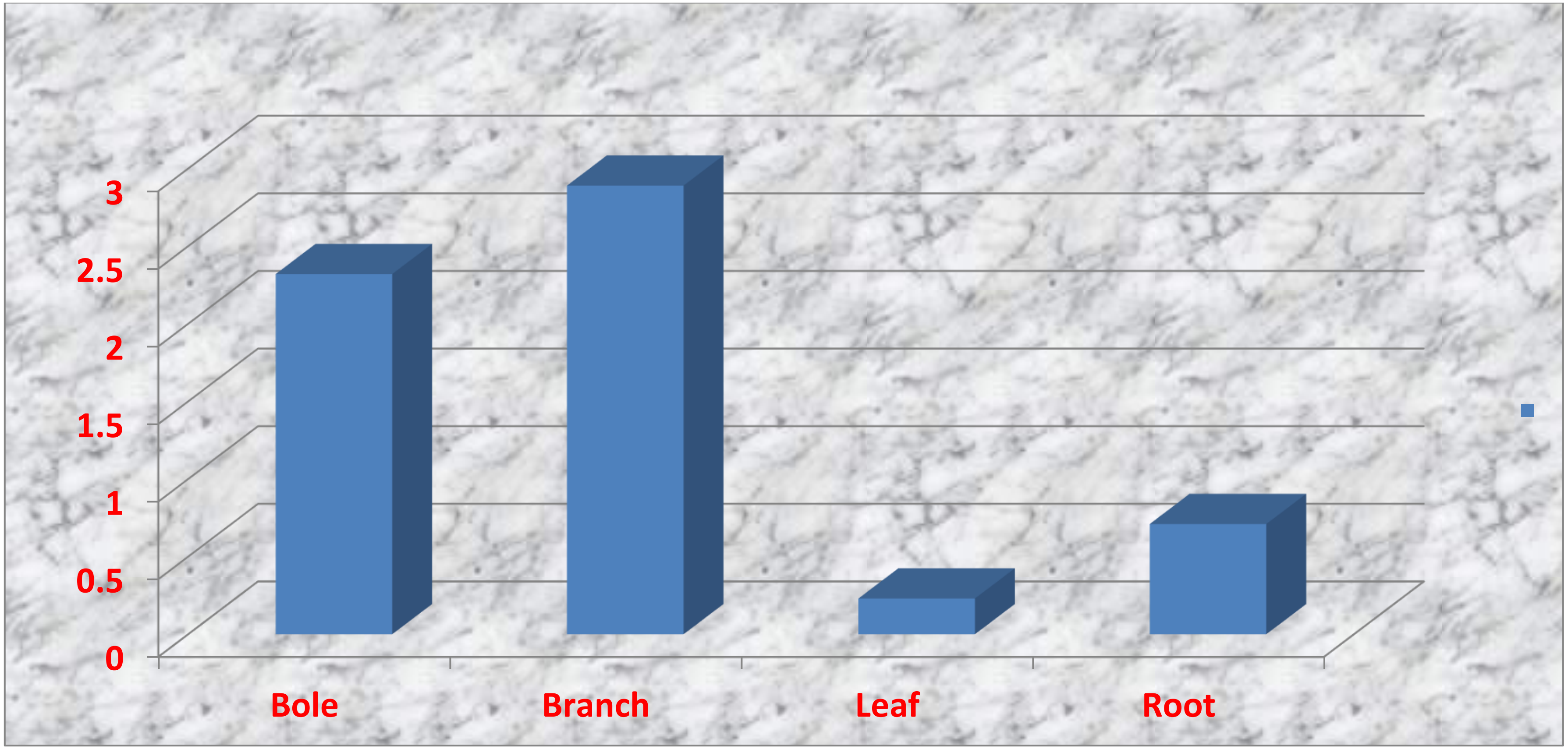

Fig 4.12 Carbon stock value for *Acacia nilotica*

Table 4.13 Carbon Stock (tons/ha) in Crop and Soil

Components	F1	F2	F3	F4	F5	F6	Average
Soil							
0-10 cm	5.49	5.24	5.80	5.22	4.97	4.92	5.27
10-20cm	9.54	4.62	5.07	4.62	3.99	4.18	4.42
TOTAL	9.54	9.86	10.87	9.84	8.96	9.1	9.69
Crop							
Residue	1.68	1.09	1.25	1.26	1.19	1.14	1.26
Grain	0.79	0.51	0.64	0.59	0.62	0.41	0.59
Total Crop	2.47	1.6	1.89	1.85	1.81	1.56	1.86

Note: F1, F2, F3, F4, F5, F6 respectively represents field 1, field 2, field 3, field 4, field 5 and field 6

4.6 Carbon Stock in Tree, Crop and Soil system

Carbon stock in tree components were 2.32 tons/ha in bole, 2.89 tons/ha in branch, 0.23 tons/ha in leaf and 0.71 tons/ha in root given in Table 4.14. Total carbon stored in tree was 6.15 tons/ha.Carbon stored in Vegetation (Tree+Crop) was 8.01 tons/ha in soil upto 20 cm depth was 9.69 tons/ha whereas the total carbon storage by the Agroforestry system was 17.7 tons/ha. It is interesting to note that of the total carbon stored in the system a significant Quantities (45%) was stored by the Vegetation and rest 55% was in soil.

Table 4.14 Carbon Stock in Tree, Crop and Soil system

Parameter	**Carbon Stock**
Crop	
Residue	1.26
Grain Yield	0.59
Total Crop	1.86
Tree	
Bole	2.32
Branch	2.89
Leaf	0.23
Root	0.71
Total	6.15
Soil	
0-20cm	9.69
Total Vegetation	8.01
Total (Soil+ Plant)	17.7

4.7 Carbon Sequestration (tons/ha) by *Acacia nilotica* based Agroforestry system

The carbon sequestration value obtained for the duration of 10 months from 8th August 2015 to 8th June 2016, sum up as 305 days, of *Acacia nilotica* was found to be 1.15

tons/ha. As reported by Jaiswal *et al* 2014 the carbon stock for *Acacia nilotica* in Attarsumba Range, Gandhinagar Forest division, was to be 1.5 tons/ha. So the present findings was found to be comparable. The total carbon sequestered by the whole vegetation was found to be 3.01 In this, Crop contributed 62% and trees 38%. Contribution by Perennial part was 28% rest was contributed by crops and tree leaves.

