Effect of field bund plantation of nitrogen fixing trees on soil and rice crop

A Thesis submitted to the
Orissa University of Agriculture and Technology
in Partial fulfilment of the Requirements for the Degree of Master of Science in Forestry
(Silviculture and Agroforestry)

By

Ashutosa Pattanayak

Adm. No. 05SAF/16

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

BHUBANESWAR-751003

2018

ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
DEPARTMENT OF SILVICULTURE AND AGROFORESTRY
COLLEGE OF FORESTRY
BHUBANESWAR-751003

Dr. A.K.Mohapatra
Professor
Department of
Agronomy College of
Agriculture

Bhubaneswar
Date:

CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of field bund plantation of nitrogen fixing trees on soil and rice crop"** submitted in partial fulfilment of the requirement for the award of degree of **MASTER OF SCIENCE IN FORESTRY (SILVICULTURE AND AGROFORESTRY)** to the Orissa University of Agriculture and Technology is a faithful record of bonafide and original research work carried out by **ASHUTOSA PATTANAYAK** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

(A.K. Mohapatra)
CHAIRMAN
ADVISORY COMMITTEE

ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

BHUBANESWAR-751003

CERTIFICATE – II

This is to certify that the thesis entitled **"Effect of field bund plantation of nitrogen fixing trees on soil and rice crop"** submitted by **ASHUTOSA PATTANAYAK** to the Orissa University of Agriculture and Technology, Bhubaneswar in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN FORESTRY (SILVICULTURE AND AGROFORESTRY)** has been approved by the students' advisory committee and the external examiner.

Advisory Committee
Chairman

Dr. A. K. Mohapatra
Professor
Dept. of Agronomy
College of Agriculture, OUAT ________________________

Members

1. **Dr. M. M.Hossain**
   Dean
   College of Forestry, OUAT ________________________

2. **Dr. P. J. Mishra**
   Professor (Agronomy) &
   Joint Director Extension, OUAT ________________________

3. **Sri B.B.Behera**
   Jr. Scientist (Soil Science)
   AICRP on IFS, OUAT ________________________

____

External Examiner **(Name and Designation)**

ACKNOWLEDGEMENT

It is a happiest moment for me as I am expressing my hearty thanks to all those people for whom I could able to complete this endeavor of my life. I am deeply indebted to all of them for their indispensable assistance and encouragement for timely completion of my report.

First of all, I ascribe all success to the gracious lord almighty for his heartfelt benediction and silent blessing which always act as my savior in the face of all sorts of peril and paved the path of my life.

I would like to express my sincere appreciation and deep gratitude to Dr. Ashok Kumar Mohapatra (Chairman of Advisory Committee) for his wise counsel, constant guidance, healthy criticism, constant encouragement, persistent inspiration and various logistic supports throughout the entire post graduate programme and in my completion of research work.

I express my heartily thanks to the honorable Dr. M M. Hossain, Dean, College of Forestry, OUAT, Bhubaneswar for his kind gesture and cordial support provided to me since the inception of the research work.

Grateful appreciation is extended to Dr. Prasannajit Mishra, for providing valuable support, suggestion and comment throughout the thesis work.

My sincere appreciation is also expressed to Mr. Bibhuti Bhusan Behera as a committee member and for his comments that improve the manuscript of this thesis.

I am also extreme thankful to Dr. N. Bhol, Dr. SaswatNayak, Sri. M.C Behera, Sri. R. Kar, Sri. T.L Mohanty and Smt. H Nayak for their concern and timely cooperation in due course of my thesis work. I am also especially thankful to for his constant support and guidance during the course of my research work.

Also thankful to all non-teaching staffs of College of Forestry, OUAT, Bhubaneswar who helped me a lot during my course of study.

I am delighted in acknowledging all my batchmates Soubhagya, Prithvi, Subudhi, Pahad, Rahul, Abhisek, Swagat, juniors and seniors in the campus with whom I have shared every moments of my life including the findings of thesis work.

I specially thank my parents for providing me everything what I wanted in my life. The support and love of my parents cannot be expressed in words. Their continuous zeal during the entire period of this venture made it possible for me to complete this endeavor.

Many have not been mentioned but none is forgotten from my memory.

(ASHUTOSA PATTANAYAK)

Adm. No. 05 SAF/16

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS USED

%	:	Percentage
ha	:	Hectare
q	:	Quintal
m	:	Metre
cm	:	Centimetre
mm	:	Millimetre
ml	:	Millilitre
kg	:	Kilogram
g	:	Gram
^{o}C	:	Degree centigrade
t	:	Tonne
i.e.	:	That is
CD	:	Critical differences
Fig.	:	Figure
GBH	:	Girth at Breastheight
DBH	:	Diameter at Breast Height
BCR	:	Benefit-cost ratio
Et al.	:	Another

ABSTRACT

A study was carried out in Ganjam district of Odisha during July2017-December2017 to study the effect of field bund plantation of nitrogen fixing trees on soil and rice crop. The experiment was carried out in a Randomized Block Design (RBD) with three replications. The experiment comprised of 3 tree species (*Acacia auriculiformis, Acacia mangium, Acacia nilotica*) and 3 distances from the tree species (near the tree base, edge of the canopy and away from canopy). For this trees of 8 years old are selected. The tree component present in the rice field bunds were taken under investigation to access their growth and performance with reference to paddy crop and their effect on paddy crop productivity. The test variety of rice was MTU-1001. Amongst the various tree species present in the rice field bunds, maximum tree height, D.B.H. and G.B.H. were recorded in *Acacia auriculiformis* trees while minimum height was recorded in *Acacia nilotica* trees. Minimum D.B.H. and G.B.H. were recorded in *Acacia nilotica* trees present in the rice field bunds. Increment in heght, DBH and GBH was maximum in case of *Acacia auriculiformis* and minimum in case of *Acacia nilotica*.The pH of soil, OC and available N, P and K status of soil was significantly found higher in rice fields having tree crop in its field bund as compared to controlled condition. N, P, K content, Organic carbon % was found maximum under *Acacia nilotica* and minimum in case of *Acacia auriculiformis* in 0-15cm depth which declined gradual with increase in soil depth. Rice yield was maximum when rice was planted at the end point of crown of *Acacia nilotica* (46.18 Q ha^{-1}) and minimum when planted near the base of Acacia auriculiformis tree. Highest gross return of Rs.70965/ha was obtanined when rice planted from the end point of crown of *Acacia nilotica* plant followed by *Acacia mangium*. Similarly, the net return (35965 Rs/ha) and BCR (2.02) were also maximum with the same treatment. The soil fertility was either maintained or improved at the end of the cropping season indicating sustainability of the system.

INTRODUCTION

Dwindling forest resources and land degradation have led to decline in forest products supply and degraded ecosystems. Farming without supply inputs to the soil diminishes productivity and to sustain soil productivity, addition of residues from biological and non-biological sources is essential. Nitrogen fixation in situ and leaf fall addition are important processes by which nitrogen-fixing trees contribute to soil fertility enhancement. Leguminous plants can produce large amount of biomass, which can release nutrients to increase soil fertility, reduce fertilizer needs and increase crop yields. However, the decomposition rate of different plant residues varies as do their effect on crop yields. Earlier studies conducted on leguminous trees showed that they contributed N 40-300 kg/ha to the soil, depending on the species, climate and soil type. However, precise data on the addition of nutrients to the soil by legumes under tropical conditions are inadequate. This study was to present results from the nutrient addition to the soil through nitrogen fixation by *Acacia mangium, Acacia auriculiformis, Acacia nilotica.*

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same piece of land management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence (Lundgren & Raintree,1982). According to ICRAF "Agroforestry is a practice where woody perennials are deliberately grown on the same land management unit with agricultural crops and or animals in some form of spatial mixture of in temporal sequence" The tree based land-use agroforestry system is an ideal scientific approach in restoring soil fertility and improving its quality in several ways. Agroforestry systems have the potential to reduce erosion and run-off, and to maintain soil organic matter, improve soil physical properties and augment nitrogen fixation and promote efficient nutrient cycling. (Nair, 1984).

Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines shrubs and trees in agriculture and forestry ecosystems to create more diverse, productive, profitable, healthy, ecologically sound, and sustainable land-use systems. In the broadest sense, it encompasses a wide range of production systems, from forest to crop monoculture. In terms of composition, structure, management practices, and production functions, wide variations exist among these systems. Bene*et al.*, 1977 defines it as a suitable land management system that increases total production, combines agricultural crops, tree crops, forest plants and/or animals simultaneously or sequentially and applies management practices compatible with cultural patterns of the local population.

It is recognized as a land-use option in which trees provide both products and environmental services. In agroforestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye,2002).

Intercropping of agroforestry trees with crop plants includes sequential systems, where the trees and crops occupy the same piece of land at different times, and simultaneous systems, where the trees and crops are grown on the same piece of land at the same time. Simultaneous systems can vary greatly in the relative proportions of trees and crops and in their spatial arrangement (Young, 1989).

The emergence of agroforestry as an important land-use activity has raised the issue of agroforestry species. Agroforestry species usually refers to woody species and come to known as “multipurpose trees” (MPTs) or “multipurpose trees and shrubs” (MPTS). Multipurpose trees in agroforestry refer to their use for more than one service or production function in an agroforestry system (Burley and Wood, 1991).

In the present scenario attempts are being made to introduce improved agroforestry practices using indigenous, multipurpose and nitrogen fixing tree species which could be planted in the field bunds to cater positive feedback to the adjoining annual corps. However, there has been a growing realization of the benefits of tree crop integration systems in the coastal areas and since

1980s there is a widespread interest in planting of a new species of *Acacias* that is native to Australia, *Acacia mangium*, popularly known as Australian teak in the farm boundaries as bund plantations, home garden, and permanent fallows. Farmers are also planting and maintaining nitrogen fixing tree species like *Acacia auriculiformis*, *Acacia nilotica* etc along with their agricultural crops as a part of commercial agroforestry.

The presence of nitrogen fixing tree in agroforestry system influences the physico-chemical properties of soil such as physical (B.D., Soil moisture, Texture) and chemical (pH, Organic carbon, available N, P & K). Agroforestry systems have the potential to improve soil organic carbon, nutrients status, promote efficient nutrient cycling, augment soil water availability to crops through its root interaction. There is a great need to identify the suitable agricultural and horticultural crops, which can grow well along with tree species with limited solar energy available underneath the trees.

Acacia mangium is a species of flowering tree in the pea family, Fabaceae that is native to northeastern Queensland in Australia, the Western Province of Papua New Guinea, Papua, and the eastern Maluku Islands. Common names include black wattle, hickory wattle, mangium. It grows up to 30 metres (98 ft), often with a straight trunk. *Acacia mangium* has about 142,000 seeds/kg.

Acacia auriculiformis commonly known as auri, earleaf acacia, earpod wattle, northern black wattle, Papuan wattle, and tan wattle, akashmoni in Bengali, is a evergreen fast-growing, crooked, gnarly tree in the family Fabaceae. It is native to Australia, Indonesia, and Papua New Guinea. It grows up to 30m tall. *Acacia auriculiformis* has about 47 000 seeds/kg. It grows between to 15–30 m tall, with a trunk up to 12 m long and 50 cm in diameter.

Acacia nilotica (commonly known as gum arabic tree, babul, thorn mimosa, Egyptian acacia or thorny acacia) is a tree in the family Fabaceae. It is native to Africa, the Middle East and the Indian subcontinent. *Acacia* *nilotica* is a tree 5–20 m high with a dense spheric crown, stems and branches usually dark to black coloured, fissured bark, grey-pinkish slash, exuding a reddish low quality gum.

Keeping in view the above facts, a study on "**Effect of field bund plantation of nitrogen fixing trees on soil and rice crop"** was undertaken with the following objectives:

1. To study growth of nitrogen fixing tress planted on the rice field bunds.

2. To study the effect of nitrogen fixing trees on physic-chemical parameters of soil.

3. To study the effect of nitrogen fixing tree on rice crop and economics.

REVIEW OF LITERATURE

Past studies pave the way for future research endeavors. An acquaintance with earlier pertinent studies was felt necessary to develop good understanding of the present study. A comprehensive and systematic review of the relevant literature is always a path finder to any research work. These literatures confirm and repudiate research outcomes with all possible reasons.

Several research studies have been conducted to access the several parameters related of tree growth on the rice field bunds. However all attempts have been made to collect relevant research studies as per the objectives framed for the present studies. The relevant literatures on all aspects of the investigation which is having direct or indirect bearing on the study has been organized and presented in this chapter.

Therefore, an attempt has been made in this chapter to review some related literature which has either direct or indirect bearings on these aspects and are presented under the following heads.

2.1 Concept and importance of agroforestry system
2.2 Growth of nitrogen fixing tress planted on the rice field bunds
2.3 Effect of nitrogen fixing trees on physico-chemical parameters of soil
2.4 Effect of nitrogen fixing tree crop yield and economics
2.5 Advantages of agroforestry system

2.1 Concept of agroforestry

Ajit et al. (2010) mentioned that in India, agroforestry practices are very age old but the advent story of organized agroforestry research began in 1979 at Imphal, the capital of Manipur when a seminar on agroforestry was organized by the Indian Council of Agricultural Research (ICAR), New Delhi to accumulate and compile the data pertaining to the research and development of agroforestry in India.

Agroforestry is an ideal land-use option as it optimizes tradeoffs between increased food production, poverty alleviation and environmental conservation (Izac, 2000). Agroforestry also mitigates the demand for wood and reduces pressure on natural forests (Pandey, 2002). India is estimated to have between 14,224 million

(Ravindranath and Hall, 1995) and 24,602 million (Prasad et al., 2000) trees outside forests, spread over an equivalent area of 17 million ha (GOI, 1999) supplying 49% of the 201 million tonnes of fuelwood and 48% of the 64 million cum of timber consumed annually (Rai and Chakrabarti, 2001). Forestry mitigation projects provide an opportunity to promote agroforestry in India.

Main agroforestry practices include improved fallows, taungya (growing annual agricultural crops during the establishment of a forestry plantation), home gardens, alley cropping, growing multipurpose trees and shrubs on farmland, boundary planting, farm woodlots, orchards or tree gardens, plantation/ crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture and apiculture with trees (Nair, 1993; Sinclair, 1999).

Agroforestry is a collective name for land-use systems in which woody perennials such as trees, shrubs and bamboos are grown in association with herbaceous plants such as crops, pasture and/or livestock in spatial or temporal arrangements in which there are both ecological and economic interactions between the tree and non-tree components of the system (Young, 1989). The main components of agroforestry systems are trees, crops, pastures and livestock together with environmental factors of climate, soils and landforms. Essentially there must be interaction between the tree and non-tree portion of the system. Agroforestry also covers biomass transfer of biological material such as incorporation of the leaf litter into the soil or feeding of such litter as browse to livestock with subsequent return to the soil as manure (Young, 1988)

Vergara (1982) defined that agroforestry as a "system of combining agricultural and tree crops of various longevity (ranging from annual through biennial and perennial plants), arranged either temporally (crop rotation) or spatially intercropping to maximize and sustain agricultural production."

