Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system

काशी हिन्दू विश्वविद्यालय
BANARAS HINDU UNIVERSITY

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THESIS

Submitted in partial fulfilment of the requirements
for the award to the degree of

Master of Science (Agriculture)
In
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Supervisor
Dr. S.K. Prasad

Submitted by
Siddharth Jha

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CERTIFICATE

To

The Joint Registrar (Academic),
Office of the Registrar,
Banaras Hindu University,
Varanasi–221 005 (India).

Sir,

I have great pleasure in forwarding the thesis entitled ***"Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system"*** submitted by **Mr.Siddharth Jha, I.D No.20430AGF025** in partial fulfilment 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,

Forwarded by

Head

(Dr. S.K. Prasad)

Supervisor

Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system

by

Siddharth Jha

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Date:

Place: BHU (Siddharth Jha)

Contents

ABBREVIATIONS AND SYMBOLS USED

et al.	and others (co-authors)	Rs.	rupees
@	At the rate of	SOC	Soil organic carbon
cm	centimetre	kg ha^{-1}	Kilogram per hectare
DAS	days after sowing	RH	Relative humidity
°C	Degree celsius	mg	milligram
Fig.	figure	dSm^{-1}	deciSiemens $meter^{-1}$
ha^{-1}	Per hectare	max.	maximum
kg	kilogram	min.	minimum
m	meter	pH	Potential of hydrogen ion
mm	millimeter	MOP	Muriate of potash
N	nitrogen	C.D.	Critical difference
P	phosphorus	SE(m)	Standard error of mean
K	potassium	SMW	Standard metrological data
viz.	Namely (*videlicet*)	t	ton
%	percent	q	quintal
SEm±	Standard error of mean	$gm^{-2}day^{-1}$	gram permeter square per day
i.e.,	That is	$gg^{-1}day^{-1}$	Gram per unit gram per day
NS	Non-significant	m^2	Square meter
Mt	Million ton	EC	Electoral conductivity

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Chapter I

INTRODUCTION

Agriculture, along with its allied sectors, is India's most important source of income. This sector employs approximately 50-55 percent of the total number of people in India and contributes approximately 20.19 percent of the GDP. However, Agriculture is also well known for contributing significantly to global greenhouse gas emissions, and traditional agricultural practises have resulted in a decline in soil quality and carbon storage However, emerging land management approaches have the ability to reduce these emissions and reverse much of the ecological and climate damage caused by overly intensive systems. Agroforestry cultivation and conservation of trees along with crop is one such technique that is a significant climate smart solution with several key co-benefits. Integrating forest trees into agricultural ecosystems is generally quite complex and may be difficult to implement in a variety of scenarios, and there is no single solution that