4.15 Carbon Sequestration (tons/ha) by *Acacia nilotica* based Agroforestry system

Parameter	Carbon sequestration	Mean
Crop Parameter		
Residue	1.26	
Grain Yield	0.59	
Total Crop	1.86	
Tree components		
Root	0.08	0.063[a]
Bole	0.25	0.228[b]
Leaf	0.30	0.306[c]
Branch	0.52	0.526[d]
Total Vegetation	3.01	**C.D**=0.000358

Note: The superscript a,b,c,d represents the level of significance at p(0.05)

Based on the Analysis of variance (ANOVA) of the carbon sequestration of different component of the tree *Acacia nilotica*, it is concluded that at 5% level of significance, all the tree components viz Bole, Branch, Leaf and Roots are contributing significantly and differently from each other.

CHAPTER-V

SUMMARY AND CONCLUSIONS

The present investigation entitled**"Biomass, Carbon Stock and Carbon Sequestration in *Acacia nilotica*-paddy based traditional agroforestry system"** in

Tropical Environment" at Nara village PO Bhansoj Raipur district (Chhattisgarh), during the year 2015-2016.

The investigation was carried out using dry weight of the crop obtained after sundrying of the sample collected from the field.

Biomass of the trees species was estimated by allometric logarithmic regression equations relating dry weight of each tree component with GBH (Girth at Breast Height) as independent variable. The climate of the study area is dry tropical and the year is divisible in three seasons viz. rainy (mid June to September), winter (December to the end of February) and summer (from March to June before the onset of monsoon).

The Soil of the study area was characterized by silty loam in texture with considerably varying proportions of sand, silt and clay. The soil p^H was in the range of 6.10 – 6.90.

Bulk density of the soil ranges from 1.29 to 1.36 g cm^{-3}. The highest bulk density was observed in field no 4 of depth 10-20cm (1.36g cm^{-3}) and the lowest bulk density was observed in field number 3 of depth 0-10cm (1.29g cm^{-3}). Soil Organic carbon was found to be maximum in the field no 3 of depth 0-10cm (0.45%) and minimum in the field no 5 of depth 10-20cm (0.30%).

The water holding capacity of the soil was found to be ranging from 26% to 42% with maximum water holding capacity observed in field no 5 (42%) and the least was observed in field no 3 (26%).The electroconductivity was lowest in field number 6 of depth 10-20cm (0.21 S/m) and highest in Field number 1 of depth 0-10cm (0.33 S/m). Phosphorus nutrients was found to be maximum in Field number 3 (17.56 Kg/ha) and minimum in field 1.

In the present study, the total crop biomass were ranged between 3.10-4.93. It was maximum in field 1 and minimum in field 6. The total crop yield ranged between 0.82 and 1.58 tons/ha. It was observed maximum in field no 1 and minimum in field no 6. The Carbon Stock of the soil ranged between 4.92 and 5.8 tons/ha. It was found to be maximum in field no 3 and minimum in field no 6. Carbon stock in tree component was 2.32 tons/ha. The total carbon stored in trees across the agroforestry system was found to be 6.15 tons/ha. Total carbon sequestered by the system was at rate of 3.0% tons/ha.Total net productivity of the tree was 2.6 tons/ha/yr.

This research concluded that *Acacia nilotica*-paddy based traditional agroforestry system have the potential to enhance carbon stock through tree biomass and soil. The magnitude and quality of carbon stock depends on the complex interaction between climate, soil, density, age of plantation, and management practices.

CONCLUSIONS

There is a worldwide concern over the global warming trends. Carbon dioxide (CO_2) emissions are one of the primary contributors to the increase in greenhouse gases (GHGs) level. Increase in concentration of green house gases in atmosphere results global warming, which would cause reduction in rainfall; yield potentiality of crops and replacement of species. Absorption of CO_2 in the biomass directly depends on the productivity of tree species. Forest tree plantations have only had a small contribution to the total balance of terrestrial carbon (3.8% or 140 million ha of the world"s total forest area; FAO 2006) but their potential to absorb and store carbon has been recognized to play a major role in the future mitigation of climate change (Canadell *et al.,* 2007). Hence proper input management plays an important role in biomass productivity. Land-use change or deforestation can modify carbon storage in above ground biomass, below ground biomass and in soil layers.

Acacia nilotica-Paddy traditional agroforestry system have the potential to enhance carbon stock through plant biomass and soil. The advantage of carbon sequestration in secondary forests / plantations is an important strategy to ameliorate changes of CO_2 into the atmosphere by acting as an important carbon sink.

SUGGESTIONS

The present investigation on biomass production of tree species is based on allometric equations. The result obtained from this investigation belongs to only 10 months of research work. To achieve a definite conclusion and recommendation it needs further continuation of the study. In order to screen out the suitability of the species a more detail study on other aspect i.e. Litter fall, fine root, and nutrient dynamics, effect of tree on microclimate is equally important.

Therefore, it is an urgent need to investigate the system on the above line also that the system can be judged on sustainable basis.

REFERENCES

Allen, S.C., Jose, S., Nair, P.K.R., Brecke, B.J., Nkedi-Kizza, P., Ramsey, C.L. 2004. Safety-net role of tree roots: evidence from a pecan (*Carya illinoensis* K. Koch)-cotton (*Gossypium hirsutum L.*) alley cropping system in the southern United States.

Anderson, F. 1970. Ecological studies in a Scandinavian wood land and meadow area. Southern Sweden II. Plant biomass, primary production and turnover of organic matters. *Botaniska Notiser*, 123: 8-15. Angelina, M. Y. and Jose, S.1990. Litterfall patterns in a tropical deciduous forest in Mexico over a fiveyear period. Journal of Tropical Ecology,: 433-444.