2.2 Growth of nitrogen fixing tress planted on the rice field bunds

Acacia mangium is a very fast growing species belonging to the family fabaceae. It has been introduced in plantations in Sarawak, Malaysia for its rapid growth and wide range of adaptability. These plantations are anticipated to play the important roles in maintaining the commercial supply of logs thus reducing timber demand from the natural forests. Many plantations now used genetically improved material whose characters and properties have been improved through many years of research. Thus the study of growth and yield are crucial in order to have a more proper planning and management of this forest resource. This study assessed the growth and yield of the two acacias namely *Acacia mangium* superbulk or *Acacia* superbulk which is actually a second generation A. mangium and Acacia hybrid. The data obtained from permanent sampling plots (PSPs) of DAIKEN Plantation Sdn. Bhd. Bintulu were analysed to determine their mean annual increment (MAI) and periodic annual increment (PAI) in terms of diameter at breast height (DBH) and volume. Survival rate reduced as age of stand increased. Although DBH and height increased in size but the mean annual height and DBH increments decreased with age. The largest mean DBH recorded for Acacia superbulk and Acacia hybrid PSPs were 23.6 and 25.6 cm, respectively. Mean total height measured for *Acacia superbulk* and *Acacia* hybrid PSPs were 32.4 and 30.2 m, respectively. The highest volume mean annual increment was 27.4 m3/ha/yr (6.9 years old) and 26.5 m3/ha/yr (7.4 years old) for *Acacia superbulk* and *Acacia hybrid*, respectively. Initially growth in volume increased then began to decrease from seven years. Results of the four PSPs indicated that the maximum growth in volume per ha was attained at approximately seven years old stands. (Jusoh I *et a.l* 2017)

Time-tested, indigenous land-use systems can provide valuable information for the design of ecologically sustainable and socially acceptable agroforestry systems. One such traditional system is the growing of *Acacia nilotica* (L.) willd. Ex-Delile trees locally known as babula in rice fields of smallholder farmers in Madhya Pradesh State of Central India an area with sub-humid monsoon climate and hot summer. The functional characteristics of the system 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 fuelwood (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). By practising the agroforestry (rice + babul) system, farmers get higher cash returns on a short-term (10-year) harvest cycle of trees, and the labour input (both family- and hired) on farms was distributed more uniformly throughout the year than in rice monoculture. Purchased inputs are seldom used in the system. The ease of management of the system, the self-generating and robust nature of the tree and the multiple products and services it provides, and easy marketability of the products is the major factor that encourages farmers to adopt the system. Furthermore, the farmers have secure ownership rights to their land, so that they are interested in long-term measures such as tree plantings on their farms. In spite of its long history and tradition as a sustainable approach to land use, the system has not attracted the attention of development agencies. More detailed investigations on its social, economic, and cultural attributes are warranted to not only improve this system, but provide insights into farmer adoption of agroforestry innovations.(Viswanath S *et al* 2014)

The experiment was carried out at the Field Laboratory of the Department of Agroforestry, Bangladesh Agricultural University, Mymensingh during the period from September, 2010 to August, 2011 to determine the optimum planting density of *Acacia auriculiformis* for maximization of fuel wood production in the crop field. *Acacia auriculiformis* seedlings were planted following Randomized Complete Block Design (RCBD) with four replications maintaining four different spacing viz., 0.5m, 0.75m, 1m and 1.25m, which were the treatments of this study. Data were collected at every three months interval i.e., 90, 180, 270, and 360 DAP. Growth parameters i.e., plant height, stem base diameter, number of primary and secondary branches and length of primary branches were significantly influenced by different spacing. During initial stage of establishment plant height of seedlings in all treatments were almost significantly similar but after six months i.e., 180 DAP plant height gradually decreased with increasing spacing of plantation. Reverse relationship was found between height and diameter growth of the plants. After six months of plantation, number of primary branch per plant gradually decreased and number of secondary branch per plant gradually increased with increasing planting density. Length of primary branch of Akashmoni was gradually increased with increasing spacing of plantation in every interval of data collection i.e, 90, 180, 270 and 360 DAP. After one year, longest (1.28 m) primary branch was in 1.25m distant plants and shortest (0.64 m) was in 0.5 m distant plant. The amount of phyllode, branch, stem and root per plant was gradually decreased with decreasing planting spacing. Total biomass yield was highest (6.45 kg/plant) in widely planted trees and lowest (3.51 kg/plant) in closely planted trees. Highest amount of weight or moisture lost from wide (1.25 m) spacing or sparsely planted trees and gradually decreased with decreasing spacing. Total yield was higher in plantation of 0.75m spacing which is statistically similar with 0.5m spacing and these were significantly greater than the total yield produced in other spacing (1m and 1.25m). Though total yield almost similar in 0.5m and 0.75m spacing but 0.75m spacing would be better option for getting more PAR interception as well as to minimize competition between tree and crops for growth resources (light, water and nutrients).(Ghosh S.R *et al*. 2011)

A study was conducted 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. 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 (a central line passing from the centre of the tree bole, and right and left to this central straight line) 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.(Bargali SS. *et al* 2009)

A field experiment was carried out at Agricultural Research Station, Mundagod, Karnataka, during 2006-07 to find out suitable management practice to manage bund planted tree to reduce negative tree crop interaction in *Acacia auriculiformis* based agroforestry system. Suitability of the method was assessed based on the growth and yield of black gram. The seed yield of black gram was significantly higher due to tree management practices imposed to *Acacia auriculiformis*. Significantly higher seeds yield was recorded in treatment receiving trenching (730 kg/ha) which was statistically on par with treatment receiving 50 per cent branch pruning (715 kg/ha). Significantly higher seed yield was recorded at 12 to 14 m distance from the tree row (742 kg /ha), which was on par with 10 to 12 m distance from tree row (714 kg /ha). The seed yield of black gram significantly lower with the combination of control and 0 to 2m distances from tree row (Patil and Channabasappa,2008)

Moore (1992) studied that the trees can judiciously contribute to mitigate the problem of salination and degradation in about 21% of agricultural lands of Australia. He further studied that there is potential for trees to also produce wood, thereby diversifying farmers' incomes, reducing Australia's bill for importing wood and increasing exports of wood products. Even though many of these multiple purpose plantings would be widely scattered and growth rates low in some regions, Australian farmers should have a comparative advantage in wood production because trees also provide substantial landcare and agricultural productivity benefits. The establishment of new industries based on wood from farmland requires leadership from Government, planning at national, regional and local levels, and innovative techniques to finance planting.

Several research works suggested that field bund plantations in the Australian environment has potentials to rehabilitate land from further degradation; improve agricultural productivity; produce timber; and contribute to diversification and increase in farm income. These benefits are examined using available information from research. The level of adoption of agroforestry by Australian farmers for these purposes is also determined. Summaries of research results provide the basis for advice that scientists can offer to farmer and decision makers in context of field bund plantations (Prinsley, 1992).

A field experiment was under Division of Social Forestry, Forest Research Institute P.O. New Forest Dehradun-248006 India to find out the influence of single row bund plantation of *Acacia nilotica* var. juquemontii on the growth and yield of associated wheat crop under irrigated conditions in Haryana, India. The indications are that the tree line does affect all crop parameters like height growth, shoot numbers, ear length, grain number and grain yield in the vicinity of trees upto 4 m distance from the tree line and establishes that as the distance from the tree line increases the growth and yield of wheat crop also improves. The effect on wheat crop was found more pronounced in the plots laid out towards the middle of the tree line as compared to plots towards the outer border (Sharma, 1992)

2.3 Effect of nitrogen fixing trees on physico-chemical parameters of soil

Intercropping forest plantations of *Eucalyptus* with nitrogen-fixing trees can increase soil N inputs and stimulate soil organic matter (OM) cycling. However, microbial indicators and their correlation in specific fractions of soil OM are unclear in the tropical sandy soils. Here, we examined the microbial indicators associated with C and N in the soil resulting from pure and intercropped *Eucalyptus grandis* and *Acacia mangium* plantations. We hypothesized that introduction of *A. mangium* in a *Eucalyptus* plantation promotes changes in microbial indicators and increases C and N concentrations on labile fractions of the soil OM, when compared to pure eucalyptus plantations. We determined the microbial and enzymatic activity, and the potential for C degradation by the soil microbial community. Additionally, we evaluated soil OM fractions and litter parameters. Soil (0–20 cm) and litter samples were collected at 27 and 39 months after planting from the following treatments: pure *E. grandis* (E) and *A. mangium* (A) plantations, pure *E. grandis* plantations with N fertilizer (E+N) and an *E. grandis*, and *A. mangium* intercropped plantations (E+A). The results showed that intercropped plantations (E+A) increase 3, 45, and 70% microbial biomass C as compared to A, E+N, and E, at 27 months after planting. The metabolic quotient (qCO2) showed a tendency toward stressful values in pure *E. grandis* plantations and a strong correlation with dehydrogenase activity. A and E+A treatments also exhibited the highest organic fractions (OF) and C and N contents. A canonical redundancy analysis revealed positive correlations between microbial indicators of soil and litter attributes, and a strong effect of C and N variables in differentiating A and E+A from E and E+N treatments. The results suggested that a significant role of *Acacia mangium* enhance the dynamics of soil microbial indicators which help in the accumulation of C and N in soil OF in intercropped *E. grandis* plantations. Our results are mostly relevant to plantations in sandy soil areas with low levels of OM, suggesting and efficient method for improving nutrient availability in the soil and optimizing *Eucalyptus* growth and development. (Pereira APA *et al.* 2018)

Invasions by exotic plants and the establishment of plantations have been associated with the enrichment of nutrients in the soil. The first aim of this study was to examine soil physico-chemical properties of the *Acacia mangium* plantation and the nearby undisturbed heath forest (HF) at the Andulau Forest Resesrve, Sungai Liang, Brunei Darussalam. The second aim was to determine the most influential soil properties that accounted for the most variation in the *Acacia* plantation and HF plots. A total of six pairs of 20 m x 20 m plots were established along two parallel transects (260 m each) in the *Acacia* plantation (6 plots) and the HF (6 plots). Each of the twelve plots was subdivided into four 10 m x 10 m subplots and one soil core (0 – 15 cm depth) was sampled in each subplot. Soil pH, gravimetric water content (GWC), organic matter (OM), organic layer depth, texture and major nutrient concentrations were determined for each soil core. Significantly higher total Calcium concentrations and organic layer depth were found in the soils of the HF than in the *Acacia* plantation. However, the *Acacia* plantation soils had significantly higher total N concentrations than the HF soils. Non-native *A. mangium* trees have the ability to change the soil physicochemical properties to improve their growth. Total Calcium concentration and GWC were the most influential soil properties in the HF, whilst for the *Acacia* plantation plots, pH was most influential. Studying soil properties of both native forests and plantations of exotic species provides insights into how non-native plants change soil properties in ways different from native plant species. (Matali S and Metali F. 2015)

This study was conducted in an industrial *Acacia mangium* plantation in Sarawak, Malaysia, to investigate the effects of planting and harvesting *A. mangium* on soil morphological and physicochemical properties. In *A. mangium* sites, the disruptive effect of planting practices extended to morphological properties in subsoil layers. The A horizon redeveloped during early stages after planting which could be ascribed to plentiful supply of organic matter through rapid decomposition of vegetation residues produced upon land preparation. However, soil C- and N-related properties appeared to decrease with stand age, while the levels of exchangeable bases and available P remained low even after 10 years. In post-harvest sites, distinct soil horizons were not observed due to severe disturbance. The levels of total C, N and exchangeable bases at depth of 0-5 cm for sites assessed 3 years after harvesting were higher than those of sites assessed 1 year after harvesting. This might be ascribed to relatively gradual release of organic matter and nutrients from harvest residues into soil due to low level of decomposition as well as low nutrient uptake of poor vegetation regrowth. (Tanaka S *et al* 2015).

Acacia hybrid (*A. mangium* × *A. auriculiformis*) is the main species planted for short-rotation forestry in Vietnam. In this study, the effect of these plantations on some key properties of degraded gravelly soils in Central Vietnam was assessed. Soil samples were collected from second- or third-rotation plantations representative of five age classes (0.5–5 years old), and in adjacent abandoned lands as controls. Compared with abandoned land, stock of total soil carbon (C) was significantly higher at ages 0.5, 1.5, 2.5 and 5 years (18.4–19.5 v. 13.0 Mg ha–1), total nitrogen (N) at 0.5 and 1.5 years (1.5–1.7 v. 1.0 Mg ha–1), exchangeable calcium at 0.5, 1.5 and 2.5 years (215–294 v. 42 Mg ha–1), magnesium at 0.5, 1.5, 2.5 and 3.5 years (39–48 v. 19 Mg ha–1), and sodium at all ages (46–59 v. 5 Mg ha–1). Electrical conductivity was significantly higher at all ages (58.5–69.4 v. 32.7 µS cm–1). Differences in extractable phosphorus and exchangeable potassium were not significantly different between plantations and abandoned land. Bulk density was significantly lower in plantations than abandoned land at all ages (1.36–1.42 v. 1.55 Mg ha–1), pHCaCl2 at 0.5 and 5 years (3.78–3.84 v. 3.98), and pHH2O at 5 years (4.30 v. 4.52). Because the soils were gravelly, differences in concentration of total C and nutrients between abandoned land and plantations were not the same as those for stocks after correction for gravel content and bulk density. Within a rotation, most soil properties did not change significantly with plantation age, although they appeared to decrease during the first 3 years; total C then recovered to initial levels, but total N and exchangeable cations remained lower. Some soil properties were strongly related to gravel content and elevation, but not to growth rate. We conclude that consecutive plantings of short-rotation *Acacia* hybrid on degraded and abandoned land can lead to changes in some soil properties. (Dong TL *et al* 2013).

