

Estimation of Carbon Credit under different Land Use Systems in Vindhyan Region



THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
Master of Science (Agriculture)
in
Agroforestry

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Sir,

I have great pleasure in forwarding the thesis entitled "*Estimation of carbon credit under different land use systems in Vindhyan region.*" submitted by **Mr. Ashutosh Yadav**, I.D No. **17430AGF008** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture) in Agroforestry**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that he has completed the requisite requirements as contained in the statutes of the University.

I certify that the entire scheme of investigation reported herein was planned, and carried out solely by the candidate under my guidance and supervision. The data presented in the thesis, to the best of my knowledge and belief, are genuine and have not been utilized for the award of other degree or dissertation.

Thanking you.

Yours faithfully

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Dr. Ram Swaroop Meena
(Supervisor)

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“Estimation of Carbon Credit under Different Land Use Systems in Vindhyan region”

Thesis submitted in partial fulfillment of the requirements for the award to degree of

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LIST OF ABBREVIATIONS

\$	Dollar
%	Per cent
@	At the rate of
AF	Agroforestry
AFS	Agroforestry systems
AFTA	Association for Temperate Agroforestry
AH	Agri-horticulture
AHS	Agri-horti-silviculture
Approx.	Approximately
AS	Agri-silviculture
BD	Bulk density
C ha ⁻¹	Carbon per hectare
C ha ⁻¹ yr ⁻¹	Carbon per hectare per year
CD	Critical difference
CH ₄	Methane
cm	Centimeter
CO ₂	Carbon dioxide
CSP	Carbon sequestration potential
DBH	Diameter at breast height
DOE	Department of Energy
<i>et al.</i>	And co-workers
FCCC	Framework Convention on Climate Change
g	gram
g Kg ⁻¹	Gram per kilogram
gcm ⁻³	Gram per centimeter cube
GHG	Green House gas
GHGs	Green house gasses
Gt	Giga tonne
ha	Hectare (10,000 m ²)
HP	Horti-pastoral
i.e	That is
IPCC	Intergovernmental Panel on Climate Change
Kg cm ⁻²	Kilogram per square centimeter
Kg CO ₂ ha ⁻¹ day ⁻¹	Kilogram carbon dioxide per hectare per day
Kg ha ⁻¹ day ⁻¹	Kilogram per hectare per day
Kg ha ⁻¹ Yr ⁻¹	Kilogram per hectare per year
Kg m ⁻²	Kilogram per square meter
Km	Kilometer
m	Meter
M ha	Million hectare
m.a.m.s.l	meter above mean sea level
MAP	Mean Annual precipitation
MAT	Mean Annual Temperature
Mg c ha ⁻¹	Mega gram carbon per hectare
Mg c ha ⁻¹ yr ⁻¹	Mega gram carbon per hectare per year
Mg ha ⁻¹	Mega gram per hectare
Mg km ⁻¹ yr ⁻¹	Mega gram per kilometer per year

MMTCY ⁻¹	Million metric tonne carbon per year
MT	Million tons
N	Nitrogen
N ₂ O	Nitrous oxide
NE	North East
NRCS	National Resource Conservation Services
oC	Degree Celsius
OC	Organic carbon
P	Phosphorus
PA	Pure agriculture
Pg	Petagram
PG	Pure grassland
Pg C	Peta gram carbon
Pg c yr ⁻¹	Peta gram carbon per year
PP	Pure plantation
PPM	Part Per Million
Rs. ha ⁻¹ yr ⁻¹	Rupees per hectare per year
SOC	Soil Organic carbon
SOM	Soil organic matter
SP	Silvi-pastoral
t c ha ⁻¹	Tonne Carbon per hectare
t c ha ⁻¹ yr ⁻¹	Tonne Carbon per hectare per year
Tg	Tera gram
Tg C yr ⁻¹	Teragram Carbon per year
UNCED	United Nations Conference on Environment and Development
US\$	United State's dollar
USA	United States of America
USDA	United State Department of Agriculture,
WANA	West Asia and North Africa

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INTRODUCTION

It is estimated that by the year 2050, world human population will climb to 9.7 billion, and India's population is projected to overtake that of China, will rise to 1.6 billion, from its current level of 1.2 billion. Skewed use of major fertilizer nutrients without soil sustainability is a major concern for achieving the ecosystem intensification required to feed the growing world population nutritious food under changing climate. A challenge for agricultural scientists is to feed the world population with nourishing food.

India contributes 2 percent of the world's land surface to 16 percent of the population. Its population is growing at a rate of 15 million per year, while the size of an average farm holding is shrinking to provide adequate food and fiber for more than a billion people. Indian agriculture is to be revolutionized from subsistent to intensive farming by increasing crop intensity. Implementation of high yielding varieties, changing patterns of land use, etc.

An estimation reveals that 5% of the world's forests are managed as agroforests; given that the total area under forest is 4000 million ha, the area under agroforestry in forest lands is 200 million ha (FAO, 2007) in an another estimate. The total area under agroforestry in the world is 1023 million ha (Nair et al., 2009). Currently Forest Survey of India reported 1, 11, 554 sq km (3.39 per cent of country's geographical area) area under agroforestry (FSI, 2013). The major shares of the land to be brought under agroforestry will come from fallows, cultivable fallows, pastures, groves and through rehabilitation of problem soils.

Agroforestry plays a vital role in the Indian economy by way of tangible and intangible benefits. It helps in rehabilitation of degraded lands on one hand and increases farm productivity on the other. Changing priorities in avenues like bio-fuels, employment generation, carbon sequestration and optimization of farm productivity are now being focused through agroforestry. Agroforestry systems of any region are characterized by specific plant composition environmental conditions and socioeconomic factors with distinct association of the components and their management. As far as estimating the area under agroforestry is concerned, a major difficulty is the lack of proper procedures for delineating the area influenced by trees in a mixed stand of trees and crops. The entire area occupied by multistrata systems

such as homegardens, shaded perennial systems and intensive tree intercropping situations is listed as under agroforestry.

The terms: 'land unit' (LU), 'land use type' (LUT) and 'land use system' (LUS) have been widely accepted since Food and Agriculture Organization introduced them in the 1970s. They were effective in illustrating that the same type of soil can function in different ways, depending on land use, when applied in the context of land assessment. Soil functioning has to be increasingly considered in a broader context than crop production alone. Environmental laws have been enacted in many countries calling for sustainable forms of land management, which implies achieving economically and socially acceptable levels of production in systems that are in harmony with nature and the environment.

Many other workers have highlighted the importance of street cultivation (Kang et al., 1981 and 1984; Kang and Wilson 1987; Kessler and Breman 1991), law farming (Jaradat 1990) and agro-horticultural and forestry systems (Dicken 1990; Das et al., 1993). Arable farming is India's dominant form of farming. Recently, alternative land-use systems consisting of pastures and perennials are receiving vigorous attention, in particular rainfed areas. Soils of the world's semiarid tropical regions are almost exhausted by organic soil matter and fertility. This is mainly due to rapid oxidation of organic matter, washing away nutrient-rich top soil with runoff water, poor recycling of crop residues, continuous and intensive crop cultivation without nutrient replenishment by chemical fertilizers. Annual crop failure results in climatic aberrations and frequent droughts. In rainfed lands, where it is remote to raise more than one crop per year, land-use systems with more than one component have a clear advantage. This led to the adoption by the farming community of diversified land-use systems such as agroforestry, agri-horticulture, agri-silviculture, silvi-pastoral, pastoral, etc., as these systems provide stability and sustainability for farming systems in semi-arid tropics, especially when frequent droughts occur. These diversified systems of land use not only help the farming community to secure income in the event of drought, but also protect the land from degradation and improve the quality of the soil. For the past three decades, the art and science of growing trees (or other woody perennial plants) in combination with crops or animals has been christened as 'agroforestry' and has gained considerable attention in the scientific community. Trees and shrubs have traditionally been managed and used for shelter, wood, browse, fruit or nuts in agricultural landscapes around the world, and in many developing countries they continue to be essential for these purposes.

The land-use systems have helped to increase the soil's organic carbon (SOC) content, cation exchange capacity (CEC), exchangeable cations, total nutrients, and hydrolysable soil pools over the arable soil. The soil fertility could be improved by managing the organic matter and nutrients in land use systems. The mechanisms leading to improved soil fertility and overall chemical soil quality through the adoption of these land-use systems could be **(i)** nutrient mining from underground layers and their efficient cycling, **(ii)** biological nitrogen fixation by tree legumes, **(iii)** solubilization of hard-to-reach plant nutrients through root exudates and acid secretions, and **(iv)** carbon sequestration to improve the soil carbon stock and mitigate the climate change. Brinson et al. (1980) pointed out that the main recognized avenue for adding organic matter from the trees standing on it to the soil was through litter fall, i.e. through dead and falling leaves, branches of twigs and so on. The term SOM was used to include all organic materials found in soil (Stevenson, 1994), excluding charcoal (Oades, 1988) and partially decomposed products and non-decomposed plant and animal tissues (McCarthy et al., 1990). It ranged from <0.5% carbon in Aridisols to 33% in Histosols (Sombroek et al., 1993). The top soil having an average depth of about 15–30 cm on which plants grow and the farming activities flourishes. Now-a-days, it is facing serious problems due to human pressure and utilization incompatible with its capacity. Hence, it is important to keep healthy and productive soil to continue our soil to function optimally to increase agriculture production with appropriate soil amendment and crop management practices (MacCarthy et al., 2013).

Research efforts that relate micronutrient deficiency in soils with human health and its remediation are only at infancy in India. The research work on soil carbon and human health is very scanty despite the obvious connection between soil nutrients status and human health are known since time immemorial. Today, most agricultural systems in the developing world do not provide enough nutrients. Many fall short of supplying enough micro/macronutrients to meet human needs, even though the production of energy and protein via cereal crops appears to be adequate to feed the world. Global climate change and energy security are two key issues that are at the forefront of environmental discussions the world over. Although they bring up unique challenges, global warming and energy security are inextricably interlinked. Increasing concentration of atmospheric carbon dioxide (CO₂) is considered the predominant cause of global climatic change. It is believed that agricultural and forestry practices can partially mitigate increasing CO₂ concentration by sequestering carbon. Similarly, alternative agricultural practices where biomass crops are cultivated can impact CO₂ levels not only by

sequestering C, but also by replacing fossil fuel with the biomass produced. Agroforestry, like many other land use systems, offers great potential for sequestering carbon and producing biomass for biofuels. Ever since the Kyoto Protocol, agroforestry has gained increased attention as a strategy to sequester carbon from both developed and developing nations. The available estimates of carbon stored in agroforestry range from 0.29 to 15.21 Mg C ha⁻¹ year⁻¹ above ground, and 30–300 Mg C ha⁻¹ up to 1 m depth in the soil (Nair et al., 2010).

The cost aspect of forest based carbon sequestration, as an offset mechanism is particularly important. It determines how carbon sequestration compares with other potential carbon offset mechanisms in the broader scheme of greenhouse gas reduction policies. According to the protocol, each country will be given carbon credits based on the carbon emission and sequestration scenario. If developing countries like India, has to improve on the issue of carbon credits, then role of vegetation patches in carbon sequestered should be considered.

According to Ravindranath et al. (1997) the standing biomass (as above and below ground biomass) in India is estimated to be 8,375 million tons for the year 1986, of which the carbon storage would be 4,178 million tones. The total carbon stored in forests, including soil is estimated to be 9578 m t. On the other hand, carbon emissions from fossil based energy production and consumption activities in India have been estimated at 152-205 m t per year

In this context, a study has been done to compare different agroforestry system and agriculture land use pattern. Keeping these points in view, the present study entitled **“Estimation of carbon credit under different land use system in Vindhyan region”** was carried out with the objectives as listed below.

- i) To study the effect of different land use system on physio-chemical properties of the soil.
- ii) To evaluate the effect of different land use systems on carbon sequestration and carbon credit.
- iii) To identify the land use system which helps to sequestrate more carbon and helps to mitigate the climate change.



REVIEW OF LITERATURE

In this chapter an attempt has been made to present review of research work done in the country on the status of soil physico-chemical properties and carbon sequestration potential of different land use system.

2.1 Soil physico-chemical properties

2.1.1 Soil pH

Surendra et al. (2003) reported that the pH of east Singhbhum rice soils ranged from extremely acidic to moderately alkaline, while Patil and Prasad (2004) reported that the pH of Madhya Pradesh district Dindori soils ranged from 5.6 to 6.8. Ved et al. (2008) observed that in the Bajaj Sugar Mill Bhasana, Muzaffarnagar district of Uttar Pradesh, the pH of the study area ranged from 7.25 to 8.26 with an average of 7.79 respectively. Kadu et al. (2009) studied soils from Maharashtra's Wardha command area and observed that soils are moderately to strongly alkaline in pH response ranging from 7.5 to 8.8. Srinivas et al. (2011) reported that the pH of west Krishna soils in Andhra Pradesh ranged from 7.0 to 7.8. Parihar et al. (2013) conducted a survey in guava orchard soils of Satpura hills of Madhya Pradesh and reported that the pH of the soils ranged from 7.0 to 9.0 (neutral to alkaline). Kavitha and Sujatha (2015) conducted a study to assess the status of soil fertility in eight major agro-ecosystems and collected 5120 samples from different agro-ecosystem: coconut, banana, rubber, paddy, arecanut, nutmeg, pepper and vegetables in Thrissur district of Kerala. Results showed that soil reactions in the study area ranged from highly acidic to slightly alkaline with pH values ranging from 2.9 to 7. Sheeja (2015) investigated macro and micronutrients in Periyakoattai (S1) and Tamil Nadu Thirumangalkkattai (S2) soils. Soil samples collected in January 2015 from Periyakoattai and Thirumangalkkattai. Soils in that study area show high pH values (< 8) indicating their alkaline nature that can be counteracted by adding basic fertilizers.

2.1.2 Electrical conductivity (EC)

Ved et al. (2008) found that EC ranged from 0.14 to 0.54 dSm⁻¹ with an average of 0.32 dSm⁻¹ in the Bajaj Sugar Mill Bhasana, Muzaffarnagar district of Uttar Pradesh, respectively. Kankal (2009) Krishi Vigyan Kendra, Selsura, under Dr. Panjab Rao Deshmukh Krishi Vidyapeeth, Akola (M.S.), conducted a survey of the Nagpur Mandarin (*Citrus reticulata* Blanco) growing belt of the Wardha district of Maharashtra State and selected 50 ambia flush orchards aged 10 to 15 from three tehsils. 27 orchards were classified as low yields from selected 50 orchards, while 23 orchards were classified as high yields. Composite soil samples have been collected and analyzed using standard procedures for 14 parameters as a measure of soil fertility status. Soil characteristics showed that the Nagpur mandarin soils growing in the district of Wardha in the Vidarbha region EC range from 0.11 to 0.91 dSm⁻¹. Bali et al. (2010) observed that the soil solution EC ranged from 0.14 to 1.37 dSm⁻¹ in Punjab state with an average value of 0.46 dSm⁻¹. Sharma et al. (2013) conducted a survey to analyse the fertility status of forest and rice land use systems in the Nagaland district of Mokokchung and found that the electrical conductivity of forest and rice land use systems varied between 0.10 and 0.28 dSm⁻¹.

2.1.3 Bulk density (g /cc)

Smith and Heath (2002) reported that the soil bulk density ranged from 0.77 to 0.84 g/cc. John (2004) reported a soil bulk density between 1.33 g/cc at 0-15 cm and 1.41 g/cc at 15-30 cm soil depth in wheat.

2.1.4 Available organic carbon

The SOC is a complex heterogeneous mixture of organic substances which imparts the physical, chemical and biological fertility of soil. Currently the scientists are gaining interest in the role of SOC as a potential sink for atmosphere CO₂. Veni et al. (2014) conducted a study to investigate the different organic carbon pools under different land-uses at IARI New Delhi. Land-use system evaluated include: Maize-wheat cropping, Rainfed *Alovera*, Forestry, Agroforestry and Rice-Wheat etc. The soil organic carbon was divided into two pools such as labile pool and recalcitrant pool from the view point of different fractions of labile and recalcitrant pools, the performance of land-use systems was in the order of; Forestry > Agroforestry > Rice-wheat system > Maize-wheat system > Rainfed *Alovera*. Bhardwaj et al (2013)

carried out a study to evaluate the status of soil organic carbon stocks under different land-use system in wet temperature, North Western Himalayas. The seven land-uses selected were; Agri-horticulture (AH), Silvi-pasture(SP), Agri-silviculture (AS), Horticulture (H), Forest (F), Agriculture (A), and Grassland (G). They reported that the maximum soil organic carbon (2.45%) was found in the forest land use system, which was followed by agri-horticulture (0.96%), agri-silviculture (0.88%), horticulture (0.85%), grassland (0.79%) and silvipasture (0.76%) and agriculture (0.58%). They further reported that the increased organic carbon content in soils under tree based system may be ascribed to more leaf litter deposition and root turnover from trees.

Chandran et al. (2009) evaluated three system viz. agriculture, horticulture and forest under semi-arid tropical climate for the changes in SOC with type of land-use. They reported the maximum value of SOC was in forest system, followed by horticulture and minimum in agriculture system. Celik (2005) compared three adjacent land-use namely the cultivated lands, which have been converted from pasture for 12 years, fragmented forests, and unaltered pastures lands. He also reported that the SOC pool cultivated lands for a depth of 0-20 cm were significantly reduced, on average by 49 per-cent relative to SOM content of the pasture lands. However SOM values of the forest and pasture lands were almost similar. There was no significance difference in SOM content at a particular depth under each land-use type.

Eswaran et al. (1993) observed that the global SOC pool contains 1500 Pg C and is two to three times greater than the amount of carbon stored in vegetation. John (2004) reported a soil organic carbon of 0.72 to 0.97 % at a depth of 0-15 cm in wheat. Das et al. (2011) observed 0.45% soil organic carbon in soil (0–15 cm depth) on 6-year-old (*Emblica officinalis*) Gaertn. cv. NA-7) orchard under rainfed calciorthent soil. While, Das et al. estimated that the maximum content of soil organic carbon for paddy was in 0-30 cm layer (0.82%). Gupta et al. (2009) at central Punjab of NW India observed an average SOC of 0.36% in sole crop and 0.66% in *poplar*-based agro-forestry plantation under agro-forestry soils. Chandra et al. (2009) conducted an experiment and observed that soil organic carbon varied in three different systems i.e., forest, horticulture and agriculture. In forest system at 0-15 cm depth of soil it was found to be SOC 44.5 Mg C ha⁻¹ and in horticulture system 22.2 Mg C ha⁻¹, in agriculture system 18.8 Mg C ha⁻¹. At 30 cm depth of soil, soil organic carbon in forest system was 79.6 Mg ha⁻¹, in horticulture 37.5 Mg C ha⁻¹ and in agriculture system 33.1 Mg ha⁻¹. Sudha and George (2011) observed that among the different cropping systems, *Coconut*

(*Cocos nucifera*) + Pineapple (*Ananas comosus*) system maintained the highest SOC of 1.30%. Koul and Panwar (2012) reported that the soil organic carbon ranged from 0.399% to 1.768 % in different agro-forestry systems but it was lower in paddy field. Gupta et al. (2014) reported that amongst orchards, the maximum SOC stock was under *Citrus lemonum* (lemon) and the minimum under *Aegle marmelos* (bael). In agroforestry land uses, *A. excels*, *Gossypium herbaceum* (kapas) model contained the highest amount of SOC whereas *Cicer arietinum* (*Chana*) – *Acacia tortilis* (Israeli babool) stored minimum amount of SOC.