Arora, G., Chaturvedi, S., Kaushal, R., Nain, A., Tewari, S., Alam, N. M.,Chaturvedi, Management., O. P. 2014. Growth, biomass, carbon stocks, and sequestration in an age series of *Populus deltoids* plantations in Tarai region of central Himalaya Turkish Journal of Agriculture and Forestry 38: 550-560

Baishya, R., Barik, S. K., Upadhaya, K. 2009. Distribution pattern of aboveground biomass in natural and plantation forests of humid tropics in northeast India Tropical Ecology, International Society for Tropical Ecology, 50(2): 295-304.

Bargali, K., and Bargali, S.S. 2009. *Acacia nilotica*: a multipurpose leguminous plant. Nature and Science, 7(4):11-19.

Bargali, S. S., Bargali, K., Singh, L., Ghosh, L., and Lakhera, M. L. 2009. *Acacia nilotica*-based traditional agroforestry system: effect on paddy crop and management.Current Science, :96 (4).

Bargali, S. S., Singh, S.P. and Pandya, K.S. 2004. Effects of *Acacia nilotica* on Gram crops in a Traditional Agroforestry system of Chhatisgarh Plains. International journal of Ecology and Environmental Sciences, 30(4):363-368.

Beniwal, R.S., Toky, O.P. and Sharma, P.K. 1992. Effect of VA mycorrhizal fungi and phosphorus on growth and nodulation of *Acacia nilotica* (L.) Willd ex Del. Crop Res, 5:172-176.

Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forest: A Primer. Food and Agriculture Association of the United Nations (FAO) Rome.

Canadell, J.G., Kirschbaum, M.U.F., Kurz, W.A., Sanz, M.J., Schlamadinger, B. and Yamagata,Y. 2007. Factoring out natural and indirect human effects on terrestrial carbon sources and sinks. Environmental Science Policy, 10:370–384.

Chaturvedi, O.P. and Singh, J.S. 1987c. The structure and function of pine forest in central Himalaya. I . Dry matter dynamics. Annals of Botany, (3): 237-252.

Chaturvedi, R. K., Raghubanshi, A. S., Singh, J. S. 2010. Non-destructive estimation of tree biomass by using wood specific gravity in the estimator. National Academy Science Letters, 33 (5/6) :133-138

Chaturvedi, R.K., Raghubanshi, A.S. and Singh, J.S. 2011. Carbon density and accumulation in woody species of tropical dry forest in India. Forest Ecology and Management, 262:1576-1588.

Chauhan, S. K., Sharma, R., Singh, B. and Sharma, S. C. 2015. Biomass production, carbon sequestration and economics of on-farm poplar plantations in Punjab, India Journal of Applied and Natural Science, 7 (1) : 452 – 458.

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Folster, H., Fromard, F., Higuchi, N., Kira,, T., Lescure, J.P., Nelson, B. W., Ogawa, H., Puig, H., Riera, B. and Yamakura, T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests Oecologia, 145: 87–99.

Chhabra, A., Palria, S. and Dadhwal, V.K. 2003. Soil organic carbon pool in Indian forests. Forest Ecology and Management, 173(1), 187-199.

Clark, D.B., Clark, D.A., Brown, S., Oberbauer, S.F. and Veldkamp, E. 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. Forest Ecol. Manag. 164 (1–3), 237– 248.

Condit, R. 2008. Methods for estimating aboveground biomass of forest and replacement vegetation in the tropics. Center for Tropical Forest Science and Forest Geo Smithsonian Tropical Research Institute Research Manual.

Seb, S., Barbhuriya, A.R., Arunachalam, A. and Arunachalam, K. 2008. Ecological analysis of traditional agroforest and tropical forest in the foothills of Indian 207 eastern Himalaya: vegetation, soil and microbial biomass. Tropical Ecology, 49(1): 73-78.

Devagiri, G.M., Money, S., Singh, S., Dadhawal, V.K., Patil, P., Khaple, A.,Davakumar, A.S. and Hubballi, S. 2013. Assessment of above ground biomass and carbon pool in different vegetation types of south western part of Karnataka, India using spectral modeling. Tropical Ecology, 54(2): 149-165.

Dhanai, C.S., Bharsakle, L. and Singh, C. 2013. Allelopathic Effect of Different Aqueous Extract of *Acacia nilotica* on Seed Germination and Growth of Wheat (*Triticum aestivum*). The Indian Forester, pp.139.

Jaiswal, D.G., Maheta, V.R., Patel, Y, B. and Pandya, H.A. 2014. Carbon stock estimation major tree species in Attarsumba range, Gandhinagar forest division, India. Annals of Biological Research, 5 (9):46-49

Dhillon, M. S., Singh, S., Atwal, A. S., Dhillon, G. S. 1984. Developing agri-silvicultural practices: effects of *Dalbergia sissoo* and *Acacia nilotica* on the yield of adjoining crops. Indian Journal of Ecology, 11(2): 249-253

Dinakaran, J., and Krishnayya, N. S. R. 2010. Variations in soil organic carbon and litter decomposition across different tropical vegetal covers. Current Science, 99(8): 1051-1060.

FAO. 1988. Interim Report on the State of Forest Resources in the Developing Countries. Food and Agriculture Organization, Rome.

FAO. 1999. State of the World's Forests. Food and Agriculture Association of the United Nations (FAO), Rome.

FAO. 2001. State of the world's forests; Food and Agriculture Organization, Rome.

FAO. 2005. Global Forest Resources Assessment. Progress towards sustainable forest management. Rome, FAO Forests Paper. 147.

Haripriya, G.S. 2000. Estimates of biomass in Indian forests. Biomass and Bioenergy, 19(250): 245-258.

Hartemink, A.E, Buresh RJ, Jama B, and Janssen, B.H. 1996. Soil nitrate and water dynamics in sesbania fallows, weed fallows and maize. Soil Sci. Soc Am J 60:568–574.

Hertel, D., Moser, G., Culmsee, H., Erasmi, S., Horna, V., Schuldt, B. and Leuschner, C. 2009. Below and above ground biomass and net primary production in a paleotropical natural forest (Sulawesi, Indonesia) as compared to neotropical forests. Forest Ecology and Management, 258: 1904-1912.

Hikmat, A. 2005. Biomass estimation, carbon storage and energy content of three virgin jungle reserves in Peninsular Malaysia. Media Konservasi, 10(2): 1-8.