Soil microorganisms and microbial processes are influenced by the quality and quantity of plant waste entering the soil, by its seasonal and spatial distribution, by the ratio of above- to below-ground inputs, and by changes in nutrient inputs. Soil management strategies sometimes promote mixed-species plantations to mitigate the loss of soil nutrients and improve biogeochemical cycling. The objective of this study was to explore changes in microbiological and chemical attributes of soils and litter in the early stages of the second rotation of mixed and pure plantations of *Eucalyptus grandis* and *Acacia mangium*, and to look for correlations between attributes. Soil samples at 0–10 cm depth were collected two, seven, 14, and 20 months after planting in the following treatments: monocultures of *A. mangium* and *E. grandis*, a monoculture of *E. grandis* with N-fertilizer, and an intercropped plantation with *E. grandis and A. mangium*. Microbial soil attributes varied dramatically between treatments 20 months after planting. Total C, N and P contents in litter showed the strongest correlations with microbial biomass C and N (Cmic and Nmic), microbial respiration, and dehydrogenase activity in all sampling periods. Lower C/N and C/P ratios in litter and lower C/N and Cmic/tC ratios in soils after 20 months in the intercropped plantation illustrated the system's capacity for supplying inputs of high-quality organic matter rich in N and P, but this did not result in higher contents of these elements or greater microbial activity in soils. An implication of this finding is that, at least in the initial growth phase of these plantations, chemical attributes of the litter and variation in those attributes govern microbial processes and, consequently, are mostly responsible for plant development. Canonical discriminant analysis revealed changes in the microbiological and chemical attributes of soil in the intercropped plantation due to the plants growth and the leaf litter accumulation. Twenty months after planting, the different plantations could be discriminated by differences in litter chemistry (C, N, and P), total soil C, Nmic, and dehydrogenase activity, which were very similar in intercropped plantations and *E. grandis* with N-fertilizer. These results from the early stages of plantation development are important for understanding the dynamics of soil attributes in these systems, and especially in intercropped plantations. In intercropped areas the cumulative effect of microbial attributes reflects a more sustainable system. Long-term studies are needed to identify patterns that develop after 20 months, during the growth period of these plantations. (Bini D *et al* 2012)

Background and aims *Eucalyptus* plantations cover 20 million hectares on highly weathered soils. Large amounts of nitrogen (N) exported during harvesting lead to concerns about their sustainability. Our goal was to assess the potential of introducing *A. mangium* trees in highly productive *Eucalyptus* plantations to enhance soil organic matter stocks and N availability. Methods A randomized block design was set up in a Brazilian Ferralsol soil to assess the effects of mono-specific *Eucalyptus grandis* (100E) and *Acacia mangium* (100A) stands and mixed plantations (50A:50E) on soil organic matter stocks and net N mineralization. Results A 6-year rotation of mono-specific *A. mangium* plantations led to carbon (C) and N stocks in the forest floor that were 44% lower and 86% higher than in pure *E. grandis* stands, respectively. Carbon and N stocks were not significantly different between the three treatments in the 0–15 cm soil layer. Field incubations conducted every 4 weeks for the two last years of the rotation estimated net soil N mineralization in 100A and 100E at 124 and 64 kg ha^{-1} yr^{-1}, respectively. Nitrogen inputs to soil with litterfall were of the same order as net N mineralization. Conclusions *Acacia mangium* trees largely increased the turnover rate of N in the topsoil. Introducing *A. mangium* trees might improve mineral N availability in soils where commercial *Eucalyptus* plantations have been managed for a long time. (Voigtlaender M *et al*. 2012)

This study was conducted to determine soil organic carbon, nitrogen, available phosphorus and pH at 3 soil depths under different ages and cycle of *Acacia mangium* after thinning of planted forest as well as to determine their variability in a tropical forest. Composite soil samples were collected at depths of 0-5, 5-10 and 10-30 cm in each plot and were analyzed for total C, N, P, Ca, Mg and K. Soil C and N were significantly higher at 0-10 cm depth in the 2^{nd} cycle of *Acacia mangium* which were 0-3 months older than the natural forest. Available P decreased in the first rotation of *Acacia mangium* of more than 20 year old stands and in plots which underwent thinning. Soil C, N, P decreased with increasing soil depth. Calcium in leaf litter of more than 20 year old stands was significantly lower than in the other study plots N, P and K concentrations were higher in leaf litter of thinned plots and in more than 20 year old stands.(Vijayanathan J *et al* 2011)

Acacia senegal is a multipurpose drought-tolerant tree or shrub legume and is commonly used in agroforestry systems in sub-Saharan Africa for gum arabic production and soil fertility improvement. Despite its wide distribution in Kenya, there has not been exhaustive evaluation on the effects of the extant varieties (*kerensis, leiorhachis and senegal*) on soil properties under their canopies for sustainable utilization of the species. Three sites in the dry lands of Kenya representing the three varieties were selected for assessment. Soil samples were collected under tree canopies at a depth of 0 to 25 cm and were compared with the soils from the open canopies. There were significant differences in soil physicochemical properties among the three varieties ($P<0.05$ and $P< 0.01$). Soil nutrients under the canopies were higher than in the open canopies mainly due to effects of litter accumulation. The three varieties have beneficial effects on soil nutrient status in their natural ecosystems and would most likely improve crop productivity in agroforestry systems as well as enhance herbage productivity in the rangelands. The varieties growing under different soil types may have an effect on their gum Arabic production and quality.(Githae EW *et al* 2011)

The role of different plantation tree species in soil nutrient cycling is of great importance for the restoration of degraded lands. The objective of the present study was to evaluate the potential of N- fixing and non- N- fixing tree species to recuperate degraded land in southern China. The soil properties and N transformations in six forest types (two N- fixing plantations, three non- N- fixing plantations and a secondary shrubland) established in 1984 were compared. The N- fixing forests had 40–50% higher soil organic matter and 20–50% higher total nitrogen concentration in the 0–5 cm soils than the non- N- fixing forests. Soil inorganic N was highest under the secondary shrubland. The N- fixing *Acacia auriculiformis* plantation had the highest soil available P. There were no significant differences in soil N mineralization and nitrification among the forest types, but seasonal variation in these N processes was highly significant. In the rainy season, the rates of N mineralization (7.41–11.3 kg N ha^{-1} $month^{-1}$) were similar to values found in regional climax forests, indicating that soil N availability has been well recovered in these forest types. These results suggest that N- fixing species, particularly *Acacia mangium* are more efficient in re- establishing the C and N cycling processes in degraded land in southern China. Moreover, the N- fixing species *A. auriculiformis* performed better than other species in improving soil P availability. (Faming WANG. *et al.* 2010)

Acacia plantation establishment might cause soil acidification in strongly weathered soils in the wet tropics because the base cations in the soil are translocated rapidly to plant biomass during *Acacia* growth. We examined whether soils under an *Acacia* plantation were acidified, as well as the factors causing soil acidification. We compared soils from 10 stands of 8-year-old *Acacia mangium* plantations with soils from 10 secondary forests and eight *Imperata cylindrica* grasslands, which were transformed into *Acacia* plantations. Soil samples were collected every 5–30 cm in depth, and pH and related soil properties were analyzed. Soil pH was significantly lower in *Acacia* plantations and secondary forests than in *Imperata* grasslands at every soil depth. The difference was about 1.0 pH unit at 0–5 cm and 0.5 pH unit at 25–30 cm. A significant positive correlation between pH and base saturation at 0–20 cm depth indicated that the low pH under forest vegetation was associated with exchangeable cation status. Using analysis of covariance (ANCOVA), with clay content as the covariate, exchangeable Ca (Ex-Ca) and Mg (Ex-Mg) stocks were significantly lower in forested areas than in *Imperata* grasslands at any clay content which was strongly related to exchangeable cation stock. The adjusted average Ex-Ca stock calculated by ANCOVA was 249 kg ha 1 in *Acacia* plantations, 200 kg ha1 in secondary forests, and 756 kg ha1 in *Imperata* grasslands at 0–30 cm. Based on a comparison of estimated nutrient stocks in biomass and soil among the vegetation types, the translocation of base cations from soil to plant biomass might cause a decrease in exchangeable cations and soil acidification in *Acacia* plantations. (Yamashita N *et al.* 2008)

The sustainability of plantation forests is closely dependent on soil nitrogen availability in short-rotation forests established on low-fertility soils. Planting an understorey of nitrogen-fixing trees might be an attractive option for maintaining the N fertility of soils. The development of mono-specific stands of *Acacia mangium* (100A:0E) and *Eucalyptus grandis* (0A:100E) was compared with mixed-species plantations, where *A. mangium* was planted in a mixture at a density of 50% of that of *E. grandis* (50A:100E). N2 fixation by *A. mangium* was quantified in 100A:0E and 50A:100E at age 18 and 30 months by the 15N natural abundance method and in 50A:100E at age 30 months by the 15N dilution method. The consistency of results obtained by isotopic methods was checked against observations of nodulation, Specific Acetylene Reduction Activity (SARA), as well as the dynamics of N accumulation within both species. The different tree components (leaves, branches, stems, stumps, coarse roots, medium-sized roots and fine roots) were sampled on 5-10 trees per species for each age. Litter fall was assessed up to 30 months after planting and used to estimate fine root mortality. Higher N concentrations in *A. mangium* tree components than in *E. grandis* might be a result of N2 fixation. However, no evidence of N transfer from *A. mangium* to *E. grandis* was found. SARA values were not significantly different in 100A:0E and 50A:100E but the biomass of nodules was 20-30 times higher in 100A:0E than in 50A:100E. At age 18 months, higher d15N values found in *A. mangium* tree components than in *E. grandis* components prevented reliable estimations of the percentage of N derived from atmospheric fixation (%Ndfa). At age 30 months, %Ndfa estimated by natural abundance and by 15N dilution amounted to 10-20 and 60%, respectively. The amount of N derived from N2 fixation in the standing biomass was estimated at 62 kg N ha_1 in 100A:0E and 3 kg N ha_1 in 50A:100E by the 15N natural abundance method, and 16 kg N ha_1 in 50A:100E by the 15N dilution method. The total amount of atmospheric N2 fixed since planting (including fine root mortality and litter fall) was estimated at 66 kg N ha_1 in 100A:0E and 7 kg N ha_1 in 50A:100E by the 15N natural abundance method, and 31 kg N ha_1 in 50A:100E by the 15N dilution method. The most reliable estimation of N2 fixation was likely to be achieved using the 15N dilution method and sampling the whole plant. (Bouillet J.P*et al.* 2012)

A 17- year chronosequence of *Acacia auriculiformis* fallows on Arenosols of the Batéké Plateau (D.R. Congo) was surveyed and compared with virgin savannah soils to assess chemical soil fertility changes induced by these N- fixing trees. Significant increases in organic carbon content, total nitrogen content, cation exchange capacity and sum of base cations were found after relatively short fallow periods of only 4 years and did not only affect the forest floor, but extended to at least 50 cm depth. The *Acacia* act as a major source of organic matter (OM), hence increasing organic carbon and nitrogen content and decreasing the C/N ratio. The increased OM content suggests that humification processes are the main cause of the significant decrease in pH. Total exchangeable cations initially increased slowly but doubled (topsoil 0–25 cm) and tripled (subsoil 25–50 cm) after 10 years. The point of zero net proton charge was systematically lower than soil pH and decreased with increasing OM content, thereby increasing the cation exchange capacity, although concurrent acidification retarded a significant beneficial impact at field pH on *Acacia* fallows of 10 years and older. Although the chemical soil fertility improves steadily with time, after 8 years of *Acacia* fallow the absolute amounts of available nutrients are still small and slash and burn practices are required to liberate the nutrients stored in the remaining biomass and litter before each new cropping period.(Kasongo RK *et al* 2009)

In forest ecosystems, the effects of litter or understory on soil properties are far from being fully understood. We conducted a study in a pure *Acacia mangium* Willd. plantation in southern China, by removing litter or understory or both components and then comparing these treatments with a control (undisturbed), to evaluate their respective effects on soil physical, chemical and biological properties. In addition, a litter decomposition experiment was conducted to understand the effects of understory on litter decomposition. Our data showed that the presence of understory favored litter decomposition to a large extent. In 1 year, 75.2 and 37.2% of litter were decomposed in the control and understory removal treatment (UR), respectively. Litter had a profound significance in retaining soil water and contributing to soil fertility, including organic matter (OM), available phosphorus (P) and alkali-hydrolyzable nitrogen (N), but understory exerted less influence than litter on soil physical and chemical properties. Both litter and understory played an important role in soil biological activity as indicated by microbial biomass carbon (MBC), while there were no significant impacts on soil exchangeable potassium (K) after either or both were removed. Contrary to our hypothesis, the effects of understory or litter removal were not always negative. A significant soil pH increase with litter removal was a positive factor for acid soil in the studied site. Except for soil moisture, significant effects, caused by removal of litter or/and understory, on measured soil chemical characteristics were only observed in the top 10 cm soil layer, but not in the 10–20 cm layer. Soil available P and exchangeable K contents were significantly higher in the rainy season than in the dry season, however, for the other soil properties, not substantially affected by season.(Xiong Y *et al.* 2008)

Litterfall and decomposition are the two main processes accounting for soil enrichment in agroforestry. The extent of enrichment in soil properties depends on the tree species, management practices and the quantity and quality of litter. A field investigation was carried out to study litterfall production, decay rates, release of nutrients and consequent changes in soil physicochemical properties under crowns of four multipurpose tree species (MPTs) in irrigated conditions in farm fields. The species were *Prosopis cineraria (L.), Dalbergia sissoo (Roxb.)* ex DC, *Acacia nilotica (L.) Del. and Acacia leucophloea (Roxb.)* Willd. Annual accretion of litter ranged from 36 to 54 kg tree−1 year−1 and was highest under *D. sissoo* and lowest under *A. nilotica*. Total litterfall production was in the order: *P. cineraria* > *A. leucophloea* > *A. nilotica* > *D. sissoo*. *P. cineraria* showed the highest NPK concentration in litter. For all MPTs, a large pulse of litterfall coincided with the winter season (November to February). Litter of *P. cineraria* decomposed fastest while that of *A. nilotica* was slowest. More than 95% of the leaf litter of *P. cineraria* decomposed in 6 months, of *D. sissoo* in 7 months and *A. leucophloea* and *A. nilotica* in 9 months. Decomposition rate of litter was highly correlated with neutral detergent fibre (NDF) (r = −0.94) and P (r = −0.91) concentration. N, P and K release were best correlated with NDF, acid detergent fibre (ADF), P, lignin, lignin/N and C/P ratios and NDF alone explained 88% to 94% of the variability in litter decomposition and nutrient release rates. There was significant build up of soil organic carbon and available NPK in the agrisilvicultural systems but also a decrease in soil pH. Build up in soil fertility was significantly correlated with litterfall and soil improvement was greatest under *P. cineraria*.(Yadav RS *et al*.2008)

Acacia melanoxylon, a N2-fixing timber tree occurring naturally in eastern Australia, is now promoted as a component of silvopastoral systems; but the interaction of the tree with pasture and soils has not been adequately studied. This study investigated the effects of *Acacia melanoxylon* on soil nitrogen (N) levels, N availability, soil pH, bulk density, organic carbon, C:N ratios and soil moisture in three separate silvopastoral sites with contrasting soil types in the North Island of New Zealand. At each site four tree stocking rates were studied (0, 500, 800, and 1700 stems ha−1). The trees were nine years old at the time of the study. Soil samples from each study site were taken once at three depths (0 to 75 mm, 75 to 150 mm, and 150 to 300 mm), with three replicates per tree stocking rate. Soil analyses showed that although there were differences between soil types, few statistically significant differences occurred due to tree stocking rate. A greenhouse pot trial growing ryegrass (*Lolium multiflorum* L. cv. ‘Concord’) in soil from the ‘A’ horizon of each soil type from under the trees and the open pasture found that ryegrass yield, N uptake and N supply increased with increasing tree stocking rate. Increased N supply under the trees, coupled with greater soil moisture compared to the open pasture may have accounted for the higher pasture yield under *Acacia melanoxylon* compared to non denitrogen fixing tree species. This study suggested that *Acacia melanoxylon* in a silvopastoral system had the potential to increase soil N availability.(Power IL *et al*.2003)

A study was conducted on farmer’s field with tree species viz. *Dalbergia sissoo, Wendlandia exserta, Borassus flabellifer L. and Phoenix sylvestris* growing on field bunds. Significant higher organic matter and nutrient were found in field along with shisham having dense canopy cover, whereas grain yield and aerial biomass of crop were significantly lower. Higher soil fertility was found near tree base, while grain yield and aerial vegetative biomass of crops increased increae in distance from tree base. Shading was the important factor responsible for the lower yield and growth of crops at position closer to tree lie especially in shisham. (Chaturvedi OP and Das DK. 2002)

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 present 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 whereas C/P ratio declined. (Pandey CB et al. 2000)

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 Bisht1992), 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)

Mohamed (2005) found that when *Acacia mangium* trees were grown in combination in combination with crops ,the photosynthetic rate was correlated significantly with soil water in both soil layers (0-75 cm and 0-250 cm) but correlation with the water in the 0-75 cm soil was found to be very low. In sole tree stands the photosynthetic rate was correlated significantly with the soil water in both the layers (0-75 cm and 0-250 cm). Tree stomatal CO2 conductance under intercropping was found to be better correlated with the soil water in the 0-75 cm topsoil layer than with that in the 0-250 cm soil layer.