2.1.5 Soil organic carbon density (t ha⁻¹)

Singh et al. (2011) observed that the C stock ranged from 8.5 to 15.2 t C ha⁻¹ at the upper 40 cm soil layer. They further reported that the SOC concentration was highest (101.8 Mg ha⁻¹ in 0–30 cm, 227.97 Mg ha⁻¹ in 0–100 cm) in temperate and lowest in subtropical climate (37 Mg ha⁻¹ in 0–30 cm, 107.04 Mg ha⁻¹ in 0–100 cm). SOC stocks were greater in natural ecosystems like forests and pastures (112.5 to 247.5 Mg ha⁻¹) than agriculture (63 to 120.4 Mg ha⁻¹). In temperate climate, SOC stock in agriculture (253.6 Mg ha⁻¹) on well-formed terraces was little higher than forest (231.3 Mg ha⁻¹) on natural slope. Srinivasa rao et al. (2013) reported that the rate of depletion of soil organic carbon was 0.15 Mg C ha⁻¹yr⁻¹ in rice based system and highest in groundnut–finger millet system (0.92 Mg C ha⁻¹yr⁻¹) in semi-arid bioclimatic (Alfisols). Gupta et al. (2009) recorded higher soil organic carbon 2.9–4.8 Mg /ha under agroforestry systems than in sole crop. Fonseca et al. (2011) reported the soil carbon accumulation of 1.1 Mg ha⁻¹ yr⁻¹ by young secondary forests (4 to 20 years), while in the forest it was 180.4 Mg ha⁻¹ (20 years). Dube et al. (2012) observed that soil organic carbon stocks at (0–40) cm depth were 193.76, 177.10 and 149.25 Mg ha⁻¹ in *Pinus ponderosa*-based silvopastoral systems (SPS), natural pasture (PST) and pine plantations (PPP) respectively. Grace et al. (2012) reported that the carbon sequestration potential of rice–wheat systems of India was 44.1 Mt C under of no- tillage of 20 years. Implementing no-tillage practices in maize–wheat and cotton–wheat production systems would yield an additional 6.6 Mt C on indo-gangetic plains. Whereas, Makumba et al. (2007) at the Makoka (Malawi) reported that the amount of organic carbon would vary from 0.8 to 4.8 Mg C ha⁻¹ by *Gliricidia*-maize and 0.4 to 1.0 Mg C ha⁻¹ by sole-maize. Kimaro (2009) recorded that soil organic carbon stocks (within 0–30 cm depth) under 5 year old rotational wood lots (15.8–25.6 Mg C ha⁻¹) in Morogoro were higher than in soils that has been continuously cropping for the same time period (13 Mg ha⁻¹) and followed by Miombo soils had 9–15 Mg C ha⁻¹.

2.1.6 Available nitrogen status in soils

Chibba et al. (1985) reported that available content of nitrogen varied from 138 to 295 kg ha⁻¹ in acidic soils of Panchrukhi, Kangra, Baijnath and Dehra blocks in Kangra district of Punjab. Rajesh et al. (1994) reported that available nitrogen content varied from 85-282 kg ha⁻¹ in soil of Guntur District of Andhra Pradesh. Kumar et al. (1995) reported that available nitrogen content varied from 203.8 to 407.2 kg ha⁻¹ in soils of Soan river valley of lower Shiwaliks. Sahu et al. (1995) observed that in soils of Sunderbans of West Bengal, available nitrogen content varied from 41 to 128 kg ha⁻¹. Verma et al. (2005) reported that the available nitrogen content 100 kg ha⁻¹ in soils of arid tract of Punjab, India. The data indicates that majority of the soil samples from all study blocks are low in available nitrogen content. The high temperature prevailing in the area is responsible for the rapid burning of organic matter, thus resulting in low organic carbon content of these soils. Since organic matter contents are an indicator of available nitrogen status of soils, thus the soils of the area are also dominantly low in respect of their available nitrogen. Meena et al. (2006) reported that the available nitrogen content varied from 125 to 555 kg ha⁻¹ with an average value of 309 kg ha⁻¹. On the basis of the rating suggested by Subbiah and Asija (1956), 32 % samples were Low (< 250 kg ha⁻¹ N), 61% medium (250 to 500 kg ha⁻¹ N) and only 7 % samples were high (> 500 kg /ha N) in available nitrogen, in light texture soils of Tonk district of Rajasthan.

2.1.7 Available phosphorous status in soils

Sood et al. (2003) studied in the Talwara block of Hoshiarpur district (Punjab) that the phosphorus content available varied from 1.8 kg ha⁻¹ to 32.5 kg ha⁻¹ with an average of 12.0 kg ha⁻¹ in surface soils. In surface soils, 59 percent of samples tested low in phosphorus available, 22 percent tested medium in phosphorus available, and 19 percent tested high in phosphorus available. Verma et al. (2005) reported that the phosphorus content of these soils ranged from 1.8 to 59.6 kg ha⁻¹ with an average value of 18.46 kg ha⁻¹ in Punjab Arid Tract Soils. In general, available phosphorus ranged from low to medium, but high values of available phosphorus are also found in some part of the area about 45% soil samples tested low, 17% medium and 38% soil samples tested high in available phosphorus content. The data indicates that majority of the soil samples from Sardulgarh and Jhunir blocks are low in available phosphorus content; whereas, that of Bhikhi and Budhlada blocks are high in available phosphorus content. Meena et al. (2006) reported the available phosphorus content varied from 9.2 to 65.2 kg ha⁻¹ with a mean value of 25.2 kg ha⁻¹ in light texture soils of Tonk District of Punjab. Kumar et al. (2009)

observed that an available phosphorus content in soils ranged from 5.80 to 14.20 (Dumka series) and 7.00 to 13.40 kg ha⁻¹ (Lachimpur series) with a mean value of 10.0 and 9.0 kg ha⁻¹ phosphorus in light texture soils of Dumka and sandy loam soils of Lachimpur series, respectively. Both the series had 70 to 60% low level of available phosphorus in soils of Santhal Paraganas Region of Jharkhand.

Rajeswar et al. (2009) reported that the available Phosphorus content in all the pedons varied from 5.3 to 33.4 kg ha⁻¹. However, the highest available phosphorus was observed in the surface horizons and distribution of available phosphorus decreased regularly with depth and higher phosphorus in the surface horizon in soils of Garikapadu in Krishna District of Andhra Pradesh. Singh et al. (2014) revealed that fertility status of alluvial and medium black soil and ravinous land, and their correlation studies were carried out for Chambal region of Madhya Pradesh. The range of available P were 7.0 to 29.5 kg ha⁻¹ in alluvial soil; 7.9 to 28.8 Kg ha⁻¹ in medium black soil and, 6.2 to 25.3 Kg⁻¹ in ravinous land, respectively. of alluvial soil samples, 14% low, 68% medium and 18% high in P. of medium black soil samples 21% low 69% medium and 10% high in P. of ravinous land soil samples, 68% low and 32% medium in P. Ramana et al. (2015) reported that the present investigation Raisingh Nagar block was selected in the district Sri Ganganagar of Rajasthan and studied the available macronutrient status and their relationship with physico-chemical properties. Twenty seven representative villages were chosen and four surface soil (0-15 cm) samples collected from each village. Results of the study shows that soils of Raisingh Nagar block were out of 108 collected soil samples medium to high in available phosphorus

2.1.8 Available potassium status in soils

Ghosh et al. (1996) reported that available content potassium varied from 62 to 262 kg ha⁻¹ and 52 to 386 kg ha⁻¹, respectively in soils of Jagannathpur and Barakonda of West Bengal. The higher value of available potassium in the Barakonda series explained as intensive weathering leading to increased released of potassium to the exchange site of clay minerals. Sharma et al. (2001) reported that status of available potassium in the soils ranged from 72.5 to 464.5 kg ha⁻¹ in soils of Aligarh District. Verma et al. (2005) reported that the available potassium content of these soils is generally medium to high, and only 3 % soil samples tested low in available potassium. It ranged from 67.2 to 851.2 kg ha⁻¹ with a mean value of 291.15 kg ha⁻¹. About 52 and 45% samples tested medium and high in available potassium, respectively. The available potassium content of soils of Sardulgarh, Bhikhi and Budhlada

blocks is medium and that of Jhunir and Mansa is high. Meena et al. (2006) reported that status of available potassium (K_2O) in the soils ranged from 105 to 1059 $kg\ ha^{-1}$ with an average of 377 $kg\ ha^{-1}$ in the light texture soils of Tonk District of Rajasthan. Kumar et al. (2009) observed that the content of available potassium in soils of Dumka series varied from 111 to 145 $kg\ ha^{-1}$ with a mean value of 124 $kg\ ha^{-1}$ and in Lachimpur series varied from 110 to 188 $kg\ ha^{-1}$ with a mean of 134 $kg\ ha^{-1}$. The available potassium in both the series was medium in status in soils of Santhal Paraganas region of Jharkhand.

2.1.9 Available Status of Iron

Iron plays role in electron carrier for many enzyme activities and it constituent of cytochromes, haem and non-haem enzymes. It promotes starch formation and seed maturation. Iron is necessary for the synthesis of chlorophyll, but it is not a constituent of chlorophyll. Deficiency of iron shows chlorosis of young leaves and veins remain green. In severe deficiency of iron, leaves become almost of pale white due to losses of chlorophyll.

Sharma et al. (2001) reported that DTPA-extractable Iron ranged from 1.8 to 26.4 ppm with a mean value of 8.5 ppm and 13.3% samples tested low in available iron in Rajgarh district of Madhya Pradesh. Meena et al. (2006) reported that status of available iron in the soils ranged from 2.23 to 14.16 $mg\ kg^{-1}$ with an average of 5.38 $mg\ kg^{-1}$ in light texture soils of Tonk District of Rajasthan. Nazif et al. (2006) reported that the AB-DTPA extractable iron ranged from 5.37-23.3 $mg\ kg^{-1}$ AB-DTPA extractable iron was found high in all sites. The micronutrient status of soils of district Bhimber (Azad Jammu and Kashmir) was made at 30 different locations. Sharma and Chaudhary (2007) reported that available iron contents in the soil profiles of different soil series ranged from 8.2 to 50.2 $mg\ kg^{-1}$ and are comparable with those reported by Gupta et al. (2003) in soils of Madhya Pradesh. All the soils had sufficient amounts of available iron in lower Shiwaliks of Solan district in North–West Himalayas. Kumar et al. (2009) observed that an available iron content of Dumka and Lachimpur series varied from 2.50 to 15.80 $mg\ kg^{-1}$ with a mean of 7.66 $mg\ kg^{-1}$ and 6.40 to 96.50 $mg\ kg^{-1}$ with a mean of 19.41 $mg\ kg^{-1}$ respectively in soils of Santhal Paraganas region of Jharkhand

2.1.10 Available zinc status in soils

Zinc involves in protein synthesis, reproductive process of certain plants, seed maturation, RNA synthesis, formation of starch and some growth hormones. It has positive role in photosynthesis and nitrogen metabolism. Deficiency of zinc shows intervenal chlorosis of

the foliage, particularly in lower leaves, with reduction in the size of young leaves. Rice plant shows 'Khaira' diseases due to deficiency of zinc. Singh et al. (2009) reported that the DTPA – Extractable Zn content in the surface and sub-surface soils varied between 0.3 to 2.1 mg kg⁻¹. About 24% of the samples were deficient in available Zn in the soils of district Ghazipur, Uttar Pradesh.

2.2 Estimation of carbon sequestration in agroforestry

Sathey and Ravindarnath (1998) reported that on an average 25 tonnes carbon sequestration potential per hectare in agro-forestry in India. The emerging carbon market may provide a new agro-forestry option for land holder provide the carbon prices are higher enough to make growing trees a worthwhile investment than existing land use. Watson et al. (2000) reported that the average sequestration potential in agro-forestry had been 30 tonne of carbon per hectare 85 million hectare in China. They also estimated carbon gain of 72 tonne of carbon per hectare on 4000 million ha land under Agro-forestry, with potential for sequestering 26 tonne of carbon per year by 2010 and 45 tonne of carbon per year by 2040. Zelek and Shively (2005) inspected 56 agroforestry practices in eight countries and found that a majority was profitable in 40 % of cases, financial return were at least 25 % higher than alternate farming practices. They also reported that agroforestry system were low cost carbon sequestration alternatives to pure forest conservation.

2.2.1 Estimation of carbon sequestration potential

Dixon et al. (1994) demonstrated that carbon stock in each tree could be assessed by multiplying the total above ground biomass of individual tree with carbon fraction 0.5. Brown et al. (1997) gave an algometric equation to estimate biomass (kg) of above-ground vegetation. That biomass regression equation was used for most species and the equation was $\exp \{-2.134 + 2.530 \times \ln \text{DBH}\}$ (DBH=diameter at breast height). Cairns et al. (1997) recorded that the below ground biomass (BGB) could be calculated by multiplying above ground biomass by 0.26 as the proportion of root to shoot. The below-ground biomass could be calculated using the default IPCC value (above-ground biomass x 0.27) according to the formula mentioned by IPCC (2006).

2.3 Parameter recorded for carbon sequestration

2.3.1 Biomass accumulation of different land use systems

2.3.1.1 Above ground biomass accumulation

Naugraiya and Puri (2001) recorded highest above ground biomass in *Leucaena leucocephala* (38.0 kg per tree) followed by *Eucalyptus tereticornis* (26.1 kg/tree) and *Albizia procera* (24.8 kg per tree). Jarecki and Lal (2003) reviewed that the potential of agroforestry systems to store carbon was 0.25–1.58 Mg C ha⁻¹ yr⁻¹ in the soil and 0.98–6.7 Mg C ha⁻¹ yr⁻¹ in above-ground biomass. Subedi (2004) conducted above ground biomass studies of *Quercus semecarpifolia* in temperate forests of Nepal. Above ground tree layer biomass was found to be 479.17, 357.53, 462.60, 358.02, 272.15 and 304.21 t ha⁻¹ from east to west directions in temperate forest respectively. Gourav and Roy (2006) studied on above ground biomass production of 12 years old trees of *Acacia tortilis* in association with pasture under Silvopastoral system showed the mean woody biomass production and total aerial biomass production. The mean woody biomass production was 4.79 t ha⁻¹ yr⁻¹ and the total aerial biomass production varied between 4.22 and 5.69 t/ha/yr⁻¹. Thus giving average production of 4.95 t ha⁻¹ yr⁻¹. All the four growth parameters influence the biomass production. NRCAF (2007) conducted a comparative study on biomass production from natural grassland and silvopastoral system and found that the rate of biomass carbon stored in silvopastoral system was 6.72 t C ha⁻¹ yr⁻¹, which was 2 times more than 3.14 t C ha⁻¹ yr⁻¹ from natural grasslands. Rai et al. (2009) studied the effect of introducing a silvopastoral system in natural grassland in semi-arid Uttar Pradesh. There, the carbon storage was reported to be 1.89-3.45 t C ha⁻¹ in silvopastoral and 3.94 t C ha⁻¹ in pure pasture. Chavan and Rasal (2012) conducted biomass analysis in *Annona squamosa* and *Annona reticulata* tree species which was estimated by destructive methods followed by the ash content method. Carbon content in *Annona reticulata* and *Annona squamosa* was 83.1 kg C ha⁻¹ and 73.5 kg C ha⁻¹ respectively. Chavan and Rasal (2012) reported that the standing above ground biomass in *Mangifera indica* trees had 82.83 t ha⁻¹. Pragasan and Karthick (2013) noticed that above ground biomass for the sites with Eucalyptus plantation and mixed species plantation 41.78 and 6.27 t ha⁻¹ respectively. Hangarge et al. (2012) reported that 31 tree species having 4000 individuals were recorded in 25 x 25 sq. meter in 80 quadrates at Somjaichi Rai (Sacred grove) of Pune district. Carbon sequestration in trees was estimated by non-destructive method. Above ground biomass (AGB) of species were calculated by multiplying the tree volume with wood density 16(Kg m⁻³). Singh et al. (2013) observed that *Z. mauritiana* + *P. cineraria* combination produced greater fruit, fodder and fuel wood and was

less competitive to wheat crop. Utilizable biomass was 2.63 t ha⁻¹ from *C. myxa* (cursive) + *P. cineraria*, 2.21 t ha⁻¹ from *C. myxa* (cursive) + *C. mopane* and 2.18 t ha⁻¹ from *Z. mauritiana* + *P. cineraria* combinations.

2.3.1.2 Below-ground biomass accumulation

Schroth et al. (2002) reported that multi-strata systems had a below-ground biomass of (4.3-12.9) Mg ha⁻¹ and for monoculture (3.2-17.1) Mg kg⁻¹. Chavan and Rasal (2012) conducted an experiment on the standing below ground biomass stalks in *Mangifera indica* trees and found it to be 21.54 C for *Mangifera indica*. Pragasan and Karthick (2013) recorded that the below-ground biomass for the sites with *Eucalyptus* plantation and mixed species plantation were 34.47 t ha⁻¹ & 5.17 t ha⁻¹ (approximately 15 years old) respectively. Hangarge et al. (2012) reported that 31 tree species having 4000 individuals were recorded in 25 x 25 sq. meter in 80 quadrates at Somjaichi Rai (Sacred grove) of Pune district. Below ground biomass (BGB) was measured by multiplying the AGB to factor 0.26 (root: shoot ratio). *Terminalia bellarica* species were found to be dominant having 180 trees and sequestered 327.78 tonnes of carbon followed by *Ficus amplissima* (221 tonnes).