Houghton, J., 1997. Global Warming: The Complete Briefing, second edi. Cambridge University Press, Cambridge

Houghton, R.A. 1996. Land-use change and terrestrial carbon: the temporal record. In: M.J. Apps & D.T. Price (eds.) Forest Ecosystems, Forest Management and the Global Carbon Cycle. Springer-Verlag, Berlin, Heidelberg, New York.

Glenday, J. 2006. Carbon storage and emissions offset potential in an East African tropicalRainforestForestEcologyandManagement, 235: 72–83

Gunatilleke C.V.S. 2009. Estimation of above ground biomass of a *Pinus caribaea* Morelet stand in lower Hantana. Natn. Sci. Foundation Sri Lanka, 37 (3):195-201.

Gundimeda, H. 2011. *Accounting for carbon in the National Accounting Framework: A note on Methodology*. Issue paper prepared for: UNSD, EEA, World Bank Expert Group Meeting on Experimental Ecosystem Accounts London, UK.

Josheph, S., Reddy, C.S., Pattanaik, C. and Sudhakar, S. 2008. Distribution of plan communities along climatic and topographic gradients in Mudumalai Wildlife Sanctuary (southern India). Biological Letter, 45: 29-41.

Joshi, N.R., Tewari, A. and Chand, D.B. 2013. Impact of forest fire and aspect on Phytosociology, tree biomass and carbon stock in Oak and Pine mixed forests of Kumaun central Himalaya, India. Researcher, 5(3): 1-8.

Jackson, M.L., 1958. Soil Chemical Analysis: Prentice-Hall, New Jersey, pp.498.

Piper, C.S. 1950. Soil and Plant Analysis. Inter science, New York

Gibbs, H. K., Brown, S., Nilesand, J. O. and Foley, J. A. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environmental Research Letter 2**:** 1–13.

Kauffman, J.B., Hughes, R.F. and Heider, C. 2009. Carbon pool and biomass dynamics associated with deforestation, land use and agricultural abandonment in the neotropics. Ecological Application, 19(5): 1211-1222.

Kaur, B., Gupta, S.R. and Singh, G. 2002. Carbon storage and nitrogen cycling in silvopastoralsystems on a sodic soil in northwestern India. Agroforestry Systems, 54: 21–29.

Khurana, P. 2012. A study on carbon sequestration in natural forests of India. Journal of Applied and Natural Science 4 (1): 132-136 (2012).

Kittur, B. H., and Bargali, S.S. 2013. Perspectives of agroforestry: present and future facets. Journal of Progressive Agriculture, 4(2).

Kumar, B. M. 2006. Agroforestry: the new old paradigm for Asian food security. Review/synthesis. Journal of Tropical Agriculture 44 (1-2): 1-14.

Kumar, J.I.N., Kumar, R.N., Kumar, R.B. and Sajish, P.R. 2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Tropical Ecology, 51(2): 273- 279.

Lal, R. 2004. Soil Carbon Sequestration In India. Climatic Change, Kluwer Academic Publishers. Printed in the Netherlands, 65: 277–296.

Madguni, O., and Singh, D. N. 2013. Potential of Forest Biomass for Energy Conversio International Journal of Research in Applied, Natural and Social Sciences, 1 (1): 53-58.

Misra, R.1968. Ecology Work Book. Oxford and IBH Publ. Co., Calcutta.

Mugendi, D.N. and Nair, P.K.R. 1997. Predicting the decomposition patterns of tree biomass in tropical highland microregions of Kenya. Agroforestry System 35: 187–201.

Munoz, E. and Beer, J. 2001. Fine root dynamics of shaded cacao plantations in Costa Rica. Agroforestry System, 51: 119–130.

Murali, K.S., Bhat, D.M. and Ravindranath, N.H. 2005. Biomass estimation equations for tropical deciduous and evergreen forests. International Journal of Agricultural Resources, Governance and Ecology, 4(1): 81-92. 230.

Murthy, I.K., Gupta, M., Tomar, S., Munsi, M., Tiwari, R., Hedge, G.T., and Rabindranath, N.H. 2013. Carbon sequestration potential of agroforestry systems in India. J. Earth Science and Climate Change, 4: 131.

Nair, P.K.R. 1993. Introduction to Agroforestry. Kluwer, Dordrecht,The Netherlands.

Nair, P.K.R. 2012. Climate change mitigation and adaptation: A low hanging fruit of Agroforestry. *National workshop on Carbon sequestration in Forest and Non Forest ecosystem*. Published in Department of Forestry, JNKVV, Jabalpur (M.P) - February 16- 17, 2015.

National Academy of Sciences.1980. *Firewood crops; shrubs and tree species for energy production (Vol. I & II).* National Academy Press, Washington, D.C. pp. 237.

Navar, J. 2011. The spatial distribution of aboveground biomass in tropical forests of Mexico. Tropical and Subtropical Agro ecosystems, 13: 149-158.

Nelson, B.W., Mesquita, R., Pereira, J.L.G., Souza S.G.A.D., Batista, G.T., Couto, L.B. 1999. Allometric regressions for improved estimate of secondary forest biomass in the central Amazon Forest Ecology and Management. 117: 149-167.

Nizalapur, V., Jha, C.S. and Madugundu, R. 2010. Estimation of above ground biomass in Indian tropical forested area using multi-frequency DLR-ESAR data. International Journal of Geomatics and Geosciences, 1(2): 167-178.

Nowak, D.J., Greenfield, E.J., Hoehn, R.E. and Lapoint, E. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution, 178: 229-236.

Pal, S. K. 1982. Statistical Techniques. A basic approach to Geography. Tata Mc Graw-Hill publishing company Limited.

Pandey, C.B., Pandya, K.S., Pandey, D., Sharma, R.B. 1999. Growth and productivity of rice (*Oryza sativa*) as affected by *Acacia nilotica* in a traditional agroforestry system, International Society for Tropical Ecology 40(1): 109-117.

Pandey, C.B., Singh, A.K. and Sharma, D.K. 2000. Soil properties under *Acacia nilotica* trees in a traditional agroforestry system in central India. Agroforestry Systems, 49: 53–61, 2000.