In a study for evaluation of available soil moisture content in different depth of soil profile of 0-30 cm and 30-60 cm (Annual report, AICRP on Agroforestry, O.U.A.T., Bhubaneswar centre, 2008), soil moisture was found to be minimum with *Acacia mangium*. Better moisture storage was evident with *Gmelina arborea* and *Dalbergia sisoo*/*Tectona grandis*. Available soil moisture varied directly with soil profile. Moisture content increased with increase in soil depth and maximum percentage was recorded in soil depth of 45-60 cm irrespective of agroforestry systems. In this system, minimum soil moisture content was observed with the annual crop arrowroot (9.41%) and maximum with turmeric (9.97%).

2.4 Effect of nitrogen fixing tree on crop yield

A long term evaluation of degraded bouldery lands in Haryana state of India was done to study the land cover management as an effective strategy in managing land degradation through the reduction of water, soil and nutrient losses and improvement in soil fertility and quality. *Acacia nilotica* (Acacia)-based silvipastoral systems with five intercrops, viz., *Eulaliopsis binata* (bhabbar), *Saccharum munja* (munj), *Vetiveria zizanioides* (vetiver), natural grasses and no grass, were evaluated in a long-term study in degraded bouldery for this purpose. . All grasses resulted in a reduction of soil, water and nutrient losses and improved microbial properties. However, their association adversely affected the growth of *Acacia*, and the decline varied with grass species. After 11 years of establishment, sole *Acacia* plantation had the maximum height (7.58 m), diameter at breast height (dbh) (21.32 cm) and crown spread (7.41 m). Munj produced the highest biomass under *Acacia*, but most adversely affected its growth, resulting in minimum survival (48 %), height (7.07 m), dbh (16.23 cm) and crown spread (6.57 m). It also provided the highest NPV (Rs 1.88 lakhs ha-1), B:C (2.37) and IRR (24.70 %) as compared to Rs 6,998 ha-1, 1.05 and 8.76 % under pure *Acacia* plantation, respectively (Yadav et.al., 2014).

The effect of *Azadirachta indica*, *Prosopis cineraria*, *Dalbergia sissoo* and *Acacia nilotica* on the yield of irrigated wheat crop. Data on crop yield for each tree species at different distances (1, 3, 5 and 7 m) and four directions (east, west, north and south) from the tree bases and control (no trees) were collected. Results indicate that *A. indica and P. cineraria* did not show any significant difference in the wheat yield while the other two species (*D. sissoo and A. nilotica*) showed a reduction in wheat yield. *A. nilotica* had the most significant and prominent effect, and a reduction of nearly 40 to 60% wheat yield was observed. The effect of this tree species was observed even beyond the spread of the crown. *D. sissoo* reduced yield by 4 to 30% but the reduction was only up to a distance of 3 m. In general, the impact of trees on wheat yield was observed up to 3 m distance and there is little, if any, impact up to 5 m distance and almost no impact at 7 m distance. In all the tree species, the wheat yield was reduced to a maximum on the north side of the trees and had almost no effect in the southern direction (Puri and Banagrwa, 2013).

A field experiment was carried out at Agricultural Research Station, Mundagod, Karnataka, during 2006-07 to find out suitable management practice to manage bund planted tree to reduce negative tree crop interaction in *Acacia auriculiformis* based agroforestry system. Suitability of the method was assessed based on the growth and yield of black gram. The seed yield of black gram was significantly higher due to tree management practices imposed to *Acacia auriculiformis.* Significantly higher seed yield was recorded in treatment receiving trenching (730 kg/ha) which was statistically on par with treatment receiving 50 per cent branch pruning (715 kg/ha). Significantly higher seed yield was recorded at 12 to 14 m distance from the tree row (742 kg /ha), which was on par with 10 to 12 m distance from tree row (714 kg /ha). The seed yield of black gram significantly lower with the combination of control and 0 to 2m distances from tree row (Patil and Channabasappa ,2008)

The study reports 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 homogeneous 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 field. Rice crop and soil were sampled at 1–7 m and 20 m distance from the tree stump. Distance at 20 m 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 C and total soil N increased up to 5 m from the tree stump in the first cropping season. By the fifth cropping season, the increase due to tree removal was confined to 2 m from the stump. Total increase in the crop yield, across the cropping seasons, was 12.5 t ha^{-1} which was nearly equal to the reduction in the crop yield suffered during 15 years of the tree growth. Soil organic C and total soil N declined with the passage of time following the tree removal, where as C/N ratio increased. (Pandey CB *et al* 2003)

The influence of a single row plantation of *Acacia nilotica* on the growth and productivity of agricultural crops was assessed in the arid regions of Haryana, India with *Triticum aestivum* (wheat), *Trifolium alexandrinum* (barseem), *Cicer arietinum* (chickpea) and *Gossypium hirsutum* (cotton) being raised on the southern side of tree belt. Crop density, biomass production (of shoot and root), crop growth (in terms of shoot and root length) and yield of all the four crops increased with increasing distance from the tree canopy. A direct negative correlation (correlation coefficient value 0·9 or above in the majority of characters) between parameters studied and the distance from the tree was noticed. The maximum affect was observed in shoot biomass (reduced by 58, 42, 42, and 41% in *T. aestivum*, *T. alexandrinum*, *C. arietinum and G. hirsutum*, respectively) and minimum affect was on root growth. Yield reduction due to trees up to 15 m distance was 37·8, 49·0, 40·6 and 34·4% in *T. aestivum, T. alexandrinum, C. arietinum and G. hirsutum*, respectively. It is suggested that farmers holding small parcels of land should not grow crops in association with *A. nilotica* trees under arid condition. (Puri S *et al* 1994)

S. SaeLee et al. (1992) conducted a study in Northeast Thailand on six rice paddy fields on a farm with similar soil (AquicQuartzipsamments-Entisol) and with a single tree on the paddy bund. There were 4 tree species: *Parinari anamensis, Dipterocarpus obtusifolius, Dipterocarpus intricatus, and Samanea saman*. Samples of soil (0-10 cm depth) and rice were collected at 3 positions (1, 5-7, and 9-11 m) away from the tree base in 3 replicated tree-soil transects in each paddy field. Significantly higher pH, organic matter, and nutrients (N, P, K, Ca, and Mg) were found in paddy fields with *Samanea saman* (a legume tree) but grain yield and biomass of rice were significantly lower. Higher soil fertility was found in the positions closer to tree base while grain yields, biomass, and number of tillers were lower, and rice was taller and had more unfilled grain. Shading was deduced to be the key factor responsible for the depressed rice yields and growth at positions closer to tree base especially in the highly shading *S. saman*.

2.5 Advantages of agroforestry systems

Sharma (2012) said that, out of the several benefits accrued from agroforestry systems in terms of soil quality, nutrient cycling is the most predominant. In a soil-plant system, plant nutrients are in a state of continuous, dynamic transfer. Plants take up nutrients from the soil and use them for metabolic activities. In turn, these nutrients are returned back to the soil either naturally as litter falls in and as pruning in some agroforestry systems or through root senescence. These plant parts are decomposed as a result of microbial activities and release the nutrients held in them into the soil. The nutrient then becomes available for plant uptake once again (Nair et al., 1999). Thus, the agroforestry land use systems play a tremendous role in influencing the nutrient flows and overall soil quality.

Sharrow and Ismail (2004) studied about the carbon and nitrogen storage in agroforests, tree plantations and pastures in western Oregon, USA in 11 year old Douglas fir (*Pseudotsuga menziesii*) + perennial rye grass (Lolium perenne) + subclover (*Trifolium subterraneum*) agroforests, rye grass + subclover pastures and Douglas fir timber plantations near Corvallis, Oregon. They concluded that agroforests accumulated approximately 740 kg ha-1 year-1 more carbon than forests and 520 kg ha-1 year-1 more carbon than pastures over 11 years since planting. Total nitrogen content of agroforests and pastures, both of which included a nitrogen-fixing legume, were approximately 530 and 1200 kg ha-1 greater than plantations, respectively. They also suggested that agroforests such as silvopastures, may be more efficient at accreting carbon than plantation or pasture monocultures. However, pastures may accrete more nitrogen than agroforests and plantations.

A study about the role of agroforestry systems in improving soil organic matter status, microbial activity and nitrogen availability to manage the fertility of moderately alkaline soil effectively was conducted at Karnal in various systems including rice-berseem crop rotation; agrisilvicultural systems of *Acacia*; *Eucalyptus* and *Populus* along with rice- berseem and single species tree plantations. They found out that microbial biomass carbon was low in rice- berseem crops (96.14 µg g-1 soil) and increased in soils under tree plantations (109.12- 143.40 µ g g-1 soil) and agri-silvicultural systems (133.80- 153.40 µg g-1 soil). Microbial biomass was higher by 42% (microbial carbon) and 13% (microbial N) in tree based system as compared to monocropping. They also found out that soil carbon increased by 11-52%, nitrogen levels by 8-74% and nitrogen mineralization by 12-37% in tree based systems as compared to monocropping. (Kaur et al., 2000)

Various workers at various places have reported the advantages of agroforestry. Most of the findings were in favour of this system with increased productivity and improved soil conditions. Higher yields of crops have been observed in forest-influenced soils than in ordinary soils. In the Tarai area of Uttar Pradesh, taungya cultivators harvested higher yields of crops such as maize, wheat, pulses, etc. without fertiliser. Approximately, 20% higher yields of grains and wood have been reported in agroforestry areas of Haryana and western Uttar Pradesh than from pure agriculture (Dwivedi and Sharma, 1989). Experiments conducted at IGFRI, Jhansi indicate that the total yield of fodder is more when fodder grasses are grown with fodder trees than pure fodder grass cultivation. *Leucaena leucocephala* inter-cropped with agricultural crops and fodder grasses, increased the total yield of food grains, fodder and fuel (Pathak, 1989).

Sanchez (1987) stated that appropriate agroforestry systems improve soils, physical properties, maintain soil organic matter and promote nutrient cycling. Nitrogen fixing trees are mentioned as one of the most promising components of agroforestry system. The leaf litter after decomposition forms humus, releases nutrients and improves various soil properties. It also reduces the fertiliser needs. Growing of trees and fodder crops, including fodder trees is more economical, particularly on marginal lands. Observations taken in hot arid and semi-arid areas of Rajasthan indicate that marginal lands are incapable of sustaining stable and dynamic cultivation of agricultural crops. Silvopasture consisting of growing trees such as *Prosopis, Albizia, Zizyphus and Acacia* species may provide many times more returns per unit of land than agriculture under such conditions (Gupta and Mohan, 1982).

Nair et al. (2009) suggested agroforestry as an integrated approach of sustainable land use due to its production and environmental benefits. They also inferred about its perceived potential which is based on the premise of the greater efficiency of integrated systems in resource capture and utilization than single species systems, thus resulting in greater net carbon sequestration.

MATERIALS AND METHODS

The present investigation entitled "Effect of field bund plantation of nitrogen fixing trees on soil and rice crop" was carried out in the Ganjam district of Odisha during July2017-December2017. Details about the experimental site, material used and methodology adopted during the course of investigation are discussed in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location:-

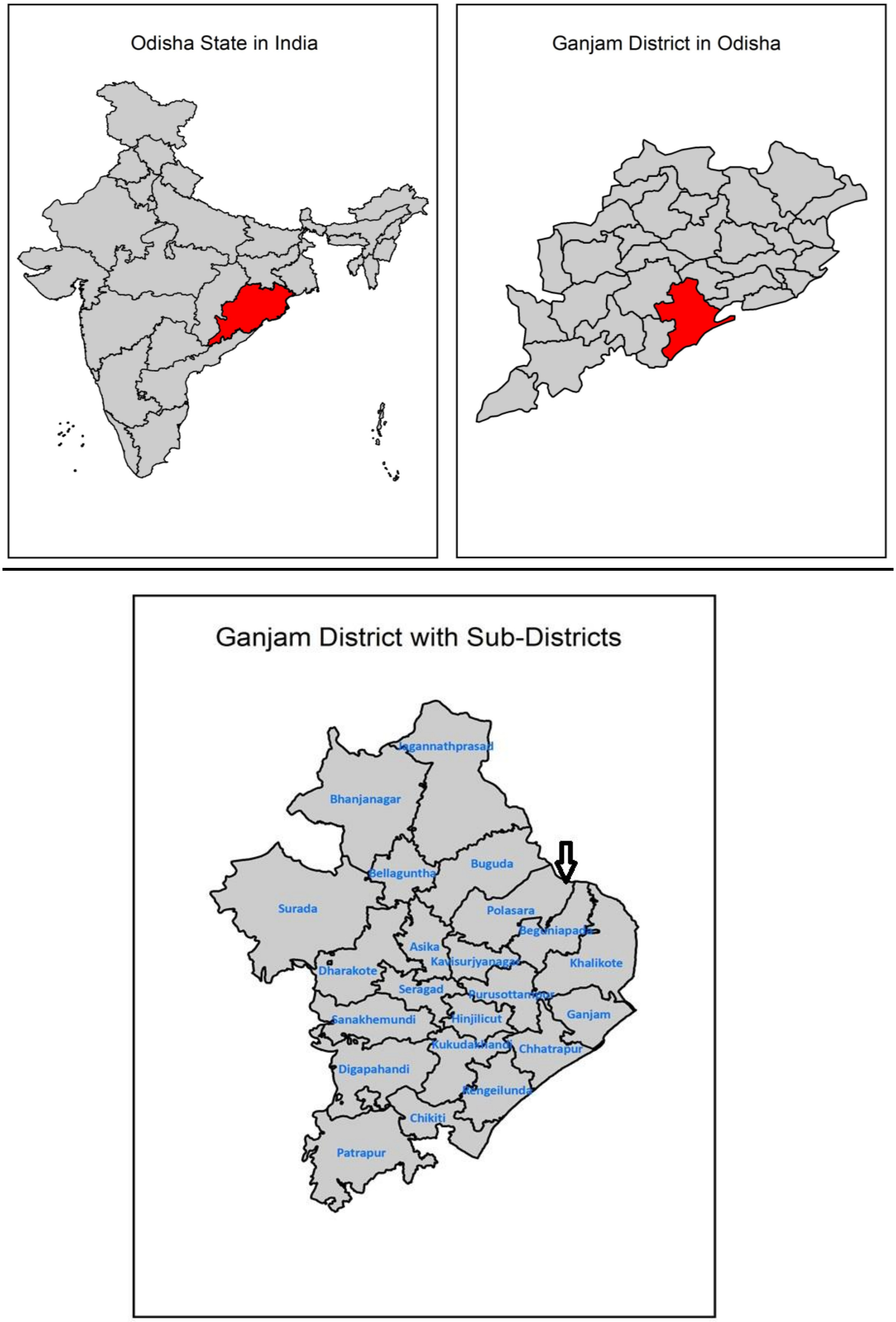
Ganjam is a coastal district of Odisha state of India. Ganjam District came into existence on 1st April 1936. The district is named after the old township and Ganjam situated on the northern bank of river Rushikulya. The Ganjam area was a part of ancient Kalinga.