2.3.1.3 Total biomass accumulation

Sharma et al. (2008) conducted a study in 20 years old plantations to investigate patches of four non-nitrogen fixing tree species viz *Gmelina arborea*, *Cleistanthus collinus*, *Lagerstroemia parviflora* and *Emblica officinalis*. Total biomass production was found to be the maximum (42.265 kg tree⁻¹) with *Gmelina arborea* and minimum (21.351 kg tree⁻¹) with *officinalis*. Kumar et al. (2011) estimated the total biomass production to be maximum at 5 x 4 m spacing. Biomass in different poplar parts decreased with increasing row spacing due to decreased number of trees. Venkatesh and Ram Newaj (2012) studied that the silvopastoral system in degraded land of Uttar Pradesh, India accumulated 18.23 t ha⁻¹ to 22.25 t ha⁻¹ biomass in natural pasture and 32.20 to 35.01 t ha⁻¹ biomass in established pasture. Kanime et al. (2013) reported a maximum total biomass of 94.8 Mg ha⁻¹ by 10-year-old *Dalbergia sissoo* monoculture plantation and minimum by an 8-year-old *Populus deltoids* block plantation (63.0 Mg ha⁻¹). Bohre et al. (2013) reported from Singrauli, M.P (India) that the total biomass accumulation rate were 279.89 t ha⁻¹ and 371.54 t ha⁻¹ for *Tectona grandis* and *Gmelina arborea*, respectively. Joshi et al. (2013) at Terai region of Central Himalaya revealed that total biomass of the tree layer by *Dalbergia sissoo* plantation (10 year) was 29.51 t ha⁻¹. Pragasan

and Karthick (2013) noticed that the total biomass for site with *Eucalyptus* plantation was greater (48.05 t ha^{-1}) than site with mixed species plantation (39.64 t ha^{-1}).

2.3.2 Carbon sequestration under different land use systems

2.3.2.1 Above ground biomass carbon

Reyes et al. (1992) reported that total above-ground biomass carbon sequestration were (0.166 t) and (11.247 t) by guava and mango, respectively. Kumar et al. (1998) revealed that *Phyllanthus emblica* sequestered 40.7 Mg ha^{-1} carbon in its above ground shoot. Brown and Schroeder (1999) proposed that the most softwood and hardwood forests had an above ground biomass in the range of $50\text{--}150 \text{ Mg C ha}^{-1}$ and $75\text{--}175 \text{ Mg ha}^{-1}$ respectively. Jana et al. (2009) observed that the total above ground biomass carbon stock in *Shorea robusta* and *Albizzia lebbek* (6 year old) were 5.22 t C ha^{-1} and 6.26 t C ha^{-1} in the forest stands. Prasad et al. (2010) reported that *Emblica officinalis* had carbon content of (39.16%) in a total dry biomass of ($32.40 \text{ kg tree}^{-1}$) (10 year old. Wardah et al. (2011) presented that the above ground carbon stock biomass (tree, herbaceous, necromass and litter) in a simple agroforestry systems was $42.42 \text{ Mg C ha}^{-1}$ and in the complex agroforestry systems was $98.46 \text{ Mg C ha}^{-1}$. The above ground biomass, standing leaf and wood litter were estimated to be $18.26\text{--}5.81$, $0.49\text{--}0.36$, $0.06\text{--}0.08 \text{ t ha}^{-1}$ carbon respectively for (10 year-old) poplar plantation Odiwe et al.(2012). Dube et al. (2012) studied the carbon sequestration potential in three predominant ecosystems. Among *Pinus ponderosa*-based silvo pastoral systems (SPS), *pine* plantations (PPP) and natural pasture (PST), PPP and SPS total above ground tree carbon were 38.4 and $53.1 \text{ kg tree}^{-1}$ in case of PPP and SPS respectively.

2.3.2.2 Below ground biomass carbon

Chavan (2010) estimated the below ground carbon of different trees at Aurangabad which were as follows, *Ficus religiosa* - $0.641 \text{ t tree}^{-1}$, *Ficus bengalensis* - 0.57 t tree^{-1} , *Mangifera indica* - 0.46 t tree^{-1} , *Delonix regia* - 0.31 t tree^{-1} , *Butea monosperma* - 0.31 t tree^{-1} , *Peltaforum pterocarpum* - 0.29 t tree^{-1} , *Azadirachta indica* - 0.26 t tree^{-1} , *Pongamia pinnata* - 0.23 t tree^{-1} and *Hyophorbe amercaulis* - 0.23 t tree^{-1} , respectively. However, Chavan and Rasal (2012) reported that the carbon sequestered by *Mangifera indica* trees below ground were 11.63 t ha^{-1} . Wardah et al. (2011) presented that the below ground carbon stock in a simple agroforestry were $83.55 \text{ Mg C ha}^{-1}$ and in the complex agroforestry $110.93 \text{ Mg C ha}^{-1}$. Dube et

al. (2012) observed that the carbon sequestration potentials among three predominant ecosystems of *Pinus ponderosa* based silvopastoral systems (SPS), *pine* plantations (PPP) and natural pasture (PST), total below ground tree carbon were 21.3 and 23.4 kg tree⁻¹ for PPP and SPS respectively. Prasad et al. (2012) suggested that the below ground biomass carbon was about 12 t ha⁻¹ by eucalyptus and it was higher in farm forestry system.

2.3.2.3 Total biomass carbon

Singh (2005) at arid region of Rajasthan reported that the total carbon storage under *Emblica officinalis* + *Vigna radiate* agri-horti system was 12.7 -13.0 t ha⁻¹. Chavan (2010) estimated that the total carbon sequestration in *Ficus religiosa* were 4.91 t tree⁻¹, *Ficus bengalensis* -4.46 t tree⁻¹, *Mangifera indica* - 3.59 t tree⁻¹, *Delonix regia* - 2.44 t tree⁻¹, *Buteamonosperma* - 2.41 t tree⁻¹, *Peltaforum pterocarpum* - 2.30 t tree⁻¹, *Azadirachta indica* - 2.08 t tree⁻¹, *Pongamia pinnata* - 1.80 t tree⁻¹ and *Hyophorbe amaricaulis* - 1.76 t tree⁻¹, respectively. Kaul et al. (2010) observed that the total carbon storage ranged from 101 to 156 Mg C ha⁻¹, with the largest carbon stock in Sal forests (82 Mg C ha⁻¹) and minimum *Poplar* (8 Mg C ha⁻¹yr⁻¹) and *Eucalyptus* (6 Mg C ha⁻¹ yr⁻¹) plantations followed by moderate growing *teak* forests (2 Mg C ha⁻¹ yr⁻¹) and slow growing long rotation *Sal* forests (1 Mg C ha⁻¹ yr⁻¹). Fang et al. (2010) reported that the total carbon stock reached 16.7 t C ha⁻¹ for the poplar with wheat–soybean cropping system and 18.9 t C ha⁻¹ for the poplar with wheat–corn cropping system. Chauhan and Gera (2010) conducted study on the carbon sequestration potential of medicinal tree species, and found by *Terminalia arjuna* (*arjun*) 137 t C which was followed by *Emblica officinalis* (amla) with 48 t C. Bohre et al. (2013) reported that the total carbon sequestration by *Tectona grandis* and *Gmelinaar borea* were 139.91 t ha⁻¹ and 185.77 t ha⁻¹, respectively. Pragasan and Karthick (2013) reported that the total carbon stock sequestered by *Eucalyptus* plantation (EP) and mixed species plantation (MP) (approximately 15 years old) were 27.72 and 22.25 t /ha respectively. Rathore and Jasrai (2013) studied the average carbon stock of different tree species at dry semi-arid type of Gujarat & the results were mango (35.75 t), anola (43.57 t) and guava (4.23 t). Pandya et al. (2013) conducted an experiment and found maximum carbon storage in *Tamarindus indica* (55.95 t C) followed by 44.8 t C for *Terminalia arjuna* and minimum in *Emblica officinalis* 1.77 t C.

2.4 Rate of carbon sequestration

Mandal et al. (2007) reported that rice mustard-sesame had significantly higher rate of

carbon sequestration ($1.91 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$) than rice-fallow-rice ($0.28 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$) and rice-wheat-fallow ($0.27 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$). Jana et al. (2009) documented that the *Shorea robusta* and *Albizia lebbek* (6 years) had the annual rate of carbon sequestration of 8.97 t C ha^{-1} and $11.97 \text{ t C ha}^{-1}$ respectively. Kaul et al. (2010) showed higher rate of carbon sequestration for *poplar* ($8 \text{ Mg ha}^{-1} \text{ yr}^{-1}$) than *eucalyptus* ($6 \text{ Mg ha}^{-1} \text{ yr}^{-1}$) and *teak* ($2 \text{ Mg ha}^{-1} \text{ yr}^{-1}$), respectively. Brakas and Aune (2011) indicated that highest rate of carbon accumulation could be for mango (*Mangifera indica* L.) plantation ($17.9 \text{ Mg ha}^{-1} \text{ yr}^{-1}$) followed by banana (*Musa* spp.) + fruit trees ($13.6 \text{ Mg ha}^{-1} \text{ yr}^{-1}$), and ($<1 \text{ Mg ha}^{-1} \text{ yr}^{-1}$) rates of carbon accumulation for coconut (*Coco snucifera* L.) plantations, coconut + banana, bush fallow, and grass lands. Rizvi et al. (2011) reported that poplar-based system had carbon accumulation rate of about $11.9 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ under irrigated conditions of Indo-Gangetic plains and acacia hybrid-based system had $3.3 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ under high rainfall conditions.

2.5 Amount of CO₂ sequestration

Reyes et al. (1992) reported the total CO₂ sequestration of 0.610 t and 41.239 t by guava and mango, respectively. Kraenzel et al. (2003) showed that the above ground CO₂ sequestration was $191.1 \text{ Mg CO}_2 \text{ ha}^{-1}$ by *Tectona grandis* (20 year old) plantations. Hairiah, (2009) referred that the atmospheric carbon dioxide (CO₂) captured by *Mangifera indica* was $206.84 \text{ t CO}_2 \text{ ha}^{-1}$. Chauhan and Gupta et al. (2011) conducted an experiment and reported that the annual average CO₂ assimilated by the biomass in the *Poplar-Wheat* based agroforestry system was higher (40.15 Mg ha^{-1}) against 20.9 Mg ha^{-1} for agricultural system.

2.6 Rate of CO₂ sequestration

Prasad et al. (2010) reported from an experiment, that the rate of CO₂ sequestration was ($4.65 \text{ Kg tree}^{-1} \text{ yr}^{-1}$) by *Emblica officinalis* of different agroforestry trees (10 years old).

2.7 Carbon credit under different land use systems

Derwisch et al. (2009) found that carbon credits were worth about $460 \text{ US \$}$ for temporary CER and $560 \text{ US \$}$ for long-term CER, which contributed to 1% overall revenues under teak plantation (20 year old).

2.7.1 Carbon sequestration of surface leaf litter under different land use systems

Ullah and Amin (2012) revealed a carbon stock of 4.21 t ha^{-1} in litter fall by the forest. Furthermore, Wardah et al. (2011) showed that the total carbon stored in lower litter averaged 1.7 Mg C ha^{-1} with a range of $1.62\text{-}1.77 \text{ Mg C ha}^{-1}$ by simple agroforestry, whereas an average of $2.29 \text{ Mg C ha}^{-1}$ with a range of 2.23 to $2.39 \text{ Mg C ha}^{-1}$ in complex agroforestry system. Moreover, Schelhaas et al. (2004) examined temperate grasslands and found 7.0 Mg C ha^{-1} in *Tectona grandis* plantations. Similarly, Kraenzel et al. (2003) at Chiriqui found that the average carbon stock 3.4 Mg C ha^{-1} in the herbaceous/litter layer, whereas average leaf litter found in the three *Tectona grandis* (3.6 Mg C ha^{-1}).



MATERIALS AND METHODS

The present research entitled “*Estimation of carbon credit under different land use systems in Vindhyan region*” was conducted to investigate the carbon accumulation potential of agriculture land and agroforestry system in the Mirzapur district of Uttar Pradesh . The study has been done for the fulfilment of requirement of M.Sc. (Ag.) in Agroforestry. The course running under the auspices of the Department of Agronomy, Institute of Agricultural Science, Banaras Hindu University, Varanasi. The details of materials used and methods followed in the present investigation are described in this chapter.

3.1 Experimental site

The experiment was carried out at the Mahamana Agricultural Research Farm of Banaras Hindu University-South Campus, Mirzapur which is situated in Vindhyan region of district Mirzapur (25° 10' latitude, 82° 37' longitude and altitude of 427 meters above mean sea level) occupying an area of more than 2763 ha where variety of crops like agricultural, horticultural, medicinal and aromatic plants are grown. Vindhyan soil comes under rainfed and invariably poor fertility status. This region comes under agro-climatic zone III A (semi-arid eastern plain zone) and the region is mostly rainfed.

3.2 Climate

The climate of BHU-South Campus is typically semi-arid, characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. Maximum temperature in summer is as high as 46.08°C (June) and minimum temperature in winter falls below 7.04°C (January). The annual rainfall of locality was 271.21 mm in 2018 of which nearly 90 per cent is contributed by South-West monsoon between June to September. The rainfall during the experimental period was recorded from the meteorological observatory of the (KVK), Horticultural farm. The total rainfall during the crop season was 262.36 mm; maximum and minimum temperature fluctuated between 46.08 °C and 7.04°C, and relative humidity between 93.82 and 23.82 per cent. The metrological data of Mirzapur district is given in **Table 3.1**.

3.3 Weather during experiment

The meteorological data obtained from the meteorological observatory of Krishi Vigyan Kendra, Banaras Hindu University-South Campus, Varanasi are presented in Fig. 3.1.

Table 3.1: The 10 years mean weather data of the area is presented in the table (2009-2018)

Months	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)		Sunshine (Hours)	Evaporation (mm)
		Max.	Min.	Max.	Min.		
January	1.9	19.70	7.04	86.23	44.67	6.27	1.73
February	1.6	26.95	11.15	84.58	45.20	8.35	2.42
March	1.08	33.10	15.83	73.46	28.40	8.39	4.64
April	0.44	35.96	20.42	57.09	23.5	9.38	5.10
May	3.27	39.85	26.65	64.86	27.50	9.18	8.64
June	53.46	46.08	27.73	72.8	50.28	7.08	7.72
July	57.18	32.14	27.18	84.34	71.24	4.72	3.41
August	74.23	31.18	26.73	88.5	75.10	5.35	3.27
September	76.51	30.9	26.50	88.36	73.62	6.26	3.12
October	0.98	31.67	20.71	85.16	45.82	8.34	3.0
November	0.23	28.41	14.67	91.31	40.65	8.20	2.5
December	0.33	21.10	9.06	93.82	56.47	6.48	1.53

Source: Annual report of the all India Co-ordinated research project on dry land agriculture, BHU (2018)

3.3.1 Rainfall (mm)

Total rainfall received during the crop growth period was 271.21 mm. The maximum rainfall of 76.51 mm was recorded in September 2018 and minimum rainfall of 0.48 mm was recorded in 2018.

3.3.2 Temperature (°C)

The monthly mean maximum and minimum temperature, during the period of experiment, ranges from 25.33⁰C to 36.75⁰C and 10.51⁰C to 27.34⁰C, respectively. The

maximum temperature 36.75°C was recorded in the month of June, whereas the minimum temperature 10.51°C was observed in the month of December.

3.3.3 Relative humidity (%)

The monthly maximum relative humidity of 90.20 to 94.68% in and monthly minimum relative humidity 55.36 to 72.81% in during the period of experimentation.

Mirzapur falls in a belt of semi-arid to sub humid climate. The normal period for the onset of monsoon in this region is the third week of June and it lasts up to the end of September or sometimes extends to the first week of October. Winter showers are often experienced in between the month of December to mid of February. However, March to May is generally dry. On an average, the major rainfall (75%) is received from June to September. The winter months are cooler whereas summer months are warmer and dry. The hottest and coldest months are June and January, respectively.

During the crop season total rainfall received was 791.00 mm. Out of total rainfall, more than 84 per cent received between 28 to 34 standard meteorological weeks (SMW). Data showed that the weekly mean maximum temperature ranged between 28.90 to 34.70 °C with an average of 31.48°C. The relative humidity varies from 33 percent to 94 percent.

3.4 Soil Characteristics of Experimental Field

The soil, as a medium of plant support and growth, is bound to affect profoundly and substantially the rate of growth as well as development and eventually the final and economic yield through its biotic and abiotic activities and physico-chemical properties.

Soil samples were taken from a depth of 0-20 cm, taking all the possible precautions prescribed for soil sampling. The samples were brought to the laboratory, air dried and crushed to pass through 2.0 mm mesh sieve. The processed samples were subjected to appropriate mechanical and chemical analyses. The results thus obtained are presented in **Table 3.2**.