Pandey, C.B. and Sharma, D.K. 2003. Residual effect of Nitrogen on rice productivity following tree removal of *Acacia nilotica* in a traditional agroforestry system in Central India. Agriculture, Ecosystems and Environment 96 :133-139.

Paoli, G.D., Curran, L.M. and Silk, J. W. F. 2008. Soil nutrients affect spatial patterns of aboveground biomass and emergent tree density in southwestern Borneo. Oecologia, 155: 287–299.

Piper, C. S. 1967. Soil and plant analysis. Asian publishing House, Bombay, New Delhi 85-102.

Prasad, J. V. N. S., Srinivas, K., Rao, Ch.S., Ramesh, Ch., Venkatravamma, K. and Venkateswarlu, B. 2012. Biomass productivity and carbon stocks of farm forestry and agroforestry systems of leucaena and eucalyptus in Andhra Pradesh, India. Current Science, 103(5).

Rai, S.N. 1984. Bole, branch, current year twig, leaf and root biomass production in tropical rain (wet evergreen) forests of Western Ghats of Karnataka. Indian Forester, 110(9): 901-913.

Ramachandran, A., Jayakumar S., Haroon, R. M.,.Bhaskaran, A., Arockiasamy, D. I. 2007. Carbon Sequestration:estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. Current Science, 92(3).

Rawat, V.R.S. 2010. Reducing emissions from deforestation in developing countries (REDD) and REDD Plus under the UNFCC negotiations, research Note. Indian Forester, 136(01).

Rizvi, R. H., Dhyani, S. K., Yadav, R. S. and Singh, R. 2011. Biomass production and carbon stock of poplar agroforestry systems in Yamunanagar and Saharanpur districts of northwestern India Current Science, 100(5).

Samra, J.S., Singh, S.C., (2000) Silvopasture systems for soil,water and nutrient conservation on degraded land of Shiwalik foothills (Sub tropical northern India). Indian journal of soil conservation 28:35-42.

Sathaye, J., Shukla, P.R. and Ravindranath, N.H. 2006. Climate change, sustainable development and India: Global and national converns, Current Science. 90(3): 314-325.

Singh, G. and Singh, N.T. 1997. Effect of land use practices on organic carbon dynamics of sodic soils. In: Lal R, Kimble J and Follett R (eds) Soil Properties and Their Management for Carbon Sequestration. USDA-Natural Resources Conservation Service, National Soil Survey Centre 129-133, 89–105.

Singh, H., Pathak, P., Kumar, M. and Raghubanshi, A.S. 2011. Carbon sequestration potential Indo-Gangetic agro ecosystem soils. InternationalSociety for Tropical Ecology 52(2): 223-228.

Singh, B., Tripathi, K.P. and Singh, K. 2011. Community structure, diversity, biomass and net production in a rehabilitated subtropical forest in north India. Open Journal of Forestry, 1(2): 11-26.

Singh, K.P. and Mishra, R. 1979. Structure and Functioning of Natural, Modified and Silvicultural Ecosystems of Eastern Uttar Pradesh. Final Technical Report (1975-1978). MAB Research Project. Banaras Hindu University, India.

Singh, L. and Singh, J.S. 1991. Species structure, dry mater dynamics and carbon flux of a dry tropical forest in India. Annals of Botany, 68: 263-273.

Singh, L. and Singh, J.S. 1993. Importance of short-lived components of a dry tropical forest for biomass production and nutrient cycling. Journal of Vegetation Science, 4: 681-686.

Singh, G. and Singh, B. 2002. Changes in soil properties and foliage nutrient composition in different age classes of *Eucalyptus camaldulensis* plantation. Journal of Tropical Forest Science, 14(3): 346-356. 230.

Singh, J.S. 2002. The biodiversity crisis: a multifaceted review. Current Science, 82:638-647.

Singh, J.S. and Kashyap, A.K. 2007. Variations in soil N-mineralization and nitrification in seasonally dry tropical forest and savanna ecosystems in Vindhyan region, India. Tropical Ecology, 48(1): 27-35.

Singh, L. 2010. Impact of Land Use on Vegetation and Soil Carbon, Net Primary Productivity and Nitrogen Budget in Tropical Dry Deciduous Forest of Barnawapara Sanctuary. Final Technical Report . MoEF Research Project. Indira Gandhi Agricultural University, India.

Singh, L., Ghosh, L., Bargali, S.S. and Saxena, R.R. 2008. Influence of Naturally occuring trees on bunds and their impacts on yield parameters of Paddy Crops.Range Mgmt.and Agroforestry 29 (2):134-137.

Singh, L., Yadav, D.K., Pagare, P., Lekha, G. and Thakur, B.S. 2009. Impact of land use changes on species structure, biomass and carbon storage in tropical deciduous forest and converted forest. International Journal of Ecology and Environmental Sciences, 35(1): 113-119.

Srivastava, S.C., Jha, A.K. and Singh, J.S. 1989. Changes with time in soil biomass C, N and P of mine spoils in a dry tropical environment. Canadian Journal of Soil Science, 69: 849-855.

Swamy, S. L. and Mishra, A. 2014. Comparison of Biomass and C Storage in Three Promising Fast Growing Tree Plantations under Agroforestry System in Sub-humid Tropics of Chhattisgarh, India Universal Journal of Agricultural Research, 2(8): 284-296.

Swamy, S.L. and Puri, S. 2005. Biomass production and C-sequestration of *Gmelina arborea* in plantation and agroforestry system in India. Agroforestry Systems, 64: 181–195.

Swamy, S.L., Dutt, C.B.S., Murthy, M.S.R., Mishra, A. and Bargali, S.S. 2010. Floristic and dry matter dynamics of tropical wet evergreen forests of Western Ghats, India. Current Science, 99(3): 253-264.

Swank, W.T. and Schreuder, H.T. 1974. Comparison of three methods of estimating surface area and biomass for a forest of young eastern white pine. Forest Science, 20: 91-100.

Takimoto, A. 2007. Carbon sequestration potential of agroforestry systems in the West African sahel: an assessment of biological and socioeconomic feasibility. A dissertation presented to the graduate school of the university of florida in partial fulfillment of the requirements for the degree of doctor of philosophy university of florida.