The headquarter Chhatrapur city is situated at nearly 150 km from state capital, Bhubaneswar. The total geographical area of the district is about 8206 sq km. The district comprises of 3250 villages. It has 3 sub-divisions namely Berhampur, Chhatrapur, Bhanjanagar , 23 tehsils and 22 blocks.The total population of the district is 35,29,031 as per 2011 Census.

Agriculture is a traditional occupation and the way of living of the inhabitants of the Ganjam District. The District is well known for its fertile soil and agricultural productivity. A large variety of crops are grown here like Paddy, Ground nut, Sugar cane, Oil seeds, Ragi, Mung, Biri etc. Because of the agro climatic condition Ganjam is included as the agricultural District.

Ganjam District is on 19.4 to 20.17 degree North Latitude and 84.7 to 85.12 degree East Longitude. It covers an area of 8206 sq km. The district is broadly divided into two divisions, the Coastal plain area in the east and hill and table lands in the west. The eastern ghats run along the western side of the District. The climate of Ganjam is characterized by an equable temperature round the year, particularly in the coastal regions. The District's cold season from December to February is followed by hot season from March to May. The District experiences normal annual rainfall of 935.2 mms.

Figure 3.1 Location Map of Ganjam District



3.1.2 Climate and Weather Condition

According to the Koppen–Geiger climate classification system the climate of Ganjam is classified as Aw (Tropical savanna climate). The city has moderate and tropical climate. Humidity is fairly high throughout the year. The temperature during summer touches a maximum of 41°C (105.8 °F) and during winter it is 17°C (62.6 °F). The average annual rainfall is 935.2 millimetres (36.81 in) and the average annual temperature is 30°C (86°F).

The rainfall received during the year 2017 was 935.2.This amount of rainfall is distributed over 141 rainy days in a year. The normal daily temperature ranges from a minimum of 17^0C to a maximum of 41^0C. April is the hottest month and having mean max temp of 41^0C. January is the coldest month having mean minimum temperature of 17^0C. Records reveal that temperature increases rapidly from February. The average temperature during the study period ranged from $24.8\ ^0$ C –32.16^0 C.

3.1.3 Agro-climatic/ecological information

It is broadly divided into 2 Agro climatic zones.

- East and South eastern costal plains-:- It covers Chatrapur Sub-Divisions and Eastern parts of Berhampur .
- North eastern ghat hill regions:- It covers Bhanjanagar Sub-Division and Western parts of Berhampur .

3.1.4 Forest area:-

The total forest area in the district was estimated only to be 3149.9 sq km. which contributes 39.02% of the total geographical area. The area is mostly situated in northern and southern part of the district. The district is having scattered mangrove forest, which play very important role in checking the high tide of the sea and maintaining ecological balance. The major forest products of the district are timber firewood, bamboo, etc. The lower patch of forest area has been degraded due to scarcity of fuel of the rural people and most of the trees are cut down for fire wood and fodder purposes.

Table 3.1 Types of forest and area covered

Sl.No.	Type of Forest	Area in sq km.
1	Reserve Forests	1485
2	Demarcated Protected Forest	143.54
3	Un demarcated Protected Forest	1167.39
4	Un classified Forest	0.86
5	Other Forests	352.45
	Total:	**3149.9**

Table 3.2 Distribution of rainfall in Ganjam District from July 2017 to June 2018

Rainfall	Average(mm)	Normal Onset (specify week and month	Normal Cessation (specify week and month)
SW Monsoon (June-Sep)	354.4	2nd week of June	Last Week of September
NE Monsoon Post Monsoon (Oct- Dec)	450.2	3rd week of October	1st week of December
Winter (Jan- Feb)	0	1st week of January	Last week of February.
Summer/Pre Monsoon (March-May)	484.5	2nd week of March	Last week of May

Figure 3.2 Average rainfall days and Precipitation of Ganjam District in 2017

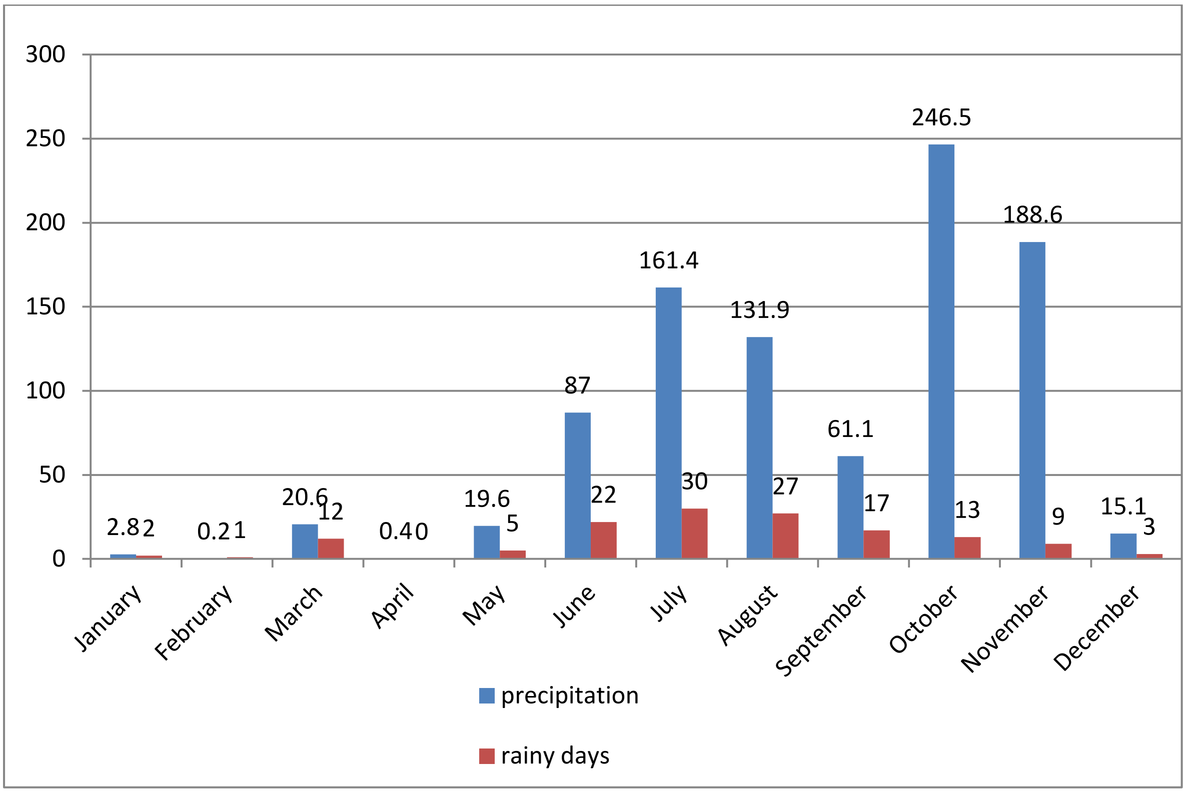


Figure 3.3 Average Temperature Graph for Ganjam District in 2017

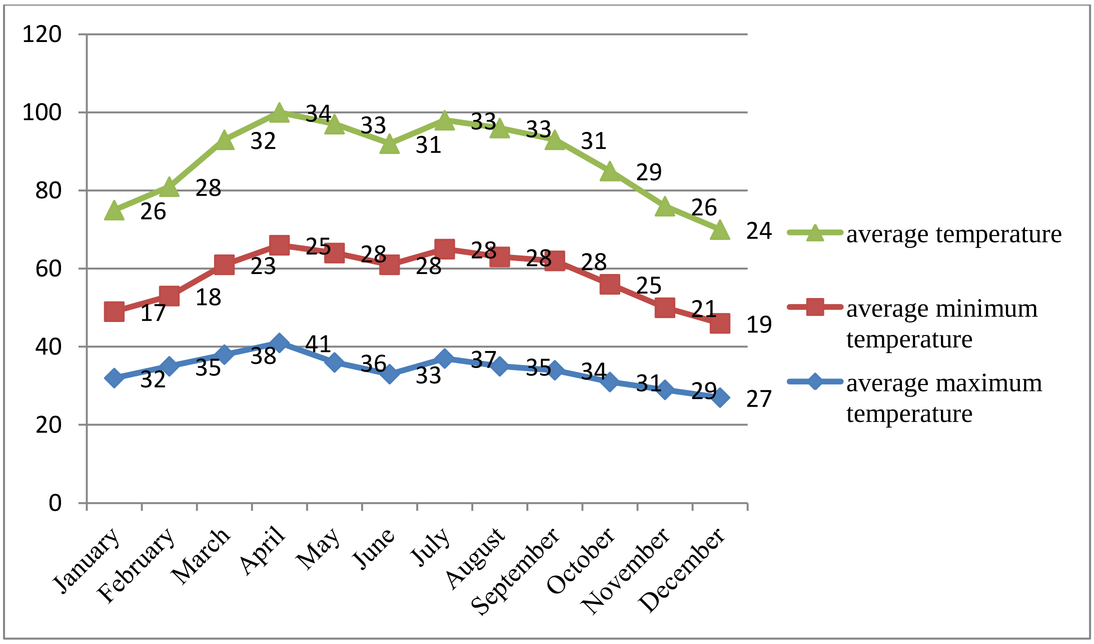


Table 3.3 Major soils in Ganjam district

Major soils	Area (000ha)	Percent of total
Coastal alluvial command	164	22.5
Rainfed lateritic soils	134	18.4
Black soils	43	5.9
Coastal alluvial soil	26	3.6
Red soils	359	49.4

Table 3.4 Operational holding of Ganjam district

Size of holding	No. of holdings	Per cent of total land holdings
Less than 1 ha (Marginal)	233069	78.9
Between 1-2 ha (Small)	42941	14.5
Between 2-4 ha (Medium)	16550	0.05
Between 4-10 ha (Large)	2577	0.008
Above 10 ha (Very Large)	252	0.0008

3.2 EXPERIMENTAL DETAILS

3.2.1 Experimental Design: The experiment was carried out in a Randomized Block Design (RBD) with three replications. For this the rice field bunds were divided into blocks. The tree component present in the rice field bunds were taken under investigation to acknowledge their growth and performance with reference to paddy and their effect on paddy crop. Subsequently, tabulations were done for crop yield, soil physicochemical properties, tree height and girth, straw yield, harvest index.

3.2.2 Treatments

There were 9 treatments as shown below:

Tree species (3)

T1- *Acacia aucuriliformis*

T2- *Acacia mangium*

T3- *Acacia nilotica*

Distance from the tree species (3)

D1- Near the tree base

D2- Edge of the canopy

D3- Away from plant

Replication-3

3.2.3 Experimental Procedure:

A preliminary survey was done in three villages of Polasara block of Ganjam district viz. Hirapalli, Belagaon, Patigada in the month of June 2017 to demarcate the suitable paddy fields containing the tree species as a part of field bund plantations. Subsequently fields from three different villages of Polasara block were taken into consideration to obtain essential data from field related to the research work. The agricultural fields selected for research work were mainly subjected to paddy cultivation since the last few years. In all rice fields MTU-1001 rice variety was mainly grown. The tree component present in the field bunds were 8 year old plantations.

Essential data related to growth and performance of different tree species present on the field bunds such as tree height, D.B.H.(o.b.), G.B.H.(o.b.) were duly recorded well before the planting season and after the harvest of paddy.

In order to study the various soil characteristics related to the tree based agroforestry systems, the soil samples were taken from 3 places i.e near tree, end point of crown and away from plant. Soil samples collected in three depth slots i.e. 0-15 cm, 15-30 cm and 30-45cm depth respectively. Successive processing of soil samples were deliberately done in the soil science laboratory of College of Agriculture, OUAT, Bhubaneswar and final findings were recorded for further discussions. Initial soil samples collected before rice plantation and final soil samples collected after the harvesting season. Soil samples collected from different villages of the block under study and analysed for bulk density, texture, organic carbon, pH, OC, EC, nitrogen, phosphorus and potassium.

Economics of *Acacia* based agroforestry system were also brought under consideration to access various economic parameters related to the paddy cultivation in association with the tree crops in the field. Economic parameters recorded such as benefit cost ratio (BCR) of the associated crops. Data related to rice yield from 3 different points were recorded.

3.2.4 Observations recorded

The observations were recorded on the growth and yield parameters related to tree crops present in the rice fields. Significant observations were also recorded for accessing various soil nutrient parameters and economics related to tree based agroforestry system was also brought under consideration. The parameters recorded are described as below.

3.2.4.1 Height of trees present in the field bunds.

Height of the trees growing in the field bunds of rice fields was measured from ground level to the tip of main shoot with the help of Ravi Altimeter. The height of and girth of trees present in the field bunds were expressed in tabular format.