Table 3.2. Physico-chemical properties & the soil of experimental plot

Soil properties	Value	Rating	Method employed
a. Physical			
Course sand (%)	10.34		International Pipette Method (Piper, 1966)
Fine sand (%)	48.31		
Silt (%)	19.40		
Clay (%)	21.95		
Textural class	Sandy clay loam (Typic <i>Ustochrepts</i>)		Textural triangle (Black <i>etal.</i> ,1965)
Bulk density (Mg m^{-3})	1270		Core sample (Black <i>et al.</i> ,1965)
Particle density (Mg m^{-3})	2470		Pycnometer (Black <i>et al.</i> ,1965)
b. Chemical			
pH(1:2.5, soil and water ratio)	5.9	Slightly acidic	Glass electrode digital pH meter (Jackson, 1973)
Electrical conductivity (1:2Soil: Water suspension) (dSm^{-1} at 25°C)	0.28	Normal	Systronics Electrical conductivity meter(Jackson, 1973)
Organic carbon (%)	0.37	Low	Walkley and Black rapid titration method (Piper, 1966)
Available nitrogen (kg ha^{-1})	153.32	Low	Modified alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus(P_2O_5) (kg ha^{-1})	14.15	Medium	0.03 N NH_4F + 0.25 N HCL (Bray and Kurtz, 1945)
Available potassium(K_2O) (kg ha^{-1})	217.58	Medium	1N neutral ammonium acetate method (Jackson, 1973)
Available sulphur(kg ha^{-1})	12.14	Low	0.15% CaCl_2 (Chesnin and Yien, 1951)

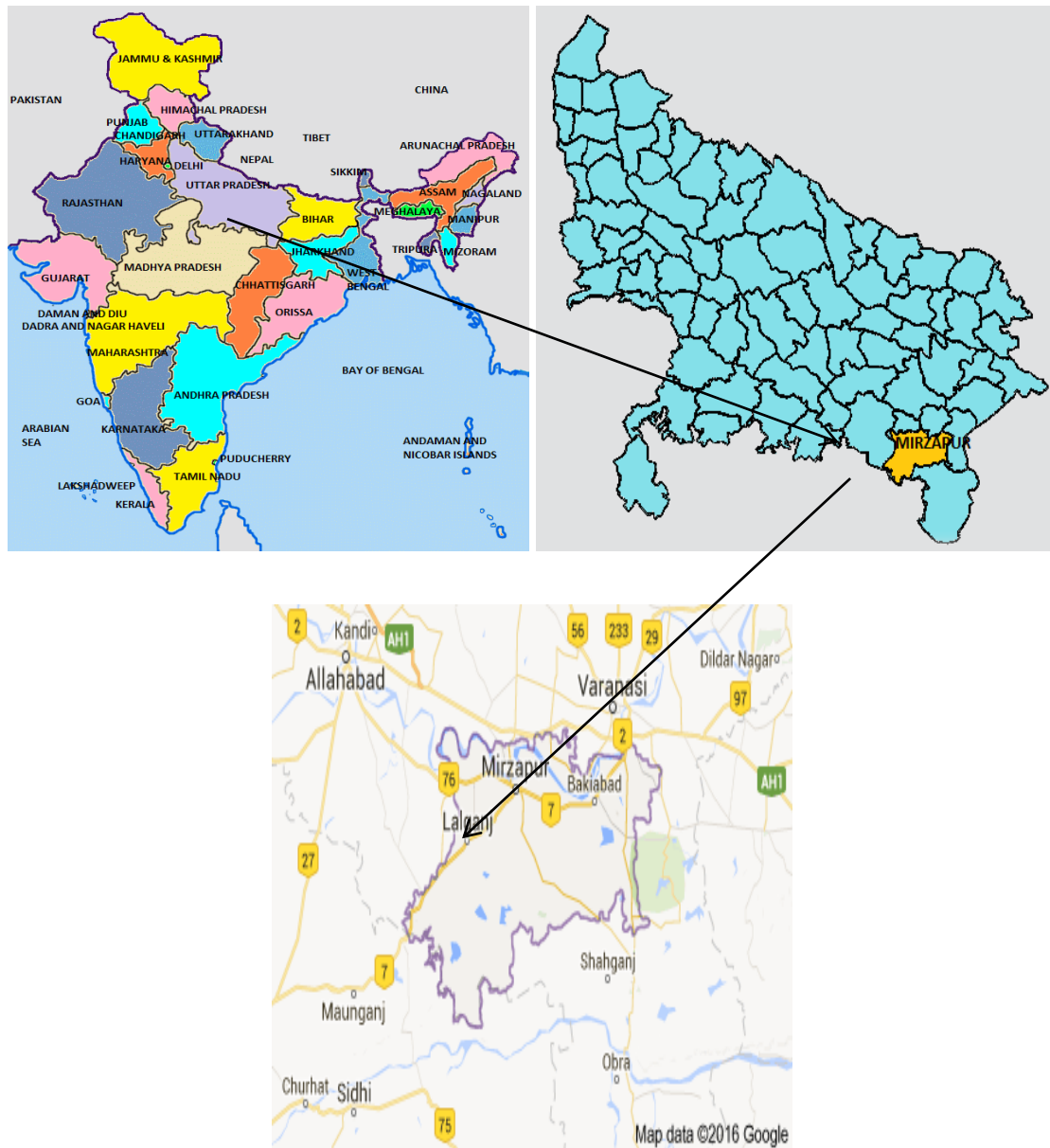
3.5 Land use system at Banaras Hindu University-South Campus

Rainfed farming is the traditional farming practiced in this area. There is a growing variety of crops such as agricultural, horticultural, medicinal and aromatic plants. BHU-South Campus soil (red laterite) is rainfed and the fertility status is invariably poor. This region is covered by agro-climatic zone III A (eastern semi-arid plain area). Table 3.3 shows land use and other features.

Table 3.3: Land use and other agricultural characteristics of the study area –Banaras Hindu University-South Campus (2018-2019)

S.No.	Agricultural parameters	Area (acre)
1	Geographical area (GA)	2763 acre
2	Forest area	500 acre
3	Land not available for cultivation–non agricultural uses	1880 acre
4	a) Current fallows	900 acre
	b) Other fallows	450 acre
5	Pasture land	200 acre
6	Net cropped area (NCA)	375 acre
7	Area sown more than once	78 acre
8	Total cropped area	450 acre
9	Intensity of cropping	120%
10	Cultivable waste land	300 acre
11	Cultivated area	450 acre
12	Barren land	1888 acre
13	Land under misc. tree crops and groves	515 acre
14	Net irrigated area	100 acre
15	Gross irrigated area	175 acre
16	Rainfed area	275 acre

Fig. 3.2: Location of Banaras Hindu University - South Campus, Mirzapur



3.6 Experimental Design and Layout

- 1) The experiment was conducted in a Randomized Block Design with 7 treatments and 3 replications. The details of treatment are as follows-

Table 3.4: Details of Treatments

Treatment	Symbol
Guava+moong	T1
karonda orchard	T2
Pasture land	T3
Wheat land (monocropping Pattern)	T4
Rice (monocropping pattern)	T5
Forest	T6
Pond	T7

Table 3.5 Experimental Design Layout

Design	Randomized block design
Treatment	07
Replication	03
Agroforestry system	
1) Guava plot size	50×10 m ²
2) Karonda plot size	50×10 m ²
Planting Distance	
Guava System	7×7 m ²
Karonda System	3×3 m ²
Agriculture land	
1) Wheat land	40×30 m ²
2) Rice land	40×30 m ²
Pasture Land	50×10 m ²
Forest land	1500×1500 m ²
Pond	50×10 m ²

3.7 Details of different land use system

3.7.1 Guava based agri-horti system

In this system, arable crops were grown in combination with guava trees. Agriculture crops viz., black gram, green gram, til, cow pea were grown in between the alleys of guava plantation, where guava trees were planted at a spacing of 7×7 m².

3.7.2 Karonda Based horti-Pasture system

Karonda (*Carissa carandas*) belongs to Apocynaceae family. It produces berry sized fruits that are commonly used as a condiment or additive to pickles and spices. It is a very hardy, drought-tolerant plant that thrives well in a wide range of soils. The green plant serves as a protective hedge around agricultural holdings. High temperature and arid climate is suitable for karonda cultivation. Karonda were planted with a spacing of 3×3 m² with no arable crop has been grown.

3.7.3 Wheat field

In this system wheat cultivation is practised from very long time only one crop is cultivated from a particular site i.e. wheat.

3.7.4 Rice field

In this system rice cultivation is practised from a very long time only one crop is cultivated from a particular site i.e. rice.

3.7.5 Pasture land

In this land there is no crop has been cultivated but the land is fully covered with grasses and weeds.

3.7.6 Forest land

The 500 acre of land of the experimental site comes under forest land with many tree species, shrubs and herbs.

3.7.7 Pond System

The pond of the experimental area is developed to maintain the ground water level of an area and for irrigation. The water is available in a pond during monsoon period from July to September and after it starts drying gradually. The drained water from all the systems and agriculture land is stored in this pond.

3.8 Soil sample collection & preparation

3.8.1 Sample collection

The experiment was conducted at Mahamana Agricultural Research Farm of Banaras Hindu University- South Campus, Barkachha, Mirzapur located in central Vindhyan plateau region and lies between 25°00'2" to 25°15'2" North latitude and 82°45'2" East longitude at an altitude of 146 m above mean sea level. The topography of agricultural farm is undulating and surface is rough; it has an area of 2763 acre. 42 soil samples were collected from study area. Soil samples were collected to a depth of 0-10 cm and 10-20 cm with the help of a core sampler from different locations of Agricultural farm and Agroforestry system of BHU- South Campus.

3.8.2 Preparation of sample and analysis

A sample, brought to the laboratory, is spread out on an aluminum tray, plastic or a thick brown paper. Coarse concretions, stones and pieces of roots, leaves, and other undecomposed organic residues are removed. Large lumps of moist soil are broken by hand. It is preferable to air dry soils at 20-25°C and 20% to 60% relative humidity. Samples may be mixed during drying to expose fresh surfaces. After air drying, soil samples are crushed gently in a pestle and mortar and sieved through a 2 mm sieve. The material larger than 2 mm is discarded. They were stored with proper labeling in polythene bags for physico-chemical analysis.

3.8.3 Laboratory work

Soil samples collected from the study area were dried and crushed with the help of wooden rod and passed through 2 mm sieve and then used for the determination of soil pH, EC, BD, PD, organic matter, macronutrients and micronutrients content by adopting standard laboratory methods.

3.9 Soil parameters to be recorded

3.9.1 Determination of soil pH in soil:

A soil water suspension was prepared in the ratio of 1:2.5 (10 gms of soil and 25 ml distilled water) and pH was recorded with the help of glass electrode digital pH meter, (Chopra and Kunwar 1982)..

3.9.2 Determination of electrical conductivity (EC) in soil

A soil water suspension was prepared in the ratio of 1:2.5 (10 gms of soil and 25 ml of distilled water) and EC was measured with the help of Conductivity Bridge at room temperature. The scale reading (mhos cm^{-1}) was converted to dSm^{-1} using the following formula, (Chopra and Kanwar 1982): $\text{EC (d Sm}^{-1}\text{)} = \text{Scale reading} \times 1000 \times \text{cell constant}$

Procedure

Weight 10 g. soil into clean 100 ml beaker. Add 25 ml of distilled water. Stir the suspension intermittently for 30 minutes and allow the suspension to settle for about one hour. Measure the EC in the supernatant solution using EC Bridge. If supernatant solution is not obtained/ clears, filter the suspension using ordinary filter paper and measure the EC infiltrate or leachate. The soil suspension prepared of pH measurement after setting down of solid particles, the E.C. was measured from supernatant solution.

3.9.3 Available nitrogen (kg ha⁻¹)

The procedure involves distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated, described by Subbbiah and Asija (1956).

Procedure

Place 20 g of soil in 1 liter kjeldahl flask. To this, add 20 ml of water and swirl. Then add 1 ml of liquid paraffin and a few glass beads to prevent frothing and bumping, respectively during distillation. Then add 100 ml each of 0.32% potassium permanganate solution and 2.5% Sodium hydroxide solutions. Distill the contents in a kjeldahl assembly at a steady rate and collect the liberated ammonia in a Erlenmeyer flask (250 ml) containing 20 ml of boric acid solution (with mixed indicator). With the absorption of ammonia, the pink color of boric acid solution turns to green. Nearly 100 ml of distillate is to be collected in about 30 minutes. Titrate the contents with 0.02 N sulphuric acids to the original shade (pink). Blank correction (without soil) is to be made for the final calculations.

Calculation

$$\text{Mineralizable N kg/ha} = (R-B) \times 31.36$$

Where, R = Volume of 0.02N H₂SO₄ required in titration for soil.

B = Volume of 0.02 N H₂SO₄ required in titration for blank.

3.9.4 Available phosphorus (kg ha⁻¹)

Plant available phosphorus was estimated by extracting soil with N/2 NaHCO₃ (pH-8.5) in 1 : 20 ratio (Olsen, *et.al.*, 1954). This method is used for estimation of phosphorus in the neutral and alkaline soil (Brays' 1 extraction method is used when soil pH is 5.5 or less, Indian Society of Soil Science). Phosphate in the extract is measured by the reaction of phosphate with ammonium molybdate in an acid medium to form molybdophosphoric acid. The molybdophosphoric acid is reduced to a blue colour complex (reduced phosphomolybdenum blue) through reaction with ascorbic acid (Murphy and Reley, 1962). The optical density of solution were measured at 660 nm by double beam spectrophotometer

and the strength of phosphorus was calculated by comparing with phosphorus standard graph of 0.0, 1.0, 2.0, 3.0, 4.0, 5.0 ppm of standard solution.

3.9.5 Available potassium (kg ha⁻¹)

The term available potassium (K) conventionally refers to exchangeable + water soluble potassium. The potassium is estimated by using a flame-photometer. Extractant are used as neutral normal ammonium acetate. Described by Jackson (1967)

$$\text{Available potassium (kg/ha)} = \text{ppm K} \times 11.2$$

Where, R = ppm of K in the extract (obtained from standard curve)

3.9.6 Available iron and zinc (ppm)

Estimation of available iron and zinc in soil (Lindsay and Norwell, 1978) by using Principle Diethylenetetraminepenta acetic acid (DTPA) being a chelating agent is used in the determination of available Fe and Zn. When the soil is shaken with a solution of DTPA, it combines with metal ions in the solution and form soluble complexes of Fe⁺⁺ and Zn⁺⁺. The CaCl₂ and triethanol amine (TEA) solution slightly raise and buffer the soil pH and mitigates the effect of Ca⁺⁺ and Mg⁺⁺. From DTPA extract Fe⁺⁺ and Zn⁺⁺ are determined with the help of Atomic Absorption Spectrophotometer by using their respective hollow cathodes.

$$\begin{aligned} \text{Dilution factor} &= \frac{\text{Volume of extractant}}{\text{weight of soil}} \times \frac{\text{ppm of micronutrient in soil}}{\text{ppm of sample reading}} \times 2 \end{aligned}$$

3.9.8 Organic carbon

Soil organic carbon content was determined by Rapid Titration Method (Walkley and Black, 1934). In this method two grams of soil was oxidized with a mixture of potassium dichromate and concentrated sulphuric acid utilizing the heat of dilution of sulphuric acid. Unused potassium dichromate was back-titrated with ferrous ammonium sulphate in presence of diphenylamine indicator.

Procedure

The soil is ground and passed through 2 mm sieve. Place 1 g. soil at the bottom of dry 500 ml conical flask and add 10 ml of 1N $K_2Cr_2O_7$ and swirl a little. The flask is kept on asbestos sheet. Then add 20 ml of concentrated H_2SO_4 and swirl again two or three times. The flask is allowed to stand for 30 minutes preferably in darkness. Add 200 ml of distilled water, 10 ml of Ortho-phosphoric acid and titrate the contents with ferrous ammonium sulphate solution till the colour changes from blue-violet to green. Simultaneously, a blank is run without soil. If more than 7 ml of dichromate solution is consumed, the determination must be repeated with a smaller quantity (0.25-0.50 g.) of soil.

Calculation

$$\text{Organic Carbon (\% in Soil)} = 10 (B-S)/B \times 0.003 \times 100/\text{wt of sample (g)}$$

Where, B & S stand for the titrate value (ml) of blank and sample respectively.

(B-Blank, S-Sample)

3.10 Observation recorded for carbon sequestration

3.10.1 Above Ground biomass

3.10.2: Tree Component

3.10.3 Stem Biomass

To estimate biomass all the tree falling in the plot (50×10) m² were enumerated. The diameter of trunk at breast height (dbh) was measured with clipper and height with Ravi's meter.

Where volume equation was not available as per the formula of Pressler's (1865) and Bitlerlich (1984)

$$f = 2h_1^3h$$

Where,

$$f = \text{form factor}$$

$$h_1 = \text{height at which diameter is half of dbh}$$

$$h = \text{total height}$$

Volume was calculated by Presseler's formula (1865)

Where,

$$V = \text{volume}$$

$$f = \text{form factor}$$

$$h = \text{total height}$$

$$g = \text{basal area} = \pi r^2 \text{ or } \pi(\text{dbh}/2)^2$$

Where,

$$r = \text{radius}$$

$$\text{DBH} = \text{Diameter at Breast Height}$$

Specific gravity

Specific gravity was determined from the available literature. Where, the specific gravity values was not available in that case the stem cores were taken to find out specific gravity which was used to determine the biomass of the stem using maximum moisture method (Smith, 1954).

$$Gf = \frac{1}{\frac{Mn - MO + 1}{MO + Gso}}$$

Where,

Gf = Specific gravity based on gross volume

Mn = Weight of saturated volume sample

Mo = Weight of oven- dried sample

Gso = Average density of wood substances equal to 1.53

Thus the weight of wood was estimated using the formula i.e. mass per unit volume

Mass = Average specific gravity of stem wood × volume

The biomass for *Guava* plantation in agroforestry system was estimated by using the regression equation given by Brown et al. (1997).

Y = exp (-2.134+ (2.530 lnD (cm)

Where,

Y = Above ground biomass (kg)

D = Diameter at breast height

ln = Natural log

Branch biomass

Total numbers of branches irrespective of size was counted on each of the sample tree and categorized on the basis of basal diameter into three groups, viz., < 6cm, 6-10cm,

and >10 cm. Fresh weight of two sampled branches from each group was recorded separately. The formula (**Chidumaya 1990**) used to determine the dry weight of branches was as follows.

$$Bdwi = \frac{Btwi}{1+Mcbdi}$$

Where,

Btwi = Oven dry weight of branch

Bdwi = Fresh/green weight of branches

Mcbdi = Moisture content of branch on dry weight basis

Total branch biomass (Fresh/dry) per sample tree was determined by:

$$Bbt = n1bw1 + n2bw2 + n3bw3 \Sigma nibwi$$

Where,

BBt = Branch biomass (fresh/dry) per tree

Ni = Number of branches in the ith branch group

Bwi = Average weight of branch of ith group

I = 1, 2, 3, ----- refers to branch group

3.10.1.1 Leaf biomass

Leaves from the branches which were removed, were weighed and oven dried separately to a constant weight at $80 \pm 5^{\circ}\text{C}$ (Chidumaya, 1990). Leaf biomass of the forest tree species was estimated using the table given by Jenkins et al. (2003). The leaf biomass of each fruit tree on the other was calculated during the leaf fall (December-January). The fallen leaves under each tree were collected and dried to a constant weight in oven. Leaf carbon was converted into carbon by multiplying with a factor of 0.5.

3.10.1.2 Tree biomass

The total tree biomass was the sum of stem biomass, branch biomass and leaf biomass. The tree biomass was converted into carbon fraction by a factor of 0.5 (IPCC, 2006).

3.10.1.3 Below ground biomass of trees

Belowground biomass of tree roots were calculated by multiplying the above ground biomass by a factor of 0.26 (Cairns *et. al.*1997).

Belowground biomass of trees= Above ground biomass of trees x 0.26.

3.10.1.4 Total tree biomass

Total tree biomass = total above ground biomass + below ground biomass of trees.

3.10.1.5 Total carbon in trees

Total carbon in trees = Total tree biomass multiplied by a factor of 0.45 due to the fact that around 45% carbon is found in the total biomass of trees (Woomer, 1990).

Total carbon in trees = Total biomass $\times$ 0.45

3.10.2 Agriculture crop biomass

3.10.1 Above ground biomass

The biomass production in agriculture land was determined by taking random samples of *Kharif* and *Rabi* crops in the experimental field from 1 m x 1 m quadrates. All the crop plants

occurring within the borders of the quadrant were cut at ground level and collected (fresh weight) and kept in oven for 24-48 hours at 65 to 70 °C to a constant weight.

3.10.2 Below ground biomass

Below ground biomass of agriculture crops were calculated by multiplying aboveground biomass with a factor of 0.26 (Cairns et. al.1997). 20 – 30% will be the below ground biomass from the total above ground biomass.

$$\text{Below ground biomass} = \text{Total above ground biomass} \times 0.26.$$

3.10.3 C and CO₂ estimation

3.10.3.1 Carbon stock

Carbon stock was estimated as per the formula mentioned by IPCC (2006)

$$\text{Carbon stock} = \text{Biomass} \times 0.5$$

3.10.3.2 CO₂ estimation

CO₂ was estimated as per the formula suggested by Pearson et al.(2007)

$$\text{CO}_2 \text{ sequestered} = \text{Biomass carbon stock} \times 3.67$$

3.10.3.3 Carbon credits

One ton of net sequestered or mitigated carbon dioxide in the form of plant biomass is equal to one carbon credit (IPCC, 2007). Therefore, total carbon credit in a land use system was calculated from CO₂-eq values of retained biomass in respective system. The eligible carbon credits were calculated from the net sequestered or mitigated carbon dioxide in the form of tree or crop biomass only.