Tiwari, A.K. 1994. Mapping forest biomass through digital processing of IRS- 1A data. International Journal of Remote Sensing, 15(9): 1849-1866.

Toky, O.P., Beniwal, R.S. and Sharma, P.K. 1994. Interaction between Rhizobium inoculation and nitrogen fertilizer application on growth and nodulation of Acacia nilotica subsp. indica. J. Arid Environ. 27, 49-54.

Toky, O.P. and Bisht, R.P. 1992. Observations on the rooting pattern of some agroforestry trees in an arid region of north-western India. Agroforestry systems. 15: 41- 59.

Tyagi, K., Sharma, S.D. and Tyagi, P. 2009. Development of biomass and productivity in an age series of *Dalbergia sissoo* plantation in sodic lands of Uttar Pradesh. Annals of Forestry, 17(2): 219-233.

Ullah, M.R. and Al-Amin, M. 2012. Above and below ground carbon stock estimation in a natural forest of Bangladesh. Journal of Forest Science, 58(8): 372-379.

Upadhyay, A. P. 2016. Yield Potential of Crops in relation to 'Changed Climate' Scenario. International Journal of Science, Environment and Technology, Vol. 5, No 2, 2016, 374 – 379.

Verma, K.S., Kumar, S. and Bhardwaj, D.R. 2008. Soil organic carbon stocks and carbon sequestration potential of agroforestry systems in H.P. Himalaya Region of India. Journal of Tree Sciences, 27 (1): 14-27.

Viswananth, S., Kaushik, P.K., Pandey, D.K., and Sahai, A. 1998. Effects of *Acacia nilotica (L)* willd ex. Del. On Rainfed Rice crop in Chhatisgarh, Madhya Pradesh. 6 (1):103-109.

Viswanath, S., Nair, P.K.R., Kaushik, P.K. and Prakasam, U. 2000. *Acacia nilotica* trees in rice fields: A traditional agroforestry system in central India. Agroforestry Systems, 50: 157–177.

Wani, A.A., Joshi, P.K., Singh, O. and Pandey, R. 2012. Carbon Sequestration Potential of Indian Forestry Land Use Systems - A Review Nature and Science, 10 (12)

Watson, R., Nobe, I.R., Bolin, B., Ravindranath, N.H., Verado, D.J. and Dokken, D.J. 2000. *IPCC Special Report on Land Use, Land-Use Change and Forestry*. Cambridge University Press, Cambridge.

Wicke, B., Smeets, M.W., Akanda, R., Stille, L.,. Singh, R.K., Awan, A. R., Mahmood, K., Faaij, A.P.C. 2013. Biomass production in agroforestry and forestry systems on salt- affected soils in South Asia: Exploration of the GHG balance and economic performance of three case studies Journal of Environmental Management.

Wu, Jinshui. 2010. Carbon sequestration in paddy ecosystems in subtropical China. Institute of Subtropical Agriculture, the Chinese Academy of Sciences, Changsha, China.*19th World Congress of Soil Science, Soil Solutions for a Changing World*. Brisbane, Australia, 1 – 6 August 2010.

Yadav, R. P., Bisht., J. K., Pandey, B. M. 2015. Above ground biomass and carbon stock of fruit tree based land use systems in Indian Himalaya The Ecoscan 9(3&4): 779-783, 2015. An international quarterly Journal of Environmental Sciences.

Yao, M.K., Angui, P.K.T., Konate, S., Tondoh, J.E., Tano, Y., Abbadie, L. and Benest, D. 2010. Effects of land use types on soil organic carbon and nitrogen dynamics in Mid-West Cote d'Ivoire. European Journal of Scientific Research 40(2): 211-222.

Young, A. 1997. Agroforestry for soil management, 2nd edn. *CAB International, Wallingford, and International Council for Research in Agroforestry*, Nairobi, pp. 320.

Zhou, X. and Hemstrom, M.A. 2009. Estimating Aboveground Tree Biomass on Forest Land in the Pacific Northwest: A Comparison of Approaches. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Pp. 18.

Appendix A:

Mean value of monthly meteorological parameters during the period of experiment (2015- 16)

Month	Temperature (^0C)		Relative Humidity (%)		Wind Speed (Kmph)	Sunshine (hr)	Rainfall (mm)
	Max.	Min.	Max.	Min.			
August 2015	31.30	25.2	91.12	73.70	7.01	3.64	8.62
September 2015	32.20	25.10	93.10	65.50	4.40	5.80	7.30
October 2015	33.30	22.30	90.80	46.90	2.70	7.90	0.00
November 2015	31.28	17.15	88.83	36.73	2.76	8.01	0.00
December 2015	29.03	14.92	84.67	38.80	2.62	5.19	0.44
January 2016	28.78	11.74	86.93	34.09	2.64	7.19	0.00
February 2016	32.76	17.71	75.06	35.68	3.18	6.49	0.01
March 2016	35.95	20.64	69.67	26.09	4.13	7.85	0.11
April 2016	41.83	25.88	49.40	17.80	6.17	9.05	0.42
May 2016	38.65	30.32	50.67	23.64	6.99	8.76	0.85

APPENDIX - B

Allometric relationship between the log dry weight (kg) of different components (Y) on log girth (X, cm) for trees in natural forests (Based on Singh, K.P. and Misra , R. 1979). All equations are of the form Log Y = a+ b log X.