3.2.4.2 Girth at Breast Height (G.B.H.):

The over bark girth of individual trees, G.B.H (O.B.) present in the rice field bunds were also calculated and its average value also calculated.

3.2.4.3 Age of trees:

Age of the tree species present on the rice field bunds were calculated by using Preseller's increment borer. On the contrary, a general questionnaire was also done to acknowledge the age of standing trees present on the rice field bunds.

3.2.5 Chemical analysis of soil

Soil samples of 500gm weight from each rice fields were collected from three different points and three different depth slots i.e. 0-15cm, 15-30 cm, 30-45cm depth in the month of July 2017. Collected samples were air dried under shade, finely dusted and passed through a 2 mm sieve and finally 250 gm. of such soil were taken from each treatment plots in polythene bag with proper label for analysis of p^H , organic carbon, Nitrogen, Phosphorus and Potash and value of electrical conductivity. The methods used were mentioned below:

a) P^H : Soil P^H was determined in 1:2 soil and water suspension by using glass electrode P^H meter(Jackson,1967)
b) Organic Carbon : Organic Carbon content of the soil sample was determined by Walkley and Black's rapid titration method(Piper,1950)
c) Available Nitrogen: Available nitrogen was determined by the method described by Subbiah and Asija(1956). Nitrogen released as ammonia during distillation of 20 gram soil with 100 ml 0.32 % of KMnO4 and 100 ml of 2.5 % NaOH was received in 2 % boric acid containing mixed indicator and ammonia was titrated against standard 0.02 NH2SO4.
d) Available phosphorous: It was determined by Bray's-I method with shaking 2 gram soil in 20 ml of extracting solution(0.03N NH4AF in 0.025N HCl) for 5 minutes. The filtrate was estimated by spectrophotometer for phosphorous after development of colour by SnC12 and measured at 660nm(Jackson,1973).
e) Available Potassium: It was determined by equilibrating 5 gram of soil in 25 ml neutral ammonium acetate (Jackson,1973) and reading of extract was taken in flame photometer.

f) Electrical Conductivity: It was determined by using an EC probe meter. The probe or sensor consists of two metal electrodes and a constant voltage is applied across the electrodes resulting in an electrical current flowing through the sample. Since the current flowing through the water is proportional to the concentration of dissolved ions in the water, the electrical conductivity can be measured in terms of dSm^{-1}.

3.2.6 Rice yield

Rice crop was harvested from 1 m sq area from each location. After drying the weight of paddy seed and straw were recorded.

3.2.7 Statistical Analysis:

The quantitative data on various observations were analysed as per the procedure described i.e. SEm (±) and Critical Difference(C.D.) were calculated at 5 % level of significance for comparing the treatment means where 'F' test was found significant. The following formulae were used for estimation of SEm and CD.

Mathematically,

$SE_m(\pm) =(EMS/R)$

$CD_{(0.05)} = SE_m(\pm) x 2 x t(0.05)$ at error degree of freedom.

Where EMS= Error Mean sum of square.

R = Number of replication.

The quantitative data on various observations were also analysed statistically by deriving the value of standard deviation which is defined as the positive square-root of the arithmetic mean of the square of the deviation of observations from its mean.

Mathematically,

$$S.D. = +\sqrt{\sum | x - \mu |^2 / N}$$

Where, S.D. = Standard Deviation

X = Individual value of observations

μ = Mean/ Average value

N = Number of observations.

Figure 3.4 Picture representing data collection from the field

***Acacia nilotica* tree**

Girth measurement

Height measurement

Soil sample collection

RESULTS

The experimental results of the present investigation "**Effect of field bund plantation of nitrogen fixing trees on soil and rice crop**" are presented in this chapter under following head:

4.1 Growth of nitrogen fixing tress planted on the rice field bunds.

4.2 Effect of nitrogen fixing trees on physico-chemical properties of soil.

4.3 Effect of nitrogen fixing tree on rice crop and economics.

4.1 Growth of nitrogen fixing tress planted on the rice field bunds

4.2 Tree height

The data presented in Table 4.1 and illustrated in Figure 4.1 indicates that the height increment is different in different plants. The maximum height was recorded in *Acacia auriculiformis* while minimum height was recorded in *Acacia nilotica.* Maximum height increment observed in case of *Acacia auriculiformis* (0.69mt) while minimum height increment observed in case of *Acacia nilotica* (0.4mt). The height increment observed in the order of *Acacia auriculiformis* >*Acacia mangium*> *Acacia nilotica*.

4.1.2 Diameter at Breast Height (D.B.H.)

The data on DBH presented in Table 4.2 and illustrated in Figure 4.2 indicates that the diameter increment is different in different plants. Maximum DBH was recorded in *Acacia auriculiformis*. While minimum DBH was recorded in *Acacia nilotica* tree. Maximum diameter increment observed in case of *Acacia auriculiformis* (1.22cm) while minimum diameter increment observed in case of *Acacia nilotica* (0.61cm). The diameter increment observed in the order of *Acacia auriculiformis* >*Acacia mangium*> *Acacia nilotica*.

4.1.3 Girth at Breast Height (G.B.H.)

The circumferential girth at the breast height (G.B.H) was presented at table 4.3 and figure 4.3. Maximum GBH was recorded in *Acacia auriculiformis*. While minimum GBH was recorded in *Acacia nilotica* tree. Maximum girth increment observed in case of *Acacia auriculiformis* (3.84cm) while minimum diameter increment observed in case of *Acacia nilotica* (1.94cm). The diameter increment observed in the order of *Acacia auriculiformis* >*Acacia mangium* > *Acacia nilotica*.

Table 4.1 Height (Initial and Final) measurement of nitrogen fixing tree species present in field bund

Tree	Height (in mt)		
	Initial	Final	Difference
Acacia auriculiformis	10.69	11.38	0.69
Acacia mangium	8.55	9.11	0.56
Acacia nilotica	6.4	6.8	0.4

4.2 Study the effect of nitrogen fixing trees on physico-chemical properties of soil.

Data on available nutrient status of soil (organic carbon, available nitrogen, available phosphorous, available potassium, electrical conductivity and pH of soil) were brought under consideration pertaining to the existence of different Nitrogen fixing trees present in field bund. Related data were presented in Table 4.4 to 4.8.

Table 4.2 Diameter (Initial and Final) measurement of nitrogen fixing tree species present in field bund

Tree	Diameter (in cm)		
	Initial	Final	Difference
Acacia auriculiformis	20.57	21.79	1.22
Acacia mangium	17.29	18.19	0.90
Acacia nilotica	15.29	15.90	0.61

Table 4.3 Girth (Initial and Final) measurement of nitrogen fixing tree species present in field bund

Tree	Girth (in cm)		
	Initial	Final	Difference
Acacia auriculiformis	64.66	68.5	3.84
Acacia mangium	54.33	57.16	2.83
Acacia nilotica	48.06	50	1.94

Fig. 4.1 Height difference of plants present in the paddy field bunds

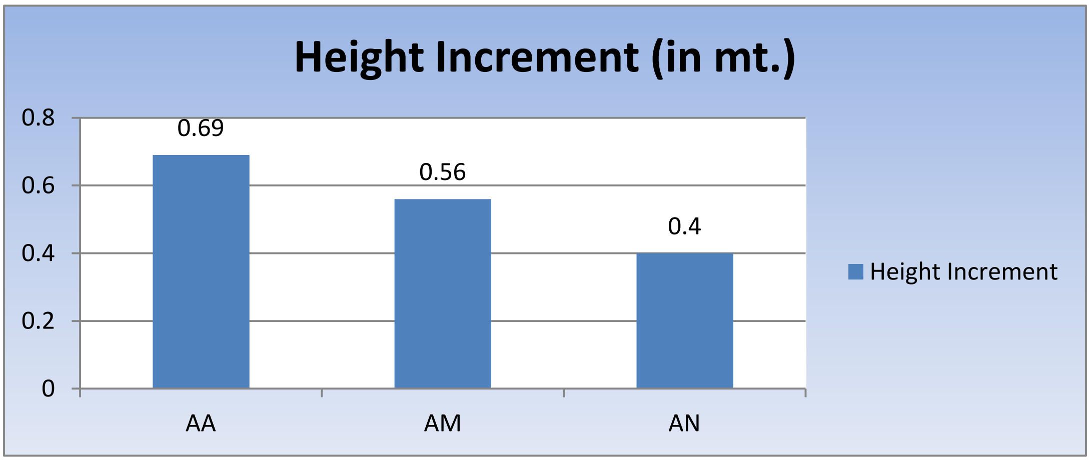


Fig. 4.2 Difference in diameter of plants present in the paddy field bunds

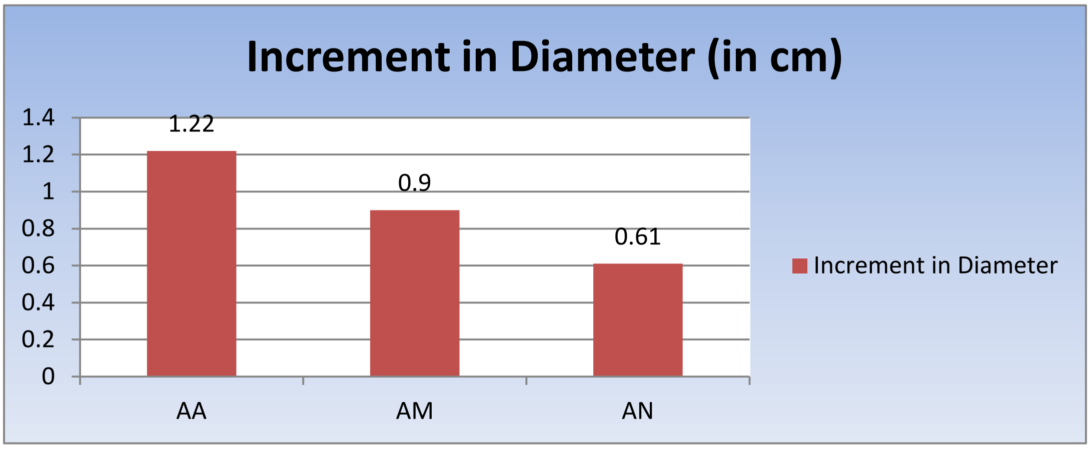
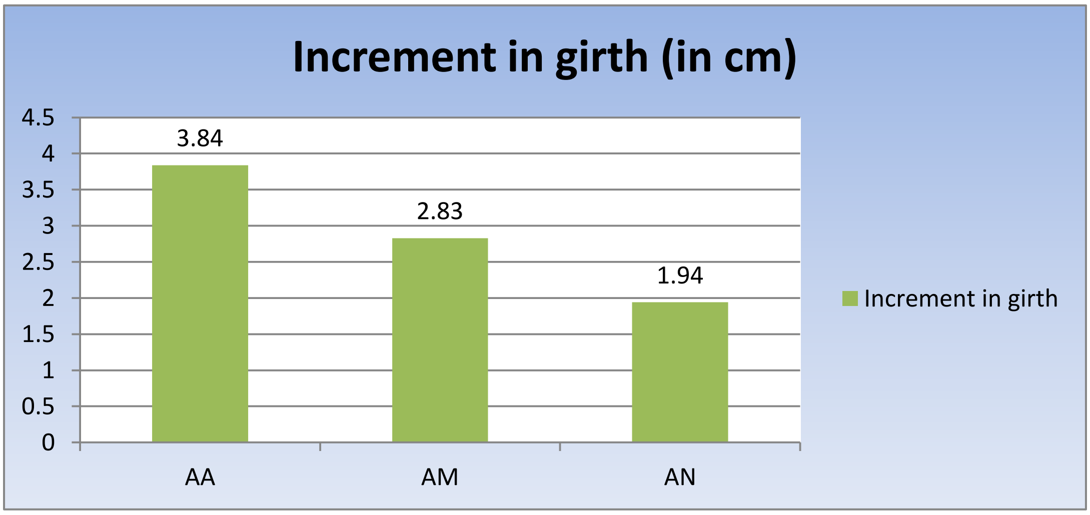


Fig. 4.3 Difference in Girth of plants present in the paddy field bunds



4.2.1 Organic carbon

Organic carbon content of soil was presented in Table 4.4. Organic carbon decreases with increase in soil depth. Organic carbon percentage was maximum near the end point of crown and minimum near tree base. Organic carbon content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis.* Organic carbon content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* (0.48%) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis.* (0.25%).

4.2.2 Available nitrogen

Available nitrogen content of soil was presented in Table 4.5. Available nitrogen decreases with increase in soil depth. Available nitrogen content was maximum near the end point of crown and minimum near tree base. Available nitrogen content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis.* Available nitrogen content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* (175.4 kg/ha) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis.* (81.4 kg/ha).

4.2.3 Available phosphorous

Available phosphorous content of soil was presented in Table 4.6. Available phosphorous decreases with increase in the soil depth. Available phosphorous content was maximum near the end point of crown and minimum near tree base. Available phosphorous content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis.* Available phosphorous content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* (35.8 kg/ha) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis* (6.2 kg/ha).

Table 4.4 Organic carbon (Initial and Final) of soil

Treatment	0-15cm	15-30cm	30-45cm
	Final (in %)	Final (in %)	Final (in %)
T1D1	0.35	0.31	0.25
T1D2	0.44	0.36	0.30
T1D3	0.38	0.32	0.28
T2D1	0.41	0.34	0.26
T2D2	0.47	0.41	0.34
T2D3	0.45	0.37	0.31
T3D1	0.45	0.37	0.33
T3D2	0.48	0.42	0.35
T3D3	0.47	0.41	0.34
Initial	0.35	0.32	0.25

4.2.4 Available Potassium

Available potassium content of soil was presented in Table 4.7. Available potassium decreases with increase in soil depth. Available potassium was maximum near the end point of crown and minimum near tree base. Available potassium content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis.* Organic carbon content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia* *nilotica* (120.3 kg/ha) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis* (71.9 kg/ha).

Table 4.5 Available nitrogen (Initial and Final) of soil

Treatment	0-15cm	15-30cm	30-45cm
	Final (kg/ha)	Final (kg/ha)	Final (kg/ha)
T1D1	132.6	111.2	81.4
T1D2	140.6	122.4	95.7
T1D3	138.8	118.4	92.6
T2D1	138.8	125.2	87.8
T2D2	142.2	124.8	97.9
T2D3	142.2	128.1	95.4
T3D1	142.5	135.4	101.6
T3D2	175.4	137.2	108.6
T3D3	150.5	128.1	98.2
Initial	134.0	122	85

Table 4.6 Available phosphorous (Initial and Final) of soil

Treatment	0-15cm	15-30cm	30-45cm
	Final (kg/ha)	Final (kg/ha)	Final (kg/ha)
T1D1	21.4	10.8	06.2
T1D2	26.7	18.3	08.4
T1D3	23.6	13.8	06.2
T2D1	25.8	12.4	06.2
T2D2	28.4	20.1	11.5
T2D3	26.7	15.1	08.4
T3D1	28.6	18.3	08.4
T3D2	35.8	23.6	16.2
T3D3	30.4	19.7	11.6
Initial	22.5	13.6	8.8

4.2.5 Electrical conductivity

Electrical conductivity of soil was presented in Table 4.9. It ranges from 0.083 to 0.086 dS m^{-1}.