EXPERIMENTAL FINDINGS

The present investigation entitled “Estimation of carbon credit under different land use system in Vindhyan region “was carried at experimental site of Banaras Hindu University-South Campus, Mirzapur. The trial is laid out in Randomized Block Design with 7 treatment (land use system) and 3 replication. The result revealing the effect of carbon sequestration potential, soil organic carbon, bulk density, nitrogen, phosphorus, potassium, zinc, and iron under different land use systems and agricultural land are presented in this chapter under the following headings.

4.1 Effect of different land use system on physico-chemical properties of soil

4.1.1 Soil organic carbon (%)

The data presented in the table 4.1 showed that the different land use systems were significantly influenced the soil organic carbon. The maximum soil organic carbon was recorded under forest land use system (0.66 %) followed by the karonda land use system (0.40%). However, the minimum organic carbon was observed in wheat land use system (0.21%).

4.1.2 Bulk density (g/cc)

The data presented in the table 4.1 showed that the different land use systems were significantly influenced the bulk density of the soil. The maximum bulk density was recorded under wheat land use system (1.60 g/cc) followed by the karonda land use system (1.59g/cc). However, the minimum bulk density was observed in forest land use system (1.39 g/cc).

4.1.3 Soil carbon stock (t ha⁻¹)

The data presented in the table 4.1 showed that the different land use systems were significantly influenced the soil carbon stock. The maximum soil carbon stock was recorded under forest land use system (18.40 t ha⁻¹) followed by the karonda land use system (12.70 t ha⁻¹). However, the minimum soil carbon stock was observed in wheat land use system (7.50 t ha⁻¹).

Table 4.1 Variation in soil organic carbon in different land use systems

Treatment	Soil organic carbon (%)	Bulk density (g/cc)	Soil Carbon stock (t ha ⁻¹)
Land use system			
Guava+moong	0.30	1.51	8.92
Karonda	0.40	1.59	12.70
Pasture land	0.28	1.45	8.21
Wheat	0.21	1.57	6.57
Rice	0.24	1.60	7.50
Forest	0.66	1.39	18.40
Pond	0.28	1.51	8.35
SEm±	0.020	0.012	0.634
CD (P=0.05)	0.061	0.037	1.954

4.1.4 Soil organic carbon (%)

The data presented in the table 4.2 showed that the different land use systems were significantly differentiate the soil organic carbon at (0-10) and (10-20) cm soil depth. The maximum soil organic carbon was recorded under forest land use system (0.69 and 0.63 %) at both soil depth (0-10 and 10-20 cm) and followed by the pond land use system (0.51 and 41%) in both depth, respectively. However, the minimum organic carbon was observed in wheat land use system at 0-10 cm (0.22%) and 10-20 cm (0.20) depth of soil.

Table 4.2 Variation in soil organic carbon in different land use systems

Treatment	Soil organic carbon (%)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava + moong	0.32	0.27
Karonda	0.43	0.36
Pasture land	0.31	0.25
Wheat	0.23	0.19
Rice	0.26	0.21
Forest	0.69	0.63
Pond	0.31	0.25
SEm±	0.019	0.021
CD (<i>P</i> =0.05)	0.059	0.063

Note

1. The biomass of agricultural crop is recorded during experimental year.
2. 12 year old plantations of guava and karonda based agroforestry system.
3. Water is available in a pond during monsoon season (July to September), after it start drying and observed some vegetation/grasses.
4. The age of forest is similar to the agroforestry system of an experimental area.

4.1.5 Particle density (g/cc)

The data presented in the table 4.3 showed that the different land use systems were non-significantly differentiate the soil particle density at (0-10 cm) soil depth but at 10-20 cm soil depth the particle density significantly differentiate in different land use system. The maximum particle density was observed under rice land use system (2.69 g/cc) and followed by the pasture land use system (2.68 g/cc) and wheat land use system (2.67 g/cc) at (10-20 cm) soil depth respectively. However, the minimum particle density was observed in forest land use system (2.51 g/cc) at 10-20 cm depth of soil.

Table 4.3 Variation in particle density in different land use systems

Treatment	Particle Density (g/cc)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	2.48	2.52
Karonda	2.58	2.63
Pasture land	2.61	2.68
Wheat	2.57	2.67
Rice	2.61	2.69
Forest	2.46	2.51
Pond	2.50	2.55
SEm±	1.94	0.04
CD ($P=0.05$)	NS	0.14

4.1.6 Bulk density (g/cc)

The data presented in the table 4.4 showed that the bulk density significantly differentiate in all the land use system at each soil depth. The highest BD was recorded in rice land use system (1.57 and 1.62 g/cc) at 0-10 cm and 10-20 cm soil depth followed by the karonda land use system. The lowest BD was recorded in forest (1.36 g/cc and 1.42 g/cc) at each soil depth, respectively.

Table 4.4 Variation in bulk density in different land use systems.

Treatment	Bulk Density (g/cc)	
	Soil depth(D)	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	1.49	1.53
Karonda	1.56	1.62
Pasture land	1.44	1.46
Wheat	1.54	1.59
Rice	1.57	1.62
Forest	1.36	1.42
Pond	1.48	1.54
SEm±	0.012	0.013
CD (<i>P</i> =0.05)	0.038	0.041

4.1.7 Electrical conductivity (dsm^{-1})

The data presented in the table 4.5 showed that the different land use systems were non-significantly improve the soil electrical conductivity at 0-10 cm and 10-20 cm depth of soil.

Table 4.5 **Variation in electrical conductivity (EC) in soil of different land use systems**

Treatment	EC (dsm^{-1})	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	0.17	0.09
Karonda	0.11	0.07
Pasture land	0.07	0.09
Wheat	0.09	0.08
Rice	0.07	0.15
Forest	0.16	0.10
Pond	0.19	0.14
SEm $\pm$	0.03	0.04
CD ($P=0.05$)	NS	NS

4.1.8 Soil pH

The data presented in the table 4.6 revealed that the different land use systems were significantly differentiate the soil p^H at 0-10 cm and 10-20 cm soil depth. The maximum soil p^H was observed under pond land use system (6.10 and 5.93), followed by the forest land use system (5.60and 5.37) at each soil depth. However, the minimum soil p^H was recorded in Guava+moong land use system (4.07 and 4.30) at both depth of soil, respectively.

Table 4.6 Variation in pH in soil of different land use systems

Treatment	pH	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	4.07	4.30
Karonda	4.37	4.67
Pasture land	5.17	5.07
Wheat	5.00	5.00
Rice	4.73	5.13
Forest	5.60	5.37
Pond	6.10	5.93
SEm±	0.20	0.21
CD (<i>P</i> =0.05)	0.62	0.63

4.1.9 Available nitrogen (kg ha⁻¹)

The data presented in the table 4.7 revealed that the different land use systems were significantly differentiate the available nitrogen at (0-10 cm) and 10-20 cm soil depth. The maximum available nitrogen was observed under forest land use system (207.60 and 194.57 kg ha⁻¹), followed by the karonda+grasses land use system (202.67 and 188.97kg ha⁻¹) at each soil depth. However, the minimum available nitrogen was recorded in wheat land use system (159.70 and 155.13 kg ha⁻¹) at both depth of soil, respectively.

Table 4.7 Variation in available nitrogen (kg ha⁻¹) in different land use systems

Treatment	Available nitrogen (kg ha ⁻¹)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	175.83	167.47
Karonda	202.67	188.97
Pasture land	167.20	158.93
Wheat	159.70	155.13
Rice	165.27	160.77
Forest	207.60	194.57
Pond	190.10	163.23
SEm±	1.68	2.01
CD (<i>P</i> =0.05)	5.17	6.19

4.1.10 Available phosphorus (kg ha⁻¹)

The data presented in the table 4.8 revealed that the different land use systems were significantly differentiate the available phosphorus at 0-10 cm and 10-20 cm soil depth. The maximum available phosphorus was observed under forest land use system (19.27 and 18.10 kg ha⁻¹), followed by the pond land use system (17.23 and 15.93 kg ha⁻¹) at each soil depth. However, the minimum available phosphorus was recorded in Guava+ moong land use system (14.87 and 13.90 kg ha⁻¹) at both depth of soil, respectively.

Table 4.8 Variation in phosphorus in different land use systems

Treatment	Available Phosphorus (kg ha ⁻¹)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	14.87	13.90
Karonda	16.50	14.90
Pasture land	16.80	15.60
Wheat	15.30	14.13
Rice	15.23	13.37
Forest	19.27	18.10
Pond	17.23	15.93
SEm±	0.42	0.60
CD (<i>P</i> =0.05)	1.30	1.85

4.1.11 Available potassium (kg ha⁻¹)

The data presented in the table 4.9 revealed that the different land use systems were significantly differentiate the available potassium in soil at 0-10 cm and 10-20 cm soil depth. The maximum amount of available potassium (204.60 and 200.87 kg ha⁻¹) was found in pasture land use system followed by the karonda land use system (203.16 and 194.20 kg ha⁻¹) at each soil depth. The minimum available potassium (181.84 and 177.55 kg ha⁻¹) observed in Guava+moong land use system, respectively.

Table 4.9 Variation in potassium in different land use systems

Treatment	Potassium (kg ha ⁻¹)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	181.84	177.55
Karonda	203.16	194.20
Pasture land	204.60	200.87
Wheat	172.47	167.30
Rice	152.07	146.00
Forest	190.50	186.93
Pond	182.53	177.60
SEm±	4.87	3.60
CD (<i>P</i> =0.05)	15.02	11.10

4.1.12 Available Iron (ppm)

The data presented in the table 4.10 showed that the different land use systems were significantly differentiate the available iron at 0-10 and 10-20 cm soil depth. The maximum available iron was recorded in karonda land use system (32.53 and 28.17 ppm), followed by pasture land use system (32.47 and 28.00 ppm) at both soil depth, respectively. However, the minimum available iron was observed in wheat land use system (22.93 and 19.87 ppm) at 0-10 cm and 10-20 cm depth of soil.

Table 4.10 Variation in available iron in different land use systems

Treatment	Available iron (ppm)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	30.20	23.77
Karonda	32.53	28.17
Pasture land	32.47	28.00
Wheat	22.93	19.87
Rice	27.73	21.07
Forest	32.20	26.63
Pond	23.83	20.90
SEm $\pm$	0.78	0.87
CD ($P=0.05$)	2.40	2.69

4.1.13 Available zinc (ppm)

The data presented in the table 4.11 showed that the different land use systems were significantly differentiate the available zinc at 0-10 and 10-20 cm depth of soil. The maximum available zinc was recorded in forest land use system (0.43 and 0.37 ppm) followed by Guava+moong land use system (0.39 and 0.33 ppm) at both soil depth, respectively. However, the minimum available iron was recorded in pond land use system (0.29 and 0.23 ppm)at 0-10 cm and 10-20 cm depth of soil.

Table 4.11 Variation in available zinc in soil of different land use systems

Treatment	Available zinc (ppm)	
	Soil depth	
	(0-10 cm)	(10-20 cm)
Land use systems		
Guava+moong	0.39	0.33
Karonda	0.37	0.30
Pasture land	0.38	0.32
Wheat	0.33	0.27
Rice	0.35	0.29
Forest	0.43	0.37
Pond	0.29	0.23
SEm±	0.01	0.01
CD (<i>P</i> =0.05)	0.02	0.04

4.2 Effect of different land use system on biomass accumulation

4.2.1 Above ground biomass (t ha^{-1})

The data presented in the table 4.12 showed that the different land use systems were significantly differentiate the above ground biomass. The maximum above ground biomass was recorded under forest land use system (49.76 t ha^{-1}) followed by the karonda (17.78 t ha^{-1}) and Guava+moong (16.84 t ha^{-1}) land use system. The above ground biomass of wheat (9.56 t ha^{-1}) and rice (7.63 t ha^{-1}) land use system recorded at par with each other. However, the minimum above ground biomass was observed in pond land use system (0.38 t ha^{-1}).

Table 4.12 Variation in above ground biomass in different land use systems.

Treatment	Biomass accumulation			
	Above ground (t ha^{-1})	Below ground (t ha^{-1})	Total (t ha^{-1})	Rate ($\text{t ha}^{-1} \text{ yr}^{-1}$)
Land use systems				
Guava+moong	16.84	4.38	21.21	1.77
Karonda	17.78	4.62	22.40	1.87
Pasture land	4.06	1.06	5.12	0.43
Wheat	9.56	2.49	12.05	1.00
Rice	7.63	1.98	9.62	0.80
Forest	49.76	12.94	62.70	5.23
Pond	0.38	0.10	0.48	0.04
SEm $\pm$	0.75	0.20	0.95	0.08
CD ($P=0.05$)	2.31	0.60	2.92	0.24

4.2.2 Below ground biomass (t ha^{-1})

The data presented in the table 4.12 showed that the different land use systems were significantly differentiate the below ground biomass. The maximum below ground biomass was recorded under forest land use system (12.94 t ha^{-1}). However, the karonda (4.62 t ha^{-1}) and Guava+moong (4.38 t ha^{-1}) land use system and wheat (2.49 t ha^{-1}) and rice (1.98 t ha^{-1}) land use system recorded at par with each other. However, the minimum below ground biomass was observed in pond land use system (0.10 t ha^{-1}).

4.2.3 Total Biomass (t ha^{-1})

The data presented in the table 4.12 showed that the different land use systems were significantly differentiate the total biomass. The maximum total biomass was recorded under forest land use system (62.70 t ha^{-1}). However, the karonda (22.40 t ha^{-1}) and guava+moong (21.21 t ha^{-1}) land use system and wheat (12.05 t ha^{-1}) and rice (9.62 t ha^{-1}) land use system recorded at par with each other. However, the minimum total biomass was observed in pond land use system (0.48 t ha^{-1}).

4.2.4 Rate of biomass accumulation ($\text{t ha}^{-1} \text{ yr}^{-1}$)

The data presented in the table 4.12 showed that the different land use systems were significantly differentiate the rate of biomass accumulation. The maximum rate of biomass accumulation was recorded under forest land use system (5.23 t ha^{-1}). The karonda (1.87 t ha^{-1}) and guava+moong (1.77 t ha^{-1}) land use system and wheat (1.00 t ha^{-1}) and rice (0.80 t ha^{-1}) land use system found at par with each other. However, the minimum rate of biomass accumulation was observed in pond land use system (0.08 t ha^{-1}).

4.3 Effect of different land use systems on potential of carbon sequestration

4.3.1 Above ground biomass carbon (t ha^{-1})

The data presented in the table 4.13 showed that the different land use systems were significantly differentiate the above ground biomass carbon. The maximum above ground biomass carbon was recorded under forest land use system (24.88 t ha^{-1}). In case of karonda (8.89 t ha^{-1}) and guava+moong (8.42 t ha^{-1}) land use system and wheat (4.78 t ha^{-1}) and rice (3.82 t ha^{-1}) land use system recorded at par with each other. However, the minimum above ground biomass carbon was observed in pond land use system (0.19 t ha^{-1}).

Table 4.13 Variation in total biomass of carbon in different land use systems

Treatment	Biomass carbon			
	Above ground (t ha^{-1})	Below ground (t ha^{-1})	Total (t ha^{-1})	Rate ($\text{t ha}^{-1} \text{ yr}^{-1}$)
Land use systems				
Guava+moong	8.42	2.19	10.61	0.88
Karonda	8.89	2.31	11.20	0.93
Pasture land	2.03	0.53	2.56	0.21
Wheat	4.78	1.24	6.02	0.50
Rice	3.82	0.99	4.81	0.40
Forest	24.88	6.47	31.35	2.61
Pond	0.19	0.05	0.24	0.02
SEm $\pm$	0.38	0.10	0.47	0.04
CD ($P=0.05$)	1.16	0.30	1.46	0.12

4.3.2 Below ground biomass carbon (t ha^{-1})

The data presented in the table 4.13 showed that the different land use systems were significantly differentiate the below ground biomass carbon. The maximum below ground biomass carbon was recorded under forest land use system (6.47 t ha^{-1}). However, the karonda (2.31 t ha^{-1}) and guava+moong (2.19 t ha^{-1}) land use system and wheat (1.24 t ha^{-1}) and rice (0.99 t ha^{-1}) land use system recorded at par with each other. The minimum below ground biomass carbon was observed in pond land use system (0.05 t ha^{-1}).

4.3.3 Total biomass carbon (t ha^{-1})

The data presented in the table 4.13 showed that the different land use systems were significantly differentiate the total biomass carbon. The maximum total biomass carbon was recorded under forest land use system (31.25 t ha^{-1}). However, the karonda (11.20 t ha^{-1}) and guava+moong (10.61 t ha^{-1}) land use system and wheat (6.02 t ha^{-1}) and rice (4.81 t ha^{-1}) land use system recorded at par with each other. The minimum total biomass carbon was observed in pond land use system (0.24 t ha^{-1}).

4.3.4 Rate of carbon sequestration ($\text{t ha}^{-1} \text{ yr}^{-1}$)

The data presented in the table 4.13 showed that the different land use systems were significantly differentiate the rate of carbon sequestration. The maximum rate of carbon sequestration was recorded under forest land use system ($2.61 \text{ t ha}^{-1} \text{ yr}^{-1}$). However, the karonda ($0.93 \text{ t ha}^{-1} \text{ yr}^{-1}$) and guava+moong ($0.88 \text{ t ha}^{-1} \text{ yr}^{-1}$) land use system and wheat ($0.50 \text{ t ha}^{-1} \text{ yr}^{-1}$) and rice ($0.40 \text{ t ha}^{-1} \text{ yr}^{-1}$) land use system recorded at par with each other. The minimum rate of carbon sequestration was observed in pond land use system ($0.02 \text{ t ha}^{-1} \text{ yr}^{-1}$).

4.3.5 Amount of CO_2 sequestration (t ha^{-1})

The data presented in the table 4.14 showed that the different land use systems were significantly differentiate the amount of CO_2 sequestration. The maximum amount of CO_2 sequestration was recorded under forest land use system (115.06 t ha^{-1}). However, the karonda (41.11 t ha^{-1}) and guava+moong (38.93 t ha^{-1}) land use system and wheat (22.10 t ha^{-1}) and rice (17.65 t ha^{-1}) land use system recorded at par with each other. The minimum amount of CO_2 sequestration was observed in pond land use system (0.87 t ha^{-1}).