Species	component	Correlation coefficient r	intercept log a	slope b	Standard error of estimate (SEE)	Standard error of b (SE of b)
Anogeissus	Bole	0.9977	-1.8132	2.0630	0.0346	0.0304
latifolia	Branch	0.9970	-2.4915	2.6983	0.0523	0.0460
(n=23)	Leaf	0.9798	-3.2713	2.4708	0.1251	0.1100
	Root	0.9938	-2.3785	2.2849	0.0635	0.0558
	Total	0.9979	-1.8287	2.4177	0.0391	0.0344
Diospyros	Bole	0.9961	-2.3639	2.4012	0.0498	0.0486
melanoxylon	Branch	0.9941	-3.7528	3.1466	0.0805	0.0785
(n=21)	Leaf	0.9678	-2.7088	1.9890	0.1217	0.1186
	Root	0.9923	-2.5205	2.2442	0.0659	0.0643
	Total	0.9988	-2.2359	2.5331	0.0289	0.0282
Buchanania	Bole	0.9957	-2.3043	2.3252	0.0567	0.0459
lanzan	Branch	0.9929	-4.6363	3.6077	0.1140	0.0923
(n=24)	Leaf	0.9858	-2.9857	2.2339	0.1000	0.0810
	Root	0.9976	-2.6984	2.2529	0.0413	0.0334
	Total	0.9952	-2.4411	2.6143	0.0679	0.0549
Pterocarpus	Bole	0.9937	-2.1871	2.3169	0.0632	0.0597
marsupium	Branch	0.9936	-3.3958	2.9497	0.0814	0.0769
(n=21)	Leaf	0.9916	-2.3706	1.7609	0.0558	0.0527
	Root	0.9754	-2.9550	2.4184	0.1326	0.1253
	Total	0.9969	-2.1540	2.4860	0.0474	0.0448
Phyllanthus	Bole	0.9970	-2.2675	2.3179	0.0436	0.0415
emblica	Branch	0.9914	-3.1576	2.8571	0.0910	0.0867
(n=21)	Leaf	0.9910	-2.2645	1.7667	0.0574	0.0547

	Root	0.9964	-2.1898	2.0283	0.0417	0.0397
	Total	0.9987	-2.0281	2.4227	0.0297	0.0283
Flaourtia	Bole	0.9850	-2.0747	2.2774	0.0818	0.1106
ramontchi	Branch	0.9939	-2.7468	2.7141	0.0617	0.0833
(n=15)	Leaf	0.9902	-2.6635	2.0118	0.0583	0.0788
	Root	0.9898	-2.5309	2.2709	0.0671	0.0907
	Total	0.9940	-1.9179	2.4300	0.0548	0.0740
Lagerstroemia	Bole	0.9957	-2.2277	2.2908	0.0492	0.0534
parviflora	Branch	0.9898	-2.9451	2.6849	0.0888	0.0964
(n=18)	Leaf	0.9853	-2.7657	2.0988	0.0840	0.0911
	Root	0.9920	-3.0475	2.5876	0.0758	0.0822
	Total	0.9965	-2.0908	2.4470	0.0472	0.0512
Saccupetalum	Bole	0.9933	-2.4161	2.5060	0.0657	0.0810
tomentosum	Branch	0.9937	-3.9360	3.2905	0.0838	0.1033
(n=24)	Leaf	0.9936	-2.7398	2.0922	0.0536	0.0660
	Root	0.9957	-3.1304	2.6249	0.0549	0.0676
	Total	0.9972	-2.4028	2.6826	0.0456	0.0561
Ggrewia	Bole	0.9925	-2.4946	2.4910	0.0723	0.0768

Species	component	Correlation coefficient r	intercept log a	slope b	Standard error of estimate (SEE)	Standard error of b (SE of b)
tiliaelfolia	Branch	0.9661	-2.7396	2.6410	0.1660	0.1764
(n=18)	Leaf	0.9910	-2.3512	1.8503	0.0590	0.0626
	Root	0.9977	-2.6802	2.3433	0.0371	0.0394
	Total	0.9893	-2.0260	2.4495	0.0852	0.0905
Eriolaena	Bole	0.9932	-2.8174	2.7104	0.0579	0.1004
hookeriana	Branch	0.9880	-3.4809	3.1303	0.0893	0.1548
(n=12)	Leaf	0.9927	-2.3127	1.7989	0.0400	0.0693
	Root	0.9855	-2.8021	2.4096	0.0758	0.1314
	Total	0.9969	-2.4665	2.7390	0.0395	0.0685
Acacia catechu	Bole	0.9938	-2.0973	2.3131	0.0508	0.0819
(n=12)	Branch	0.9906	-3.1626	2.9565	0.0800	0.1290
	Leaf	0.9822	-2.2882	1.6889	0.0634	0.1022
	Root	0.9920	-2.1735	2.0756	0.0518	0.0835
	Total	0.9949	-1.9235	2.4333	0.0482	0.0777
‘Other	Bole	0.9874	-2.1725	2.2880	0.0842	0.0260
species’(Total of	Branch	0.9569	-3.2888	2.9420	0.2051	0.0635
all species)	Leaf	0.9678	-2.6977	2.0403	0.1219	0.0377
(n=200)	Root	0.9697	-2.0645	2.2913	0.1327	0.0410
	Total	0.9844	-2.0854	2.4750	0.1015	0.0314
Tectona grandis	Bole	0.9950	-2.3687	2.3636	0.0520	
(n=15)	Branch	0.9900	-3.2713	2.6579	0.0850	
	Leaf	0.9960	-2.8054	2.2401	0.0430	
	Root	0.9540	-2.2276	2.0172	0.1450	
	Total	0.9940	-1.9663	2.3001	0.0560	

n = no. of trees felled.

APPENDIX-C

Biomass Estimation

Serial No	Field-1 Replication	Biomass of Paddy Fresh weight	Dry Weight in (gm)	In gm/m2	In t/ha
1	R-1	168.1	149.6	598.4	5.984
2	R-2	275.1	157.6	630.4	6.304
3	R-3	332.1	234.1	936.4	9.364
4	R-4	375.1	245.6	982.4	9.824
5	R-5	432.1	322.6	1290.4	12.904
6	R-6	568.6	336.1	1344.4	13.444
7	R-7	471.1	288.6	1154.4	11.544
8	R-8	368.1	313.1	1252.4	12.524
9	R-9	268.1	215.1	860.4	8.604
10	R-10	349.6	205.6	822.4	8.224
				AVERAGE	9.872
		S.D	2.67108301		
		STANDARD ERROR	0.845279433		