4.2.6 pH

pH of soil was presented in Table 4.8. pH increases with increase in soil depth. pH was maxim near the end point of crown and minimum near tree base. pH reading was maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis*. pH was highest in the deeper layer (30-45cm) of soil present at the end point of crown of *Acacia nilotica* (6.83) and lowest in uppermost layer (0-15cm) of soil present near tree base of *Acacia auriculiformis* (5.35).

Table 4.7 Available potassium (Initial and Final) of soil

Treatment	0-15cm	15-30cm	30-45cm
	Final (kg/ha)	Final(kg/ha)	Final (kg/ha)
T1D1	100.8	88.4	71.9
T1D2	115.9	91.8	74.8
T1D3	106.4	88.4	73.7
T2D1	100.8	91.5	73.7
T2D2	117.4	94.8	77.1
T2D3	111.3	93.7	74.8
T3D1	113.5	91.5	76.4
T3D2	120.3	94.8	81.2
T3D3	115.9	93.7	79.2
Initial	105.2	87.6	70.5

Table 4.8 pH (Initial and Final) of soil

Treatment	0-15cm	15-30cm	30-45cm
	Final	Final	Final
T1D1	5.35	5.40	5.61
T1D2	5.49	5.67	6.09
T1D3	5.29	5.64	5.46
T2D1	5.45	5.85	6.08
T2D2	5.53	6.07	6.27
T2D3	5.48	5.98	6.14
T3D1	6.01	6.19	6.50
T3D2	6.21	6.35	6.83
T3D3	6.13	6.32	6.67
Initial	5.35	5.41	5.72

4.3 Study of yield & economics related to different tree based agroforestry system

The data in Table 4.9 to 5.0 and figure 4.4 to 4.6 revealed that the economic parameters such as gross return, net return, B:C ratio (BCR) varies according to different plant.

4.3.1 Gross Return

It was observed that the gross return was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that return was maximum near the edge of crown and minimum near the base of tree. Hence the Gross return return was maximum near edge of crown under *Acacia nilotica* (70965 Rs ha^{-1}) and minimum near the base of *Acacia auriculiformis* tree (62040 Rs ha^{-1}).

4.3.2 Net Return

Net return was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that return was maximum near the edge of crown and minimum near the base of tree. Hence the return was maximum near edge of crown under *Acacia nilotica* (35965 Rs ha^{-1}) and minimum near the base of tree of *Acacia auriculiformis* (27040 Rs ha^{-1}).

4.3.3 BCR

It was observed that the B:C Ratio was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that B:C Ratio was maximum near the edge of crown and minimum near the base of tree. Hence the B:C Ratio was maximum near edge of crown under *Acacia nilotica* (2.02) and minimum near the base of *Acacia auriculiformis* tree (1.77).

4.3.4 Rice yield

From the Table 5.0 it was clear that it was clear that yield near *Acacia nilotica* was maximum while yield was minimum under *Acacia auriculiformis.* Yield was maximum near the edge of the *Acacia nilotica* crown (48.11 quintal ha^{-1}) and minimum near tree base of *Acacia auriculiformis* (41.36 quintal ha^{-1}).

Table 4.9 Effect of nitrogen fixing tree on rice crop yield

Treatment	Rice yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T1D1	41.36	49.21	45.66
T1D2	45.17	54.20	45.45
T1D3	43.76	53.3	45.04
T2D1	43.08	50.83	45.87
T2D2	46.48	55.77	45.45
T2D3	44.74	54.13	45.24
T3D1	44.63	55.34	44.64
T3D2	47.31	58.66	44.64
T3D3	46.18	55.41	45.45
CD(5%)	1.32	1.82	NS

Table 4.10 Effect of nitrogen fixing trees on crop economics

Treatment	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	BCR
T1D1	62040	27040	1.77
T1D2	67755	32755	1.93
T1D3	65640	30640	1.87
T2D1	64620	29620	1.84
T2D2	69720	34720	1.99
T2D3	67110	32110	1.91
T3D1	66945	31945	1.91
T3D2	70965	35965	2.02
T3D3	69270	34270	1.97

Cost of cultivation = Rs35000/ha

Price per quintal = Rs1500/-

Fig. 4.4 Gross return

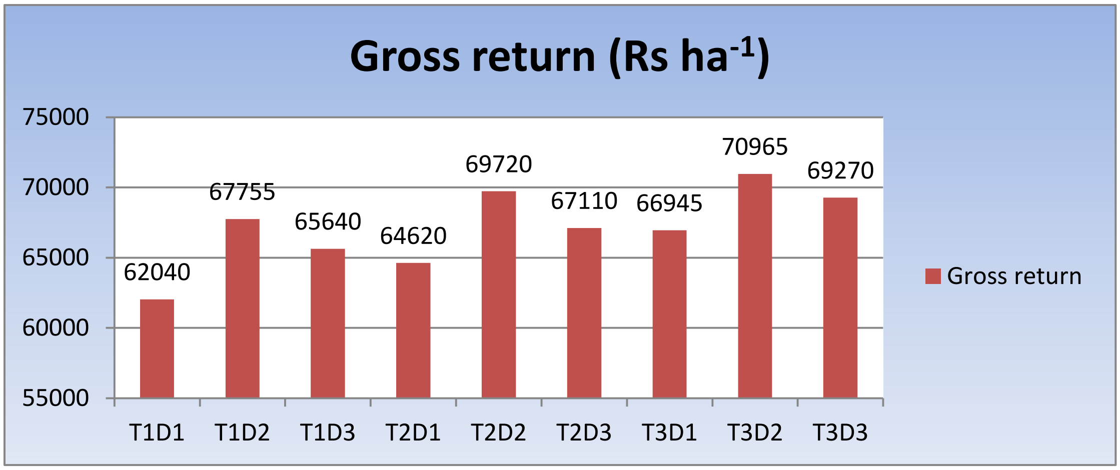


Fig. 4.5 Net return

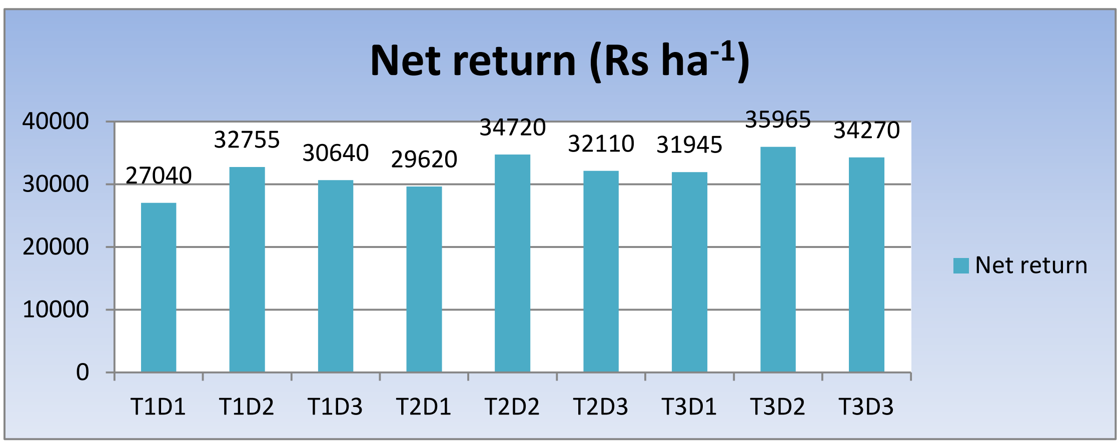
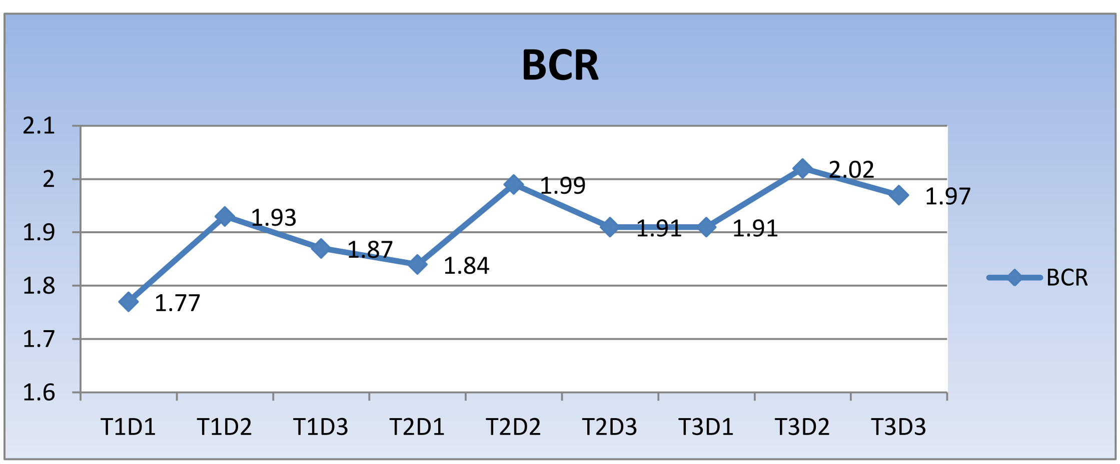


Fig.4.6 BCR Analysis



DISCUSSION

A field experiment was carried out in Ganjam district of Odisha state during July2017-December2017 to study the effect of field bund plantation of nitrogen fixing trees on soil and rice. Data on growth and performance of nitrogen fixing trees on the crop field bunds, the effect of nitrogen fixing trees on the soil characters and effect of nitrogen fixing tree on rice crop and economics have been presented in the preceding chapter. An attempt has been made in this chapter to analyze the results and interprete the findings in the line of research concluded.

5.1 Growth of nitrogen fixing tress planted on the rice field bunds.

5.2 Effect of nitrogen fixing trees on physico-chemical properties of soil.

5.3 Effect of nitrogen fixing tree on rice crop and economics.

5.1 Growth of Nitrogen fixing tree species on the crop field bunds

The data indicates that the height increment is different in different plants. The maximum height was recorded in *Acacia auriculiformis* while minimum height was recorded in *Acacia nilotica.* Maximum height increment observed in case of *Acacia auriculiformis* (0.69mt) while minimum height increment observed in case of *Acacia nilotica* (0.4mt). The height increment observed in the order of *Acacia auriculiformis* >*Acacia mangium*> *Acacia nilotica*. which is similar to the findings of (Schmerbeck J, Naudiyal N. 2004)

The data on DBH indicates that the diameter increment is different in different plants. Maximum DBH was recorded in *Acacia auriculiformis*. While minimum DBH was recorded in *Acacia nilotica* tree. Maximum diameter increment observed in case of *Acacia auriculiformis* (1.22cm) while minimum diameter increment observed in case of *Acacia nilotica* (0.61cm). The diameter increment observed in the order of *Acacia auriculiformis* >*Acacia mangium*> *Acacia nilotica*.

The circumferential girth at the breast height (G.B.H) indicates that Maximum GBH was recorded in *Acacia auriculiformis*. While minimum GBH was recorded in *Acacia nilotica* tree. Maximum girth increment observed in case of *Acacia auriculiformis* (3.84cm) while minimum diameter increment observed in case of

Acacia nilotica (1.94cm). The diameter increment observed in the order of *Acacia auriculiformis* >*Acacia mangium* > *Acacia nilotica*. which corroborates the report of (Jusoh I *et al.2017)*

5.2 Soil characters related to different agroforestry system in the rice field

Organic carbon percentage was maximum near the end point of crown and minimum near tree base. Organic carbon content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis*. Organic carbon content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis.* This is because of the leaf litter falling on soil which causes increase in soil carbon.(Pereira APA *et al.* 2018) also found same result in his experiment. (Tanaka S *et al* 2015) also concluded the same findings.

Available nitrogen content was maximum near the end point of crown and minimum near tree base. Available nitrogen content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis*. Available nitrogen content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* (175.4 kg/ha) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis*. (81.4 kg/ha). Similar findings also reported by (Voigtlaender M *et al*. 2012)

pH increases with increase in soil depth. pH was maxim near the end point of crown and minimum near tree base. pH reading was maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis.* pH was highest in the deeper layer (30-45cm) of soil present at the end point of crown of *Acacia nilotica* (6.83) and lowest in uppermost layer (0-15cm) of soil present near tree base of *Acacia auriculiformis* (5.35).

Available phosphorous content was maximum near the end point of crown and minimum near tree base. Available phosphorous content is maximum in case of *Acacia nilotica* and minimum in *Acacia auriculiformis*. Available phosphorous content was highest in the topmost layer (0-15cm) of soil present at the end point of crown of *Acacia nilotica* (35.8 kg/ha) and lowest in deeper layer (30-45cm) of soil present near tree base of *Acacia auriculiformis* (6.2 kg/ha).

Moreover, the N-fixing species *A. auriculiformis* performed better than other species in improving soil P availability. (Faming WANG. *et al.* 2010)

5.3 Effect of nitrogen fixing tree on rice crop and economics.

From previous data was clear that it was clear that yield near *Acacia nilotica* was maximum while yield was minimum under *Acacia auriculiformis.* Yield was maximum near the edge of the *Acacia nilotica* crown (48.11 quintal ha^{-1}) and minimum near tree base of *Acacia auriculiformis*(41.36 quintal ha^{-1}). *Acacia nilotica* give better yield as it fixes more nitrogen as compare to other two trees. At the edge of crown the yield is more because of the leaf litter and partial shade.

It was observed that the gross return was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that return was maximum near the edge of crown and minimum near the base of tree. Hence the Gross return return was maximum near edge of crown under *Acacia nilotica* (70965 Rs ha^{-1}) and minimum near the base of *Acacia auriculiformis* tree (62040 Rs ha^{-1}).

Net return was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that return was maximum near the edge of crown and minimum near the base of tree. Hence the return was maximum near edge of crown under *Acacia nilotica* (35965 Rs ha^{-1}) and minimum near the base of tree of *Acacia auriculiformis*(27040 Rs ha^{-1}).

It was observed that the B:C Ratio was maximum in case of *Acacia nilotica* tree and minimum in case of *Acacia auriculiformis* tree. When compared with various distance it was found that B:C Ratio was maximum near the edge of crown and minimum near the base of tree. Hence the B:C Ratio was maximum near edge of crown under *Acacia nilotica* (2.02) and minimum near the base of *Acacia auriculiformis* tree (1.77).