Table 4.14 Variation in total CO₂ sequestration in different land use systems

Treatment	CO ₂ sequestration		Carbon credit (₹ t ha ⁻¹ yr ⁻¹)
	Amount (t ha ⁻¹ of the total age-12yrs)	Rate (t ha ⁻¹ yr ⁻¹)	
Land use systems			
Guava+moong	38.93	3.24	8577
Karonda	41.11	3.43	9058
Uncultivated land	9.40	0.78	2071
Wheat	22.10	1.84	4870
Rice	17.65	1.47	3888
Forest	115.06	9.59	25352
Pond	0.87	0.07	193
SEm±	1.74	0.14	383
CD (<i>P</i> =0.05)	5.35	0.45	1179

Carbon credit was calculated as per the following formula:

Rate (t ha⁻¹yr⁻¹) × 38 US \$ × 69.58 Indian rupees (Brinkman, 2009)

One ton CO₂ sequestered per year = One carbon credit

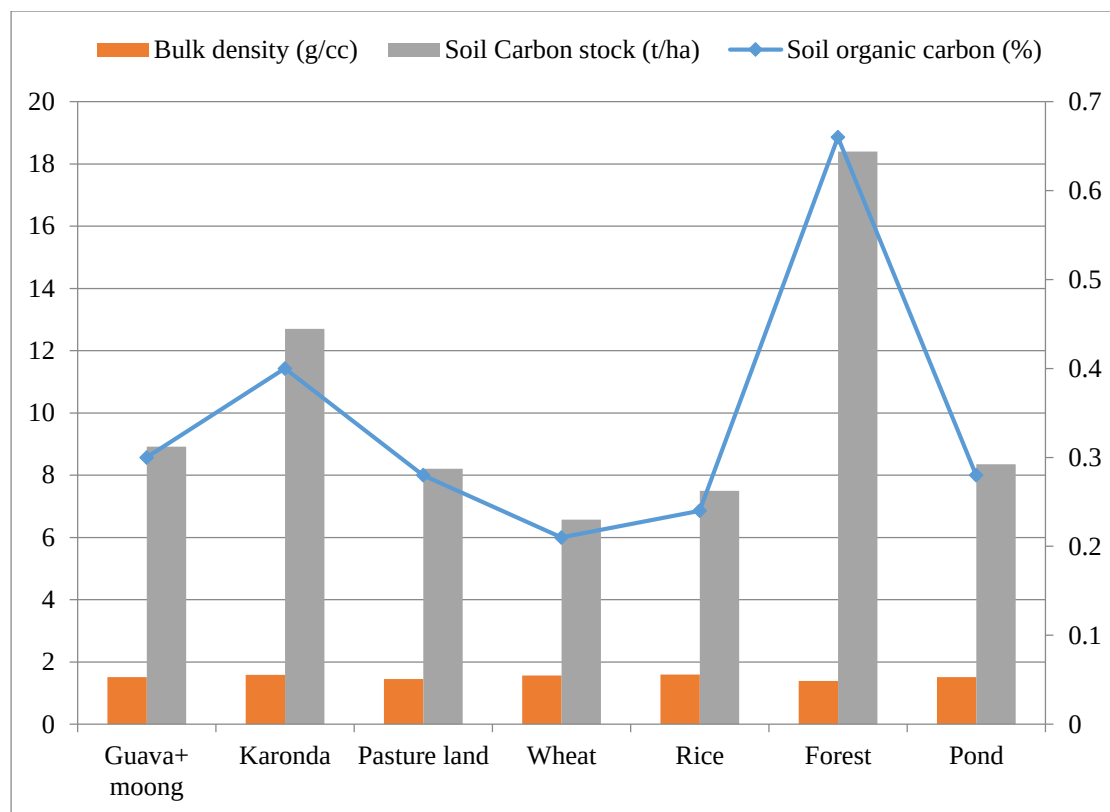
4.3.6 Rate of CO₂ sequestration (t ha⁻¹yr⁻¹)

The data presented in the table 4.14 showed that the different land use systems were significantly differentiate the amount of CO₂ sequestration. The maximum rate of CO₂ sequestration was recorded under forest land use system (9.59 t ha⁻¹). However, the karonda (3.43 t ha⁻¹) and guava+moong (3.24 t ha⁻¹) land use system found and wheat (1.84 t ha⁻¹) and rice (1.47 t ha⁻¹) land use system recorded at par with each other. Moreover, the minimum rate of CO₂ sequestration was observed in pond land use system (0.07 t ha⁻¹).

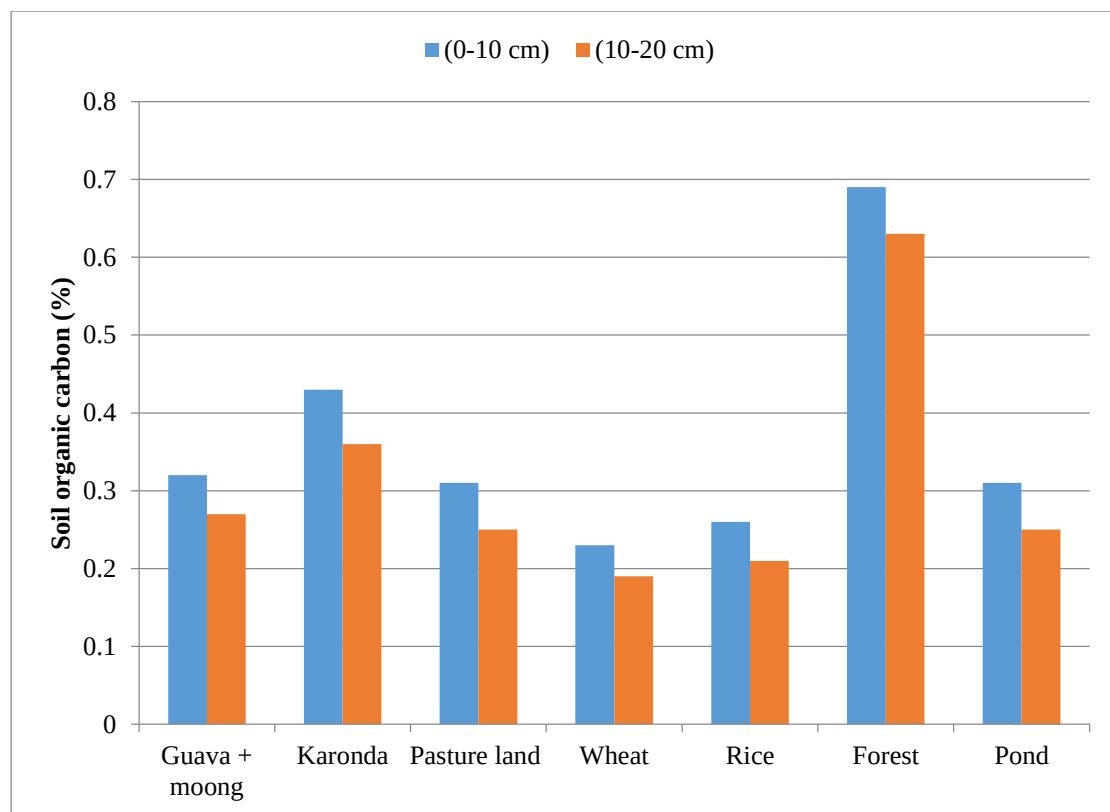
4.4 Carbon credit under different land use system (₹ t ha⁻¹ yr⁻¹)

The data presented in the table 4.14 showed that the different land use systems were significantly differentiate the amount of CO₂ sequestration. The maximum rate of CO₂ sequestration was recorded under forest land use system (25352 ₹ t ha⁻¹ yr⁻¹). However, the karonda (9058 ₹ t ha⁻¹ yr⁻¹) and guava+moong (8577 ₹ t ha⁻¹ yr⁻¹) land use system and wheat (4870 ₹t ha⁻¹ yr⁻¹) and rice (3888 ₹ t ha⁻¹ yr⁻¹) land use system recorded at par with each other. The minimum rate of CO₂ sequestration was observed in pond land use system (193 ₹ t ha⁻¹ yr⁻¹).

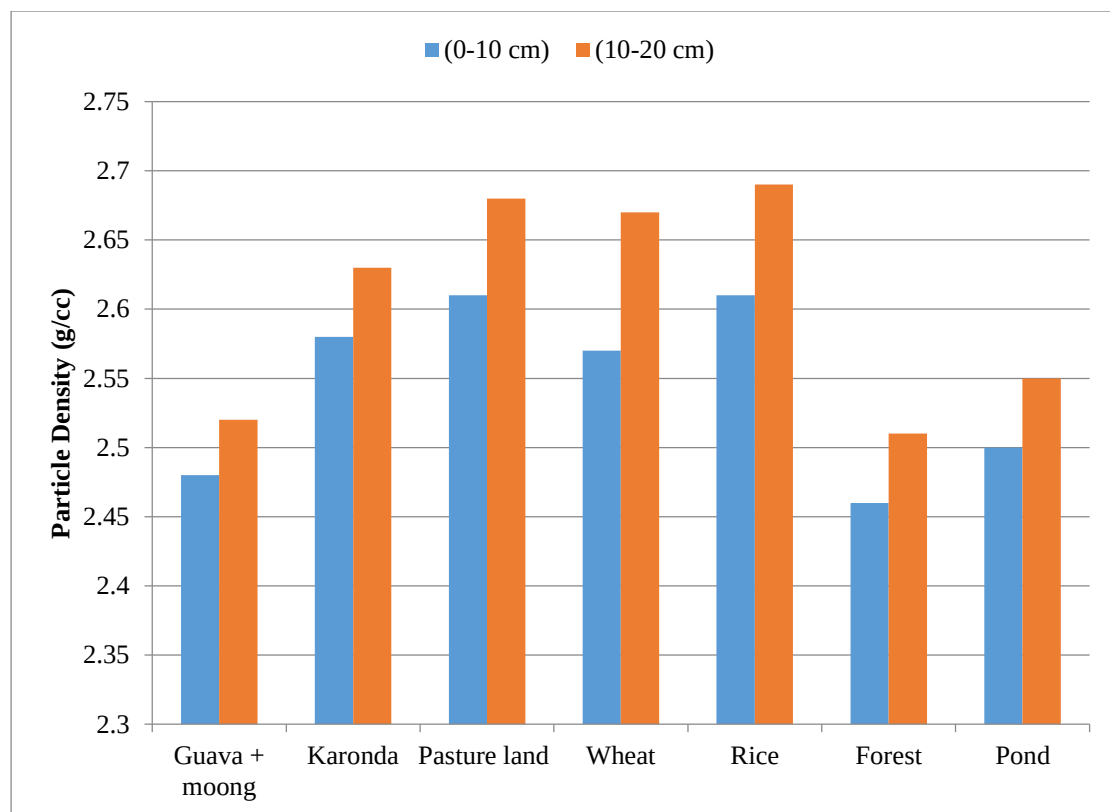




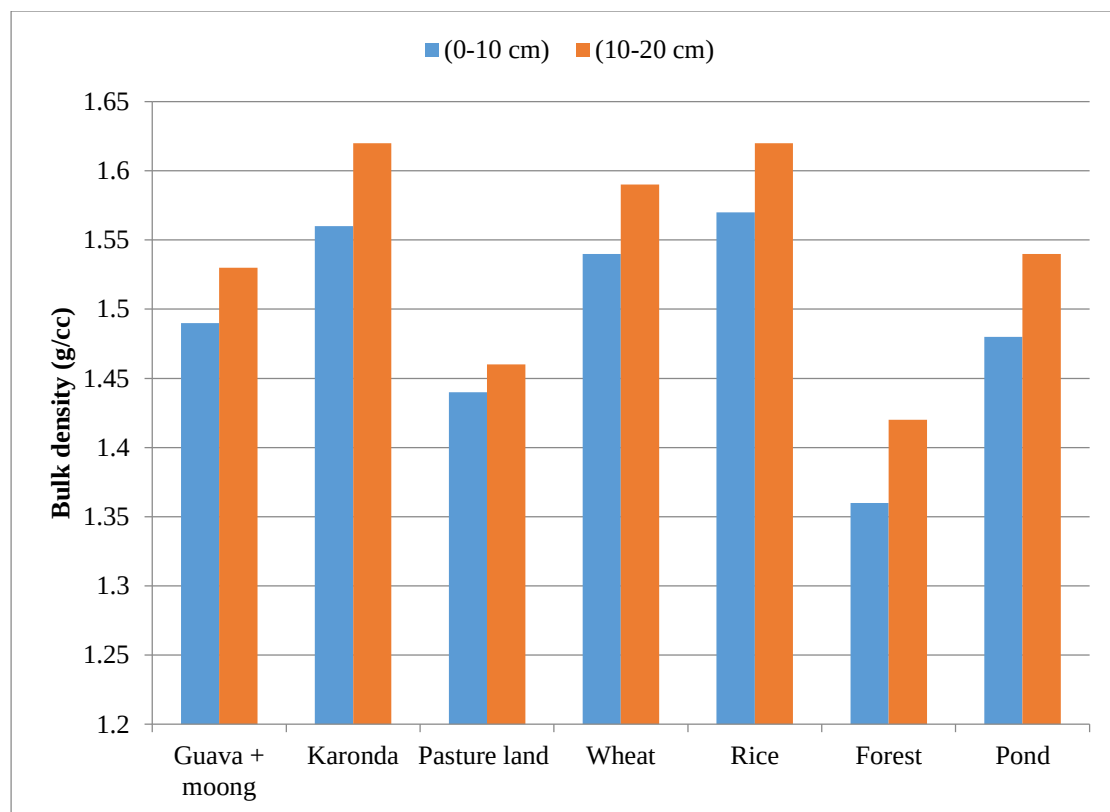
Graph 4.1 Variation in soil organic carbon (%), bulk density (g/cc), soil carbon stock in different land use systems



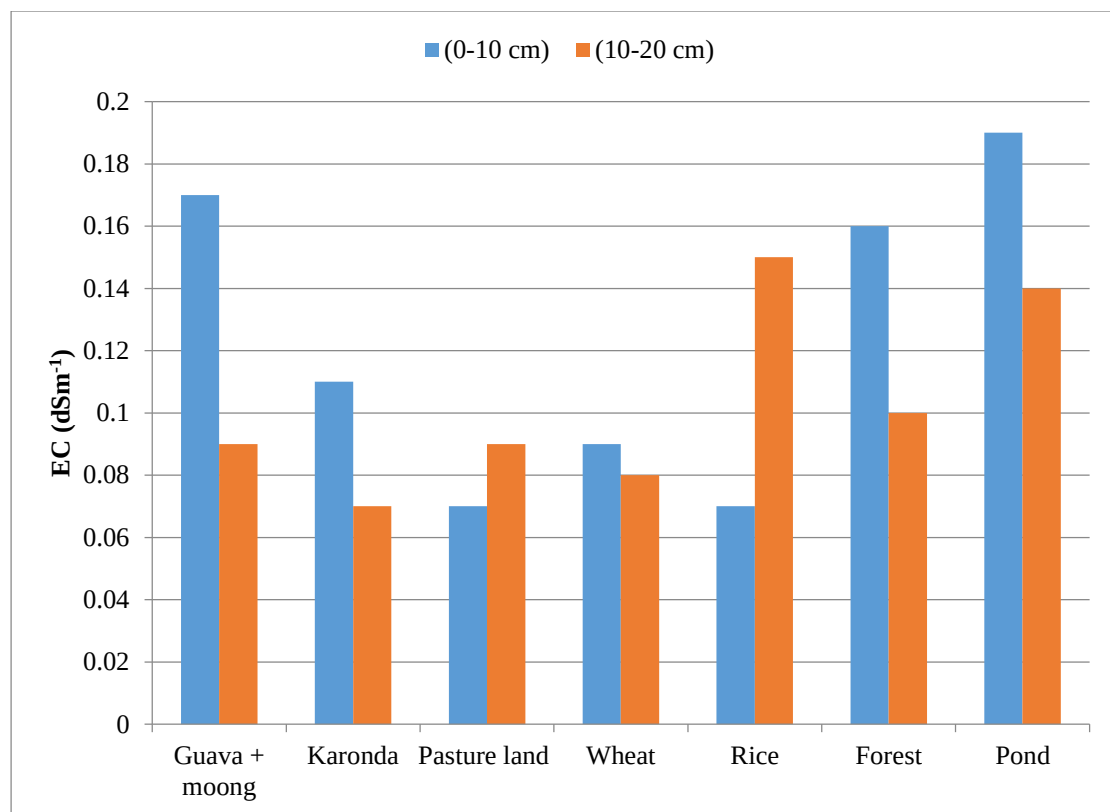
Graph 4.2 Variation in soil organic carbon in different land use systems



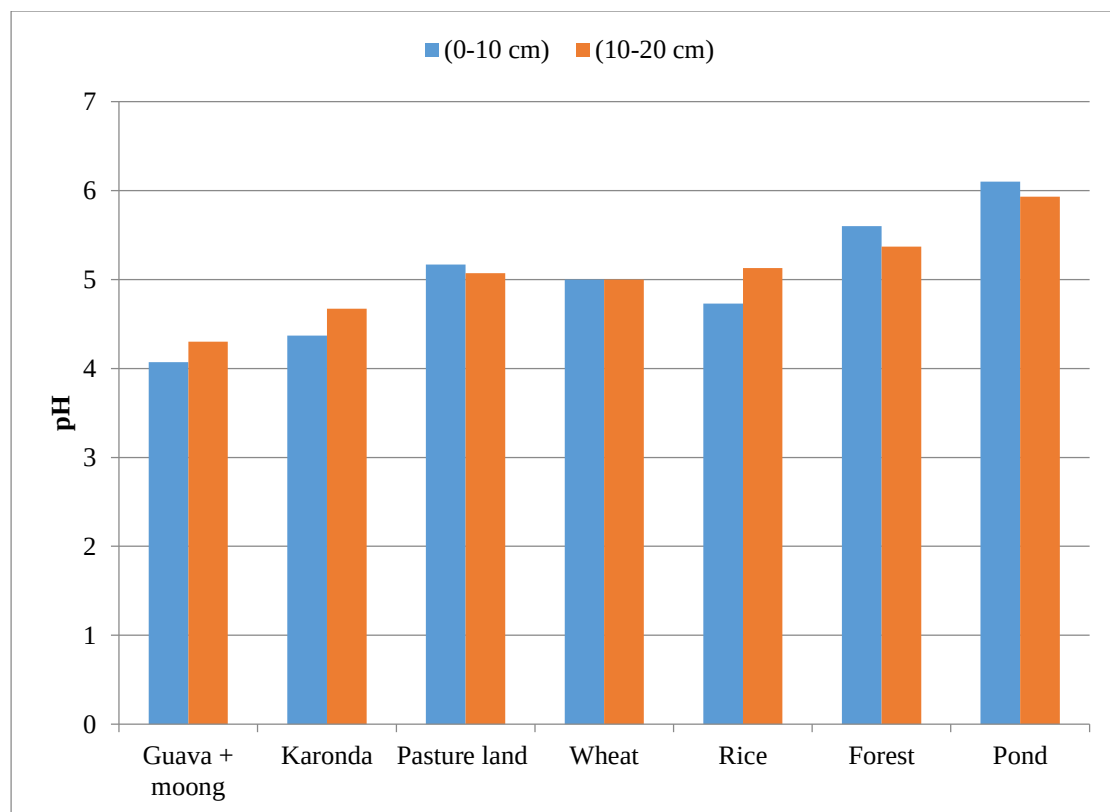
Graph 4.3 Variation in particle density in different land use systems