Serial No	Field-2 Replication	Biomass of Paddy Fresh Weight	Dry Weight	In gm/m2	In t/ha
1	R-1	107.1	100.6	402.4	4.024
2	R-2	80.6	46.6	186.4	1.864
3	R-3	195.1	146.1	584.4	5.844
4	R-4	310.1	202.1	808.4	8.084
5	R-5	355.6	188.1	752.4	7.524
6	R-6	374.6	249.1	996.4	9.964
7	R-7	298.1	194.6	778.4	7.784
8	R-8	138.6	90.6	362.4	3.624
9	R-9	320.1	219.1	876.4	8.764
10	R-10	277.1	166.1	664.4	6.644
				AVERAGE	6.412
		S.D		2.551674	
		STANDARD ERROR		0.8074918	

Serial No	Field-3 Replication	Biomass of the Paddy Fresh Weight	Dry Weight	In gm/m2	In t/ha
1	R-1	158.6	118.1	472.4	4.724
2	R-2	311.6	192.1	768.4	7.684
3	R-3	456.1	258.6	1034.4	10.344
4	R-4	307.1	211.6	846.4	8.464
5	R-5	255.6	137.6	550.4	5.504
6	R-6	317.6	244.1	976.4	9.764
7	R-7	241.6	177.6	710.4	7.104
8	R-8	137.6	116.1	464.4	4.644
9	R-9	358.1	219.6	878.4	8.784
10	R-10	325.1	213.1	852.4	8.524
				AVERAGE	7.554
		S.D	2.023445906		
		STANDARD ERROR	0.640330983		

Serial No	Field-4 Replication	Biomass of the Paddy Weight of the sample	Dry Weight	In gm/m2	In t/ha
1	R-1	306.6	201.1	804.4	8.044
2	R-2	564.1	301.6	1206.4	12.064
3	R-3	353.1	191.1	764.4	7.644
4	R-4	337.1	231.1	924.4	9.244
5	R-5	343.1	168.6	674.4	6.744
6	R-6	221.1	168.1	672.4	6.724
7	R-7	249.1	166.6	666.4	6.664
8	R-8	327.1	216.1	864.4	8.644
9	R-9	113.6	76.1	304.4	3.044
10	R-10	199.1	126.6	506.4	5.064
				AVERAGE	7.388
		S.D	2.427487041		
		S.E.	0.768192102		

Serial No	Field-5 Replication	Biomass of the Paddy Fresh Weight	Dry Weight	In gm/m2	In t/ha
1	R-1	236.1	156.1	624.4	6.244
2	R-2	369.6	223.1	892.4	8.924
3	R-3	239.6	154.6	618.4	6.184
4	R-4	153.1	119.1	476.4	4.764
5	R-5	214.6	128.6	514.4	5.144
6	R-6	300.6	180.1	720.4	7.204
7	R-7	415.6	268.6	1074.4	10.744
8	R-8	255.6	172.1	688.4	6.884
9	R-9	331.6	228.6	914.4	9.144
10	R-10	275.6	183.1	732.4	7.324
				AVERAGE	7.256
		S.D	1.870904713		

Serial No	Field-6 Replication	Biomass of the Paddy Fresh Weight	Dry Weight	In gm/m2	In t/ha
1	R-1	363.1	183.1	732.4	7.324
2	R-2	217.6	133.6	534.4	5.344
3	R-3	232.6	134.1	536.4	5.364
4	R-4	300.1	172.1	688.4	6.884
5	R-5	201.6	142.6	570.4	5.704
6	R-6	185.6	137.1	548.4	5.484
7	R-7	352.1	198.6	794.4	7.944
8	R-8	216.6	163.1	652.4	6.524
9	R-9	225.1	166.6	666.4	6.664
10	R-10	201.6	122.6	490.4	4.904
				AVERAGE	6.214
		S.D	0.997830981		
		STANDARD ERROR	0.315769298		

FIELD	AVERAGE BIOMASS	50%	Biomass	Crop Biomass in tons/ha
F1	9.872	50	493.6	4.936
F2	6.412	50	320.6	3.206
F3	7.554	50	377.7	3.777
F4	7.388	50	369.4	3.694
F5	7.256	50	362.8	3.628
F6	6.214	50	310.7	3.107

FIELD	AVERAGE BIOMASS	50%	Biomass	CROP BIOMASS
F1	3.16	50	158	1.58
F2	2.038	50	101.9	1.019
F3	2.554	50	127.7	1.277
F4	2.342	50	117.1	1.171
F5	2.486	50	124.3	1.243
F6	1.646	50	82.3	0.823

APPENDIX D. Tree Biomass

Girth Class	Mid Value	BOLE Mid Girth Biomass	No of Tree	Total Biomass of all trees
20-40	30	16.1101	4	64.4404
40-60	50	51.8203	2	103.6404
60-80	70	111.8922	4	447.5688
80-100	90	198.9298	5	994.649
100-120	110	314.7023	2	629.4046
120-140	130	461.4238	1	461.4238
140-160	150	639.8821	1	639.8821
			SUM =	**3341.0091**

Girth Class	Mid Value	BRANCH Mid Girth Biomass	No of Tree	Total Biomass of all trees
20-40	30	11.3972	4	45.5888
40-60	50	51.2035	2	102.407
60-80	70	137.7526	4	551.0104
80-100	90	288.6689	5	1443.3445
100-120	110	520.8348	2	1041.6696
120-140	130	851.53	1	851.53
140-160	150	1296.8806	1	1296.8806
				5332.4309

Girth Class	Mid Value	LEAF Mid Girth Biomass	No of Tree	Total Biomass of all trees
20-40	30	2.0701	4	8.2804
40-60	50	5.8681	2	11.7362
60-80	70	11.6573	4	46.6292
80-100	90	19.4715	5	97.3575
100-120	110	29.3156	2	58.6312
120-140	130	41.2287	1	41.2287
140-160	150	55.195	1	55.195
				319.0582

Girth Class	Mid Value	ROOT Mid Girth Biomass	No of Tree	Total Biomass of all trees
20-40	30	6.0242	4	24.0968
40-60	50	19.4133	2	38.8266
60-80	70	41.9662	4	167.8648
80-100	90	74.662	5	373.31
100-120	110	118.2224	2	236.4448
120-140	130	173.3803	1	173.3803
140-160	150	240.6024	1	240.6024
				1254.5257

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