Weather condition during the study period

The study was undertaken during the July2017-December2017 under the agroclimatic condition prevailing at Ganjam district under East and South-Eastern Coastal Plain zone and North eastern ghat hill regions. The agroforestry systems require a specific range of temperature, precipitation and sunshine hours during different stages of growth for fullest expression of their yield potential because of the shade effect of the tree species (8 years old). Any imbalance in the requirements of the above environmental factors leads to depression in both the crop yield as well as the growth of tree component. The optimum temperature requirement for good yield of rice was found to be 26.9°C during critical period of growth stages. The total rainfall received during the study period was 935.2 millimetres (36.81 in). Sunshine hours had significant correlation with growth and yield performance of the crop because of the presence of tree crop on the rice field bunds.

Environmental factors like temperature, rainfall and relative humidity also affect the growth and yield of both rice and other crops chilli, mango ginger, brinjal and okra (Annual report, AICRP on Agroforestry, OUAT, Bhubaneswar,2008). *Acacia nilotica* recorded the minimum height of 6.8 m due to low level of solar radiation. Similar findings have been reported by (Cornet *et al*. 2014). Other environmental factors also affect the growth and yield of both rice and other tree species present in the rice field bunds (Bhol and Nayak, 2014). The prevailing mean temperature and sunshine hours during the growth stages of rice crop and the associated tree species present in the adjoining field bunds during kharif season were more or less congenial for growth and development of the rice crop and the associated tree crops in the agrisilvicultural system.

SUMMARY AND CONCLUSION

An experiment entitled "**Effect of field bund plantation of nitrogen fixing trees on soil and rice crop**" was conducted in Ganjam district. The experiment was laid out in randomized block design with nine treatments and replicated three times. The results have been discussed in the preceding chapter. The salient findings of the experiment are as follows:

- *Acacia auriculiformis* trees planted in the field bunds were the tallest ones as compared to *Acacia mangium* and *Acacia nilotica*.
- *Acacia nilotica* trees in the field bunds were the shortest as compare to *Acacia auriculiformis* and *Acacia mangium* trees.
- Highest D.B.H and G.B.H recorded in case of *Acacia auriculiformis*.
- *Acacia nilotica* trees were found to have minimum D.B.H. and G.B.H. among bund planted trees.
- The pH of soil in the tree based agroforestry system was found to be more as compared to the pH of soil present in the controlled condition where no tree crop was incorporated.
- Soil present at Edge of crown (30-45cm) under *Acacia nilotica* has maximum pH and minimum pH found near tree base (0-15cm) below *Acacia auriculiformis*. The pH showed an increasing trend with the increase in soil depth.
- Nitrogen content maximum in the topmost layer of soil which decreases with increasing soil depth. Soil under *Acacia nilotica* has maximum Nitrogen content while nitrogen content was found minimum under *Acacia auriculiformis.*
- Status of organic carbon was found maximum near the edge of the canopy and minimum near the base of tree. Organic carbon maximum under *Acacia nilotica* and minimum under *Acacia auriculiformis*.
- The organic carbon content of soil in the 0-15cm soil depth was found to be significantly more as compared to that of soil in the 15-30cm and 30-45 cm depth. The organic carbon content showed a decreasing trend with respect to 0-15 cm depth and then increasing trend with the increase in soil depth

- The phosphorus and potassium status of soil found maximum at edge of canopy and minimum near tree base. Phosphorous and potassium content was highest in the topmost layer which gradually decreases with increase in depth
- Phosphorous and potassium content was maximum under *Acacia nilotica* and minimum under *Acacia auriculiformis.*
- Maximum rice yield and straw yield was found near the edge of the canopy below *Acacia nlotica* tree (47.31 q ha^{-1} and 58.66q ha^{-1} respectively) and rice yield and straw yield was minimum near the tree base of *Acacia auriuculiformis*(41.36 q ha^{-1} and 49.21 q ha^{-1} respectively).
- Gross return was maximum near edge of crown under *Acacia nilotica* (70965 Rs ha^{-1}) and minimum near the base of *Acacia auriculiformis* tree (62040 Rs ha^{-1}).
- Net return was maximum near edge of crown under *Acacia nilotica* (35965 Rs ha^{-1}) and minimum near the base of tree of *Acacia auriculiformis* (27040 Rs ha^{-1}).
- The BCR of various tree based agroforestry system was found to be significantly more as compared to the BCR of the controlled condition.
- B:C Ratio was maximum near edge of crown under *Acacia nilotica* (2.02) and minimum near the base of *Acacia auriculiformis* tree (1.77).

CONCLUSION

Acacia auriculiformis in field bunds recorded maximum growth parameters in terms of tree height (11.5m), D.B.H. (21.9 cm), G.B.H. (69cm). The nutrient status of soil such as soil pH, Organic carbon , available N, P and K was also found significantly higher near the edge of crown as compare to base of tree and away from plant . Net return (Rs 35,965 ha^{-1}) was found highest near the edge of *Acacia nilotica* and also the BCR (2.02). Soil fertility was either maintained or improved in tree based system indicating sustainability of the tree based agroforestry system. Overall, tree based agroforestry system seems to be more beneficial (both in qualitative and economic aspect) in comparison to conventional controlled method of crop cultivation.

REFERENCES

Ajit RP, Handa AK, Choudhury S, Prasad YVK and Pilli AB. 2010. Application of DBMS in forestry and agroforestry, Recent trends for online extension of technology, NCRAF, arid region of north-western India. Agroforestry systems, **15**: 41- 59.

Bargali SS, Bargali K, Singh L, Ghosh L and Lakhera ML. 2009. *Acacia nilotica*-based traditional agroforestry system: effect on paddy crop and management, *Current Science,* **96**(4): 581-587.

Bene JG, Beall HW and Cote A. 1977.Trees, Food and People, IRDC, Ottawa, Canada.

Beniwal RS, Toky OP and Sharma PK. 1996. Effect of VA mycorrhizal fungi and phosphorus on growth and nodulation of *Acacia nilotica* (L.) Wild ex Del. Crop Research (Hisar). **5**: 172-176.

Bini D, Alcantara C, Pierre JB and Cardoso EJBN. 2012. Eucalyptus grandis and *Acacia mangium* in monoculture and intercropped plantations: Evolution of soil and litter microbial and chemical attributes during early stages of plant development, *Applied Soil Ecology***, 63**: 57-66.

Bouillet JP, Laclau JP, Gonçalves JLM, Moreira MZ, Trivelin PCO, Jourdan C, Silva EV, Piccolo MDC, Tsai SM and Galiana A. 2008. *Forest Ecology and Management*, **255** (12): 3918-3930.

Burley J and Wood PJ. 1991. A Tree for All Reasons: The Introduction and Evaluation of Multipurpose Trees for Agroforestry, ICRAF, Nairobi, Kenya.

Chaturvedi OP and Das DK. 2002. *Range management and agorforestry*, **23**(2): 90-94

Dong TL, Doyle R, Beadle CL, Corkrey R and Quat NX. 2013. Impact of short-rotation *Acacia hybrid* plantations on soil properties of degraded lands in

Central Vietnam. *Soil Research* **52**(3): 271-281

Faming WANG, Zhian LI, Hanping XIA, Bi ZOU, Ningyu LI, Jin LIU and Weixing ZHU. 2010. *Soil science plant nutrition*, **56**(2): 297-306.

Ghosh SR, Wadud MA, Mondol MA and Rahman GMM. 2011. *Journal of Agroforestry and Environment*, **5** (2): 1-6.

Githae EW, Gachene CKK and Njoka JT.2011. *African journal of plant science*, **5**(8): 475-482

GOI. 1999. National Forestry Action Programme, Vols. 1/2. Ministry of Environment and Forests, Government of India, New Delhi (Summary).Indian Institute of Forest Management, Bhopal, India.

Izac AMN and Sanchez PA. 2000. Towards a natural resource management paradigm for international agriculture: the example of agroforestry research, *Agricultural Syst*ems, **69**: 5–25.

Jusoh I, Suteh JK, Adam NS. 2017. Growth and Yield of *Acacia mangium* Based on Permanent Sampling Plots in a Plantation. *Transactions on Science and Technology*. **4**(4): 513 - 518

Kasongo RK, Ranst EV, Verdoodt A, Kanyankagote P and Baert G. 2009. *Soil use and management*.**25**(1): 21-27

Kuyah S and Rosenstock Todd S. 2015. Optimal Measurement Strategies for Aboveground Tree Biomass in Agricultural Landscapes. Above ground tree dynamics. Jomo Kenyatta University of Agriculture and Technology (JKUAT), P.O. Box 62000, Nairobi, 00200, Kenya. Agroforestry System. **89**: 125-133.

Lundgren BO and Raintree JB. 1982. Sustained agroforestry, In B. Nestel ed. Agricultural research for development: potentials and challenges in Asia, 37–49.

Mohamed AG. 2005. Improvement of traditional Acacia Senegal Agroforestry. Ecophysiological characters as indicators for tree crop interaction on sandy soil in Western Sudan. A thesis presented with the permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public discussion in auditorium XIII of the University of Helsinki Main Building.

Moore R. 1992. Integrating Wood Production into Australia Farming Systems.*Agroforestry System Journal*. **20**: 167-186.

Nair PKR. 1984. Fruit trees in tropical agroforestry system, EAPI Working Paper. Environmental and Policy Institute, East-West Center, Honolulu, Hawaii USA.

Nair PKR. 1984. Role of trees in soil productivity and conservation, Soil productivity aspects of agroforestry, p. 85, The international council for Research in Agroforestry, Nairobi.

Nair PKR. 1993. An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 499.

Otegbeye GO. 2002. Report on Agroforestry and Land Management Practices, Diagnostics survey of Katsina State of Nigeria, May 2000, Katsina State of Agricultural and Rural Development Authority, Katsina, 89.

Pandey CB, Sharma DK. 2003. Agriculture, Ecosystems & Environment.**96**(1–3): 133-139

Pandey CB, Singh AK and Sharma DK. 2000, Agroforestry systems, **49**(1): 53-61

PandeyDN. 2002. Carbon sequestration in agroforestry systems, *Climate Policy*, **2**:367–377.

Patil MB and Channabasappa KS. 2008. Effect of Tree Management Practices in Acacia auriculiformis Based Agroforestry System on Growth and Yield of Associated Black Gram Karnataka Journal Of Agricultural Science 21: 4.

Patil MB and Channabasappa KS. 2008. Effect of Tree Management Practices in Acacia auriculiformis Based Agroforestry System on Growth and Yield of

Associated Black Gram Karnataka Journal Of Agricultural Science 21: 4.

Pereira APA, Zagatto MRG, Brandani CB, Mescolotti DL, Cotta SR, Gonçalves JLM , Cardoso1 EJBN. 2018. Acacia Changes Microbial Indicators and Increases C and N in Soil Organic Fractions in Intercropped Eucalyptus Plantations. Front Microbiol. 9: 655.

Prasad R and Pandey DN. 2000. Trees outside forests in India: A national assessment.

Prinsley RT. 1992. The Role of Trees in Sustainable Agriculture - an Overview. Bureau of Rural Resources, DPIE Australia, *Agroforestry Journal*, **20**: 87-115.

Power IL, Thorrold BS, Balks MR. 2003. Soil properties and nitrogen availability in silvopastoral plantings of Acacia melanoxylon in North Island, New Zealand Agroforestry systems. **57**(3): 225–237.

Puri S. and Banagrwa KS. 2013. Effects of Trees on the Yield of Irrigated Wheat Crop in semi-arid Regions. Department of Agroforestry Haryana Agricultural University 125 004 Hisar India. **4**: 229-241.

Puri S. and Banagrwa KS. 2013. Effects of Trees on the Yield of Irrigated Wheat Crop in semi-arid Regions. Department of Agroforestry Haryana Agricultural University 125 004 Hisar India. **4**: 229-241.

RaiSN and ChakrabartiSK. 2001. Demand and supply of fuelwoodand timber inIndia, Indian Forester, **127(3)**:263–279.

Ravindranath NH and Hall DO. 1995. Biomass, energy and environment: a developing country perspective from India, p. 376, Oxford University Press, New York.

SaeLee S, Vityakon P, Prachaiyo B. (1992). Effects of trees on Paddy bunds on Soil Fertility and Rice Growth in Northeast Thailand.*Agroforestry System Journal*. **18**: 213-223.

Sharma KK. 1992. Wheat Cultivation in Association with Acacia nilotica (L.)Willd ex. Del. Field bund plantations - a Case Study .Agroforestry System **17**: 43-51.

Sinclair FL. 1999. A general classification of agroforestry practice, *Agroforestry systems*, **46**: 161- 180.

Toky OP, Beniwal RS and Sharma PK. 1994. Interaction between rhizobium inoculation and nitrogen fertilizer application on growth and nodulation of *Acacia nilotica* subsp. *indica*

VergaraNT. 1982. New Directions in Agroforestry: The potential of tropical tree legumes, p. 52, Honolulu: Environment and Policy Institute, East-WestCenter.

Viswanath S., Nair PKR, Kaushik PK andPrakasam U. 2000, *Acacia nilotica* trees in rice fields: A traditional agroforestry system in central India **50**: 157–177

Voigtlaender M, Laclau J, Gonçalves JLM, Piccolo MC, Moreira MZ, Nouvellon Y, Ranger J and Bouillet J. 2012. *Plant Soil*, **(352)**:99–111

Xiong Y, Xia H, Li Z, Cai X and Fu S. 2008. *Plant and soi*,. **304**(1-2): 179-188

Yadav RP, Sharma P, AryaSwarn L. and Pankaj 2014 *Acacia Nilotica*-Based Silvipastoral Systems for Resource Conservation and Improved Productivity from Degraded Lands of the Lower Himalayas. *Indian Forester* **88**: 851-863.

Yadav RS, Yadav BL. Chhipa BR.2008. Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. *Agroforestry systems*, **73**(1):1–12

Yamashita N, Ohta S and Hardjono A. 2008.Forest Ecology and Management**(254)**: 362–370

Young A. 1989a. Agroforestry for Soil conservation and Erosion Control, p. 102-115, CAB International, Wallingford, UK.

Young A. 1989b. 10 Hypotheses in Agroforestry for the Conservation or improvement of Soil Fertility. Agroforestry Today, ICRAF Publication, **1**: 22-31.

Young, A. 1988. Agroforestry and its potential to contribute to land development,

Annual Report (2009). AICRP on Agroforestry, O.U.A.T., Bhubaneswar, pp 36.

Puri S, Singh S and Kumar A.1994. Journal of Arid Environments**27**(1): 37-48.

Matali S and Metali F. 2015. Malaysian Journal of Soil Science .**19;** 45-58.

Tanaka S, Kano S, Lat J and Kendawang JJ. 2015. Article in Journal of Tropical Forest Science **27**(3): 357-368

Vijayanathan J, Yahya AZ, Yaacob A, Kassim AS and Chik SW. 2011. *Malayasian journal of soil science* **15;** 75-85.