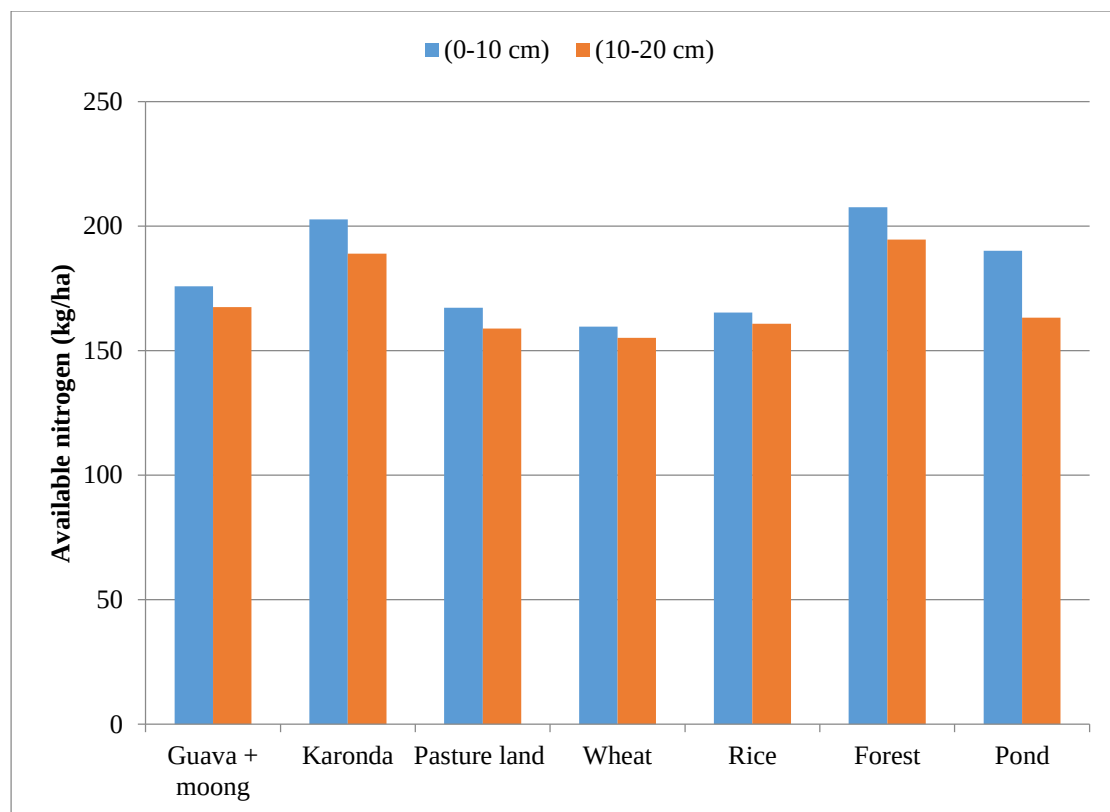
Graph 4.4 Variation in bulk density in different land use systems.



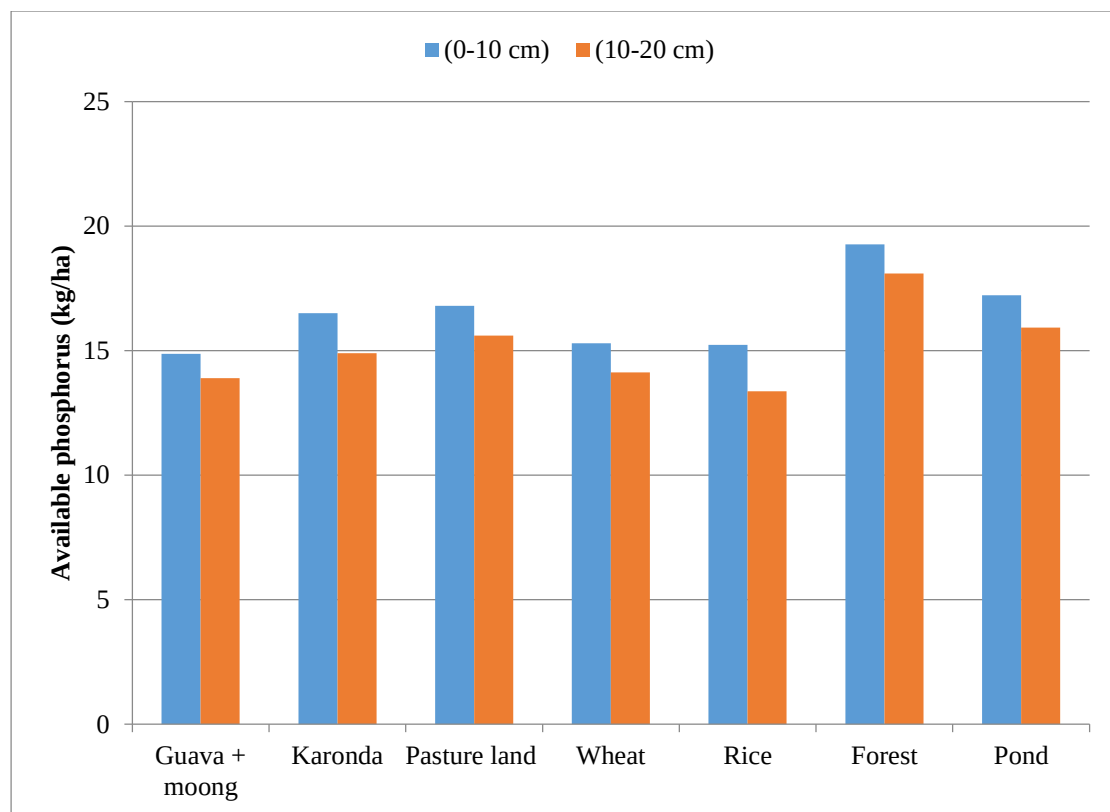
Graph 4.5 Variation in electrical conductivity (EC) in soil of different land use systems



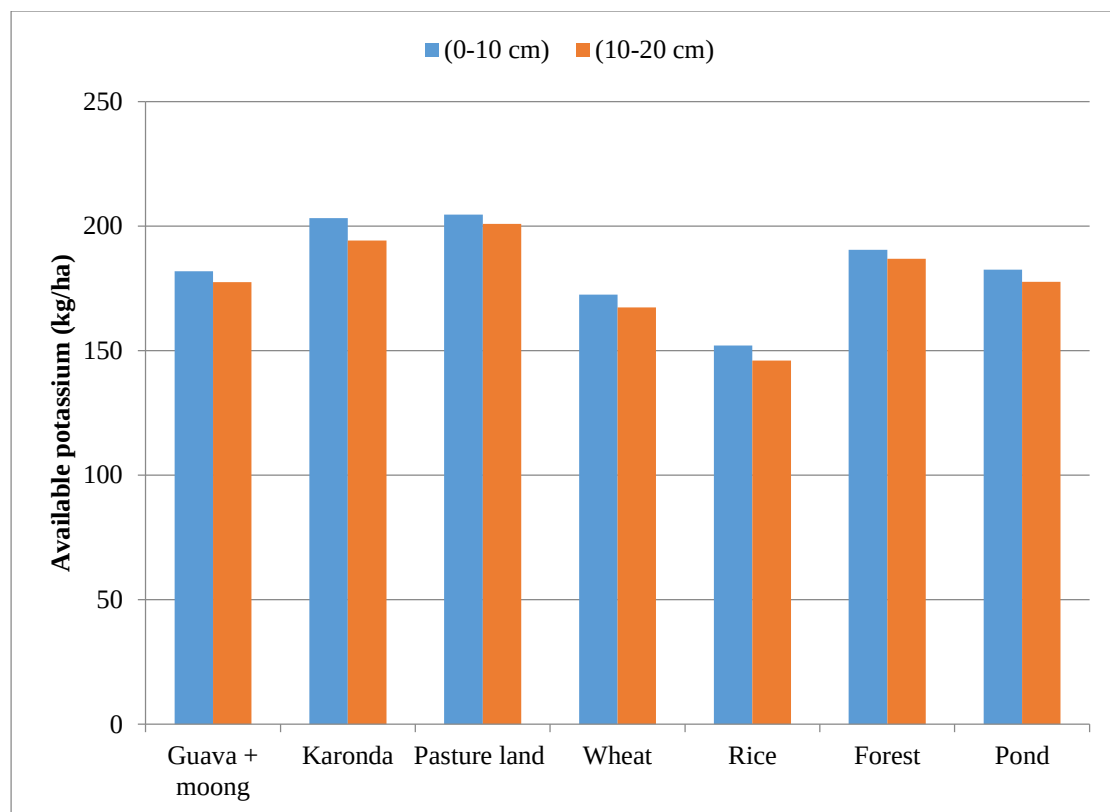
Graph 4.6 Variation in pH in soil of different land use systems



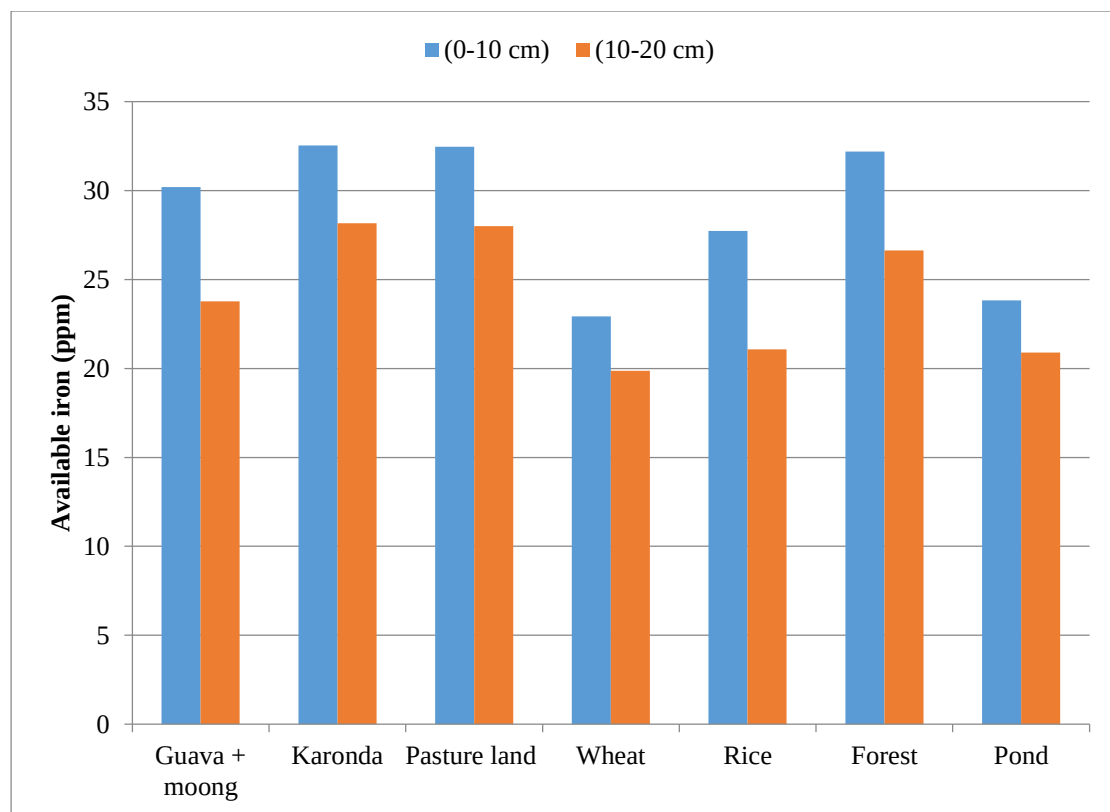
Graph 4.7 Variation in available nitrogen (kg ha^{-1}) in different land use systems



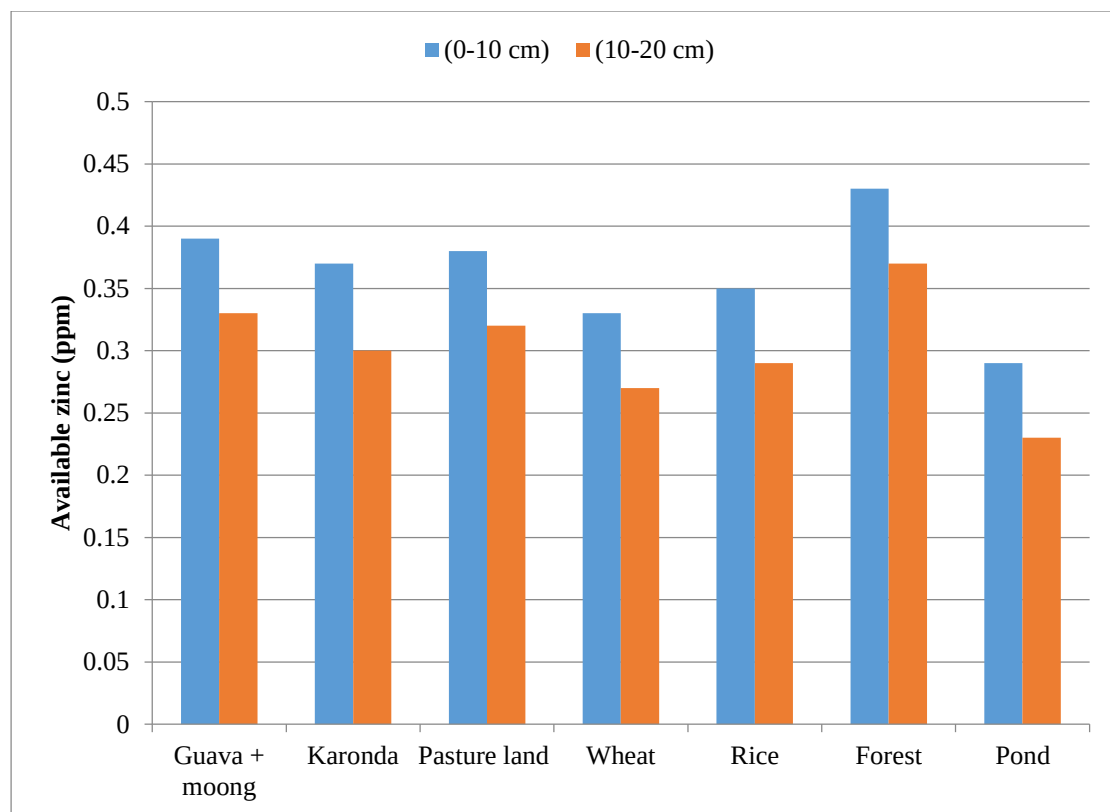
Graph 4.8 Variation in phosphorus in different land use systems



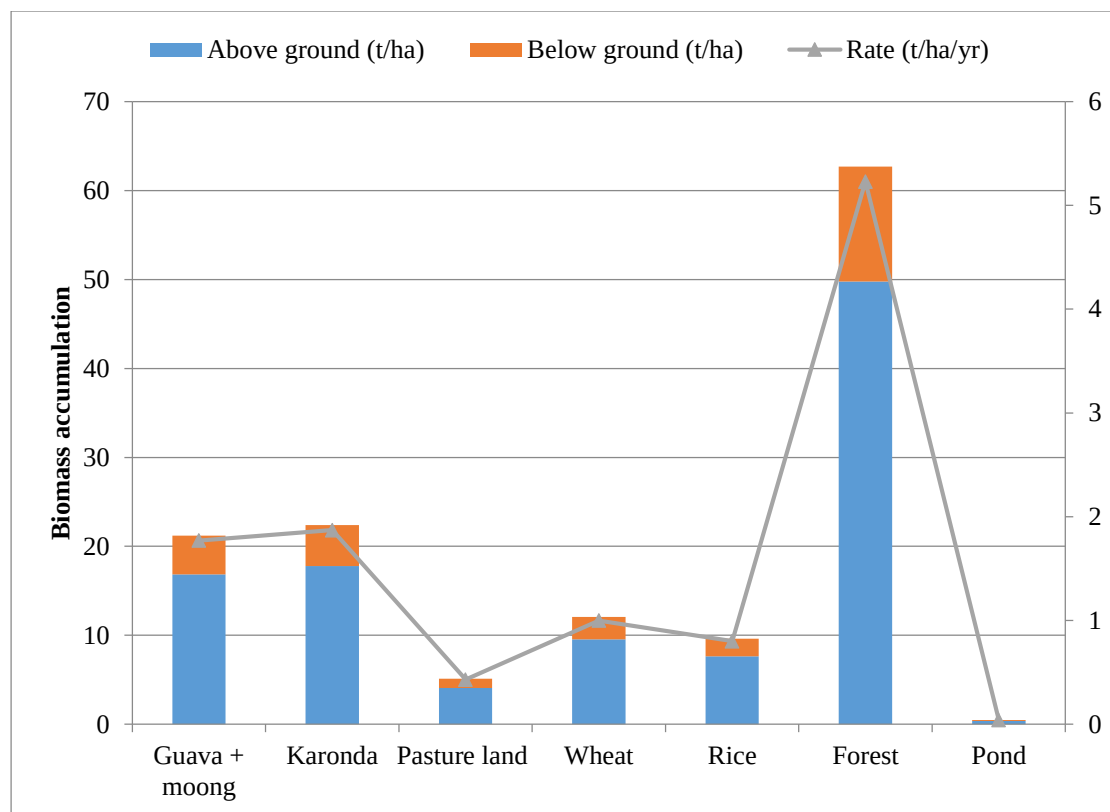
Graph 4.9 Variation in potassium in different land use systems



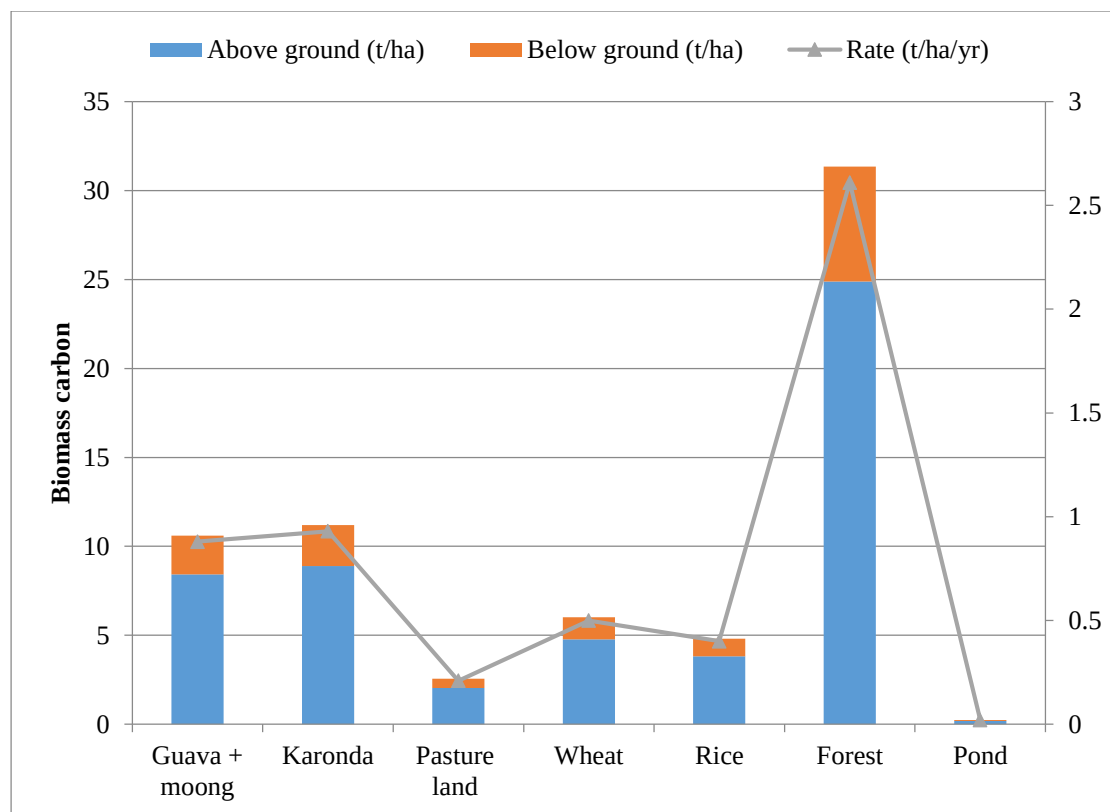
Graph 4.10 Variation in available iron in different land use systems



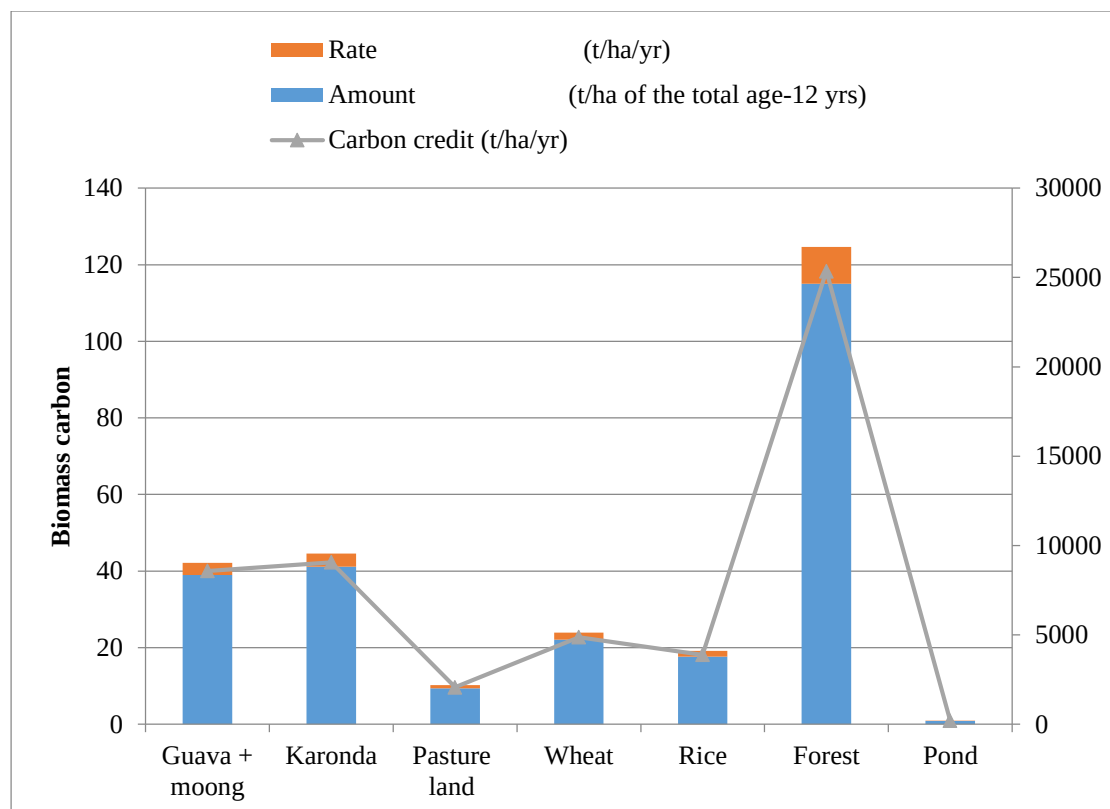
Graph 4.11 Variation in available zinc in soil of different land use systems



Graph 4.12 Variation in above ground biomass in different land use systems.



Graph 4.13 Variation in total biomass of carbon in different land use systems



Graph 4.14 Variation in total CO₂ sequestration in different land use systems

DISCUSSION

The investigations on “Estimation of carbon credit under different land use systems in Vindhyan region” were carried out at Banaras Hindu University-South Campus, Barkachha, Mirzapur district of Uttar Pradesh (India) during the years of 2018-2019. The present study is a maiden attempt to know the biomass, carbon stocks and carbon credit from different land use systems at, BHU-South Campus. This chapter has been devoted to examine the results of the current study based on logical arguments in the light of scientific evidences wherever available in the literature. The results have been proved by establishing the cause and effective relationship among them to derive a fruitful conclusion under the following heads and subheads:

5.1 Effect of land use systems

Soil Physico-chemical properties

The different land use system significantly influenced the soil physico-chemical properties viz., soil organic carbon, bulk density, p^H , available N, P, K, Zn and Fe at both depth of the soil (0-10) and (10-20) cm but particle density at (0-10) cm and EC found non-significant at both depth of soil.

It was crystal clear from the data that organic carbon (%) varied significantly under different land use systems and soil layers in the experiment. The maximum soil organic carbon was recorded under forest land use system and followed by the pond land use system in both depth of soil, respectively. Lal et al., (1998) reported significantly higher organic carbon in forest and fruit tree based land use systems than in annual cropping systems. Low soil organic carbon under arable land use systems may be attributed to the intensive cropping in annual based land use systems. Mandal et al., (2007) also reported that the rate of decomposition of SOM is generally higher in tropical than in temperate climate. However, crop species also play an important role in maintaining SOC pools, through the quality and quantity of the residues that were returned to the soil. The carbon fixed by the plant is the primary source of organic matter input into the soil, which provides substrate for microbial process and accumulation of

soil organic matter. The below ground allocation of photosynthetic is also an important factor for improving soil organic carbon content (Kaur et al., 2002).

Bulk density (g/cc). The data presented in the table 4.4 showed that the bulk density (g/cc) varied significantly under different land use systems and soil layers. Similarly, Mishra et al., (2014) reported that in the surface soil layer (0–15 cm), the bulk density (BD) decreased under agroforestry, horticultural plantations and rice–wheat systems over the uncultivated barren sodic soil. Under the *Casuarina equisetifolia* L. the lowest BD (1.36 mg /cc) was observed, whereas the highest BD of 1.52 mg/cc was recorded under the uncultivated barren sodic soil. The higher value of bulk density in the soils can also be ascribed to lower soil organic carbon content in these systems. These findings were in agreement with the findings of Sharma (2004).

5.2 Soil organic carbon stock

Soil organic carbon stock was determined by multiplying organic carbon with soil weight for a particular depth. It was evident from the data presented in the table 4.4 that soil organic carbon was significantly influenced by land use systems. Maximum soil organic carbon density was recorded in karonda based horti-pasture system(T2) (8.92 t ha⁻¹) cropping pattern, which remained statistically at par with all woody component based land use systems but was found significantly higher than the agriculture crop based land use system. This might have been happened because of enhanced accumulation of leaf litter under the tree and fruit based agri-horti systems. The abundant leaf litter or pruned biomass returned to the soil, (combined with decay of roots) contributed to the improvement of organic matter content under complex land use systems (Beer et al., 1990). The findings were similar to those obtained by a few other worker like Koul and Panwar, (2012) and Odiwe et al., (2012). It was also evident from data that soil organic carbon density declines appreciably from D1 (0-10 cm) to D2 (10-20 cm) soil layer. The increase or decrease in the soil organic carbon pool is associated with the bulk density and organic carbon content of the soil at a particular depth. The higher amount of soil organic carbon stock on the surface layer i.e. 0-10 cm soil depth might be explained by the fact that there was continuous accumulation of leaf litter on the surface, which kept on decomposing and thus enriched the upper soil layer (0-10 cm) continuously. These results were in line with the findings of Woomer and Palm (1998), Chauhan and Gupta et al., (2011). Further among the four land uses (forest, grassland, horticulture, agriculture) on SOC stock as well as

concentration was found to be the highest at soil depth (0-10 cm) in temperate and the lowest in subtropical climate in the same soil (Singh et al., 2011). Ghimire et al., (2008) also reported that soil (0-50 cm depth) under no-tillage retained higher carbon than conventional tillage treatment.

5.3 Biomass production

All the land use systems were directly influenced the micro-climate of the soil and plant which will affect the different growth stages of the crop and ultimately productivity. Results showed that the biomass viz., above, below, total biomass and rate of biomass accumulation were significantly influenced by the different land use systems (Table 4.12). The maximum above, below, total biomass and rate of biomass accumulation was recorded in forest land use system but karonda and guava+moong land use system found at par with each other. Swamy et al., (2003) revealed that the nutrient rich soil, produced more biomass is allocated to the above ground parts of the tree and crops. The similar result was also presented by Yadava (2011), Chavan and Rasal (2012) and Bohre et al., (2014). The below ground biomass, in general, follows the same trend as that of above ground biomass (Pande, 2005). The production of above ground biomass of trees were affected by a number of factors like, growth habit of the species, site quality, soil, age of the tree, management practices, intercultural operations, moisture conservation and its interaction with below ground biomass (Yadav 2012). The rate of biomass accumulation in different land use system depends on a number of factors including the growth habit of species, site quality, age, management practice and the interaction between trees and under store crops, with the increase of age in woody components the rate of biomass accumulation decreases. (Jana et al., 2009, Kanime et al., 2013)

5.4 Carbon sequestration potential

Data indicated that all the traits of biomass carbon *i.e.* above ground carbon, below ground carbon, total carbon and rate of biomass carbon were significantly influenced by the different land use systems (Table 4.13). In the present investigation the maximum above ground, below ground, total and rate of biomass carbon sequestration were exhibited by forest based land use system. Carbon mitigation potential of forestry and agroforestry systems is dependent on the tree density, age, structure and C concentration in different components

(Oelbermann et al., 2004, Swamy and Puri 2005; Kanime et al., 2013). The below ground carbon sequestration and total carbon sequestration in general, followed more or less same trend as depicted by the above ground carbon sequestration. Only slight variation was detected in annually based cropping systems, which can be attributed to their variation in carbon allocation pattern to aerial and below ground component (Oelbermann et al., 2004, Swamy and Puri 2005; Kanime et al., 2013). The amount of carbon sequestered largely depends on the kind of land use system, management practices adopted, soil and climate of the region (Prasad et al., 2012). Carbon sequestration in different land use systems can be broadly divided into sequestration in above ground and below ground plant parts. The above ground carbon sequestration rates in some major land use systems around the world are highly variable in nature (Nair et al., 2010). The similar results were also reported by Chavan and Rasal (2012), Bohre et al., (2011), Koul and Panwar (2008), Rathore and Jasrai (2013).

5.5 Rate of C and CO₂ sequestration

The rate of C and CO₂ sequestration, removal and retention follows the same trend as that of the above, below and total biomass carbon sequestration and rate of biomass production. This is because the rate of C and CO₂ sequestrations are simply derived from the rate of biomass production. The highest rates of C and CO₂ sequestration were recorded under forest based land use system. This was in conformity with findings of Kanime et al., (2011) and Barakas and Aune (2011).

5.6 Carbon credits ($\text{ha}^{-1} \text{yr}^{-1}$)

Carbon credits expressed in term of $\text{₹ha}^{-1}\text{yr}^{-1}$ were calculated based on the quantum of CO_2 absorbed from the atmosphere and locked in the form of biomass. One ton of CO_2 fixed in biomass is equal to 1 carbon credit and the value of one carbon credit is 38 US \$.

In the agriculture farm of BHU-South Campus, critical appraisal of data showed that carbon credit ($\text{₹ha}^{-1}\text{yr}^{-1}$) varied appreciably under different land use systems. Maximum carbon credit ($\text{₹ } 25352 \text{ ha}^{-1} \text{ yr}^{-1}$) was evaluated under forest (T6), and this was followed by karonda orchard (T2), guava+moong (T1), wheat (T4), rice (T5), pasture land (T3), pond (T7), respectively in descending order. From above results, it can be inferred that more carbon credit can be realized from forest. The amount of carbon credits which can be realized from a land use system is the function of rate of CO_2 capturing ability of plants and its locking in the form of biomass..



Pictures of different land use system



Fig. 1: (T1) Guava +moong system



Fig. 2: (T2) Karonda



3: (T3) Pasture land

Fig.



Fig. 4: (T4) Wheat field



Fig. 5: (T5) Rice field



Fig.6: (T6) Forest

Pictures of different land use system



Fig. 7: (T7) Pond



Fig. 8: Sample collection from field



Fig. 9: Lab work

SUMMARY AND CONCLUSION

A field experiment entitled “Estimation of carbon credit under different land use systems in Vindhyan region” was carried out at Mahamana Agricultural Research Farm of Banaras Hindu University-South Campus, Mirzapur (U.P.) during 2018-2019. The experiment was carried out in a Randomized Block Design (RBD) with seven treatments (land use systems) and 3 replications. The data was recorded on above and below ground biomass of all the land use systems. Crop and grass biomass was estimated by using 1x1 m² spacing. Crop and fruit trees were either determined on unit area basis. Soil attributes viz., electrical conductivity, p^H, bulk density, particle density, available nutrients (N, P, K, Zn and Fe) and soil organic carbon were also determined and these were used for preparing the soil organic carbon stock. These soil samples were taken from (0- 10) cm and (10-20) cm soil depth. The salient findings of the experiment are summarized as under:

- ❖ The different land use systems had significant influence on the soil organic matter. Data showed that the maximum organic carbon observed in forest land use system (0.66%) followed by the karonda land use system (0.40%).
- ❖ The results of the experiment showed that different land use systems had significant influence on bulk density. The maximum bulk density was observed in wheat land use system (1.60 g/cc) followed by the karonda land use system (1.59 g/cc).
- ❖ The different land use systems had significant influence on the carbon stock. Data showed that the maximum soil carbon stock was recorded under forest land use system (18.40 t ha⁻¹) and followed by the karonda land use system (12.70 t ha⁻¹), respectively.
- ❖ The results of the experiment showed that different land use systems had significant influence on particle density. The maximum particle density was observed in rice land use system (2.69 g/cc) followed by the pasture land use system (2.68 g/cc) at 10-20 cm depth of soil.
- ❖ The different land use systems had significant influence on the bulk density. Data showed that the highest BD was recorded in rice land use system (1.57 and 1.62 g/cc) at 0-10 cm and 10-20 cm soil depth and followed by the karonda land use system.
- ❖ The data showed that the different land use systems were non-significantly improve the soil electrical conductivity at 0-10 cm and 10-20 cm depth of soil.

- ❖ The data revealed that the different land use systems were significantly differentiate the soil p^H at 0-10 cm and 10-20 cm soil depth. The maximum soil p^H was observed under pond land use system (6.10 and 5.93), followed by the forest land use system (5.60 and 5.37) at each soil depth.
- ❖ The data showed that the different land use systems were significantly differentiate the available nitrogen. The maximum available nitrogen was observed under forest land use system (207.60 and 194.57 kg ha⁻¹), followed by the karonda land use system (202.67 and 188.97 kg ha⁻¹) at each soil depth.
- ❖ The data revealed that the different land use systems were significantly improved the available phosphorus at 0-10 cm and 10-20 cm soil depth. The maximum available phosphorus was observed under forest land use system (19.27 and 18.10 kg ha⁻¹), followed by the pond land use system (17.23 and 15.93 kg ha⁻¹) at each soil depth.
- ❖ The data indicated that the different land use systems were significantly increased the available potassium in soil at 0-10 cm and 10-20 cm soil depth. The maximum amount of available potassium (204.60 and 200.87 kg ha⁻¹) was found in pasture land use system followed by the karonda land use system (203.16 and 194.20 kg ha⁻¹) at each soil depth
- ❖ The data showed that the different land use systems were significantly improved the available iron at 0-10 and 10-20 cm soil depth. The maximum available iron was recorded in karonda land use system (32.53 and 28.17 ppm), followed by pasture land use system (32.47 and 28.00 ppm) at both soil depth, respectively.
- ❖ The data indicated that the different land use systems were significantly increased the available zinc at 0-10 and 10-20 cm depth of soil. The maximum available zinc was recorded in forest land use system (0.43 and 0.37 ppm) followed by guava+moong land use system (0.39 and 0.33 ppm) at both soil depth.
- ❖ The results of the experiment showed that different land use systems had significant influence on the accumulation of above, below and total biomass and rate of biomass accumulation. The maximum above ground biomass (49.76t ha⁻¹), below ground biomass (12.94 t ha⁻¹), total biomass (62.70 t ha⁻¹) and rate of biomass (5.23 t ha⁻¹yr⁻¹) recorded under forest land use systems.
- ❖ The results of the experiment indicated that different land use systems had significant influence on the above, below and total biomass carbon and rate of carbon sequestration. The maximum above ground carbon biomass (24.88 t ha⁻¹), below

ground carbon biomass (6.47 t ha^{-1}), total carbon biomass (31.35 t ha^{-1}) and rate of carbon sequestration ($2.61 \text{ t ha}^{-1}\text{yr}^{-1}$) were recorded in forest land use system.

- ❖ The maximum amount of CO_2 sequestration (115.06 t ha^{-1}) and the maximum rate of CO_2 sequestration ($9.59 \text{ t ha}^{-1}\text{yr}^{-1}$) were displayed by forest land use system.
- ❖ Carbon credit varied appreciably among different land use systems at BHU-South Campus. The maximum carbon credit ($25352 \text{ ₹ ha}^{-1} \text{ yr}^{-1}$) was recorded in the forest land use system.

CONCLUSION

On the basis of above, it can be concluded that at Banaras Hindu University-South Campus, Mirzapur, forest and fruit based land use systems viz., guava based agri-horti system and karonda based horti-pasture system are not only biologically productive but has more carbon density, CO_2 sequestration potential than field crops based land use system. On the other hand, from the carbon mitigation potential point of view land use systems need to be promoted over the traditional field crops based land use system for realizing better environmental benefits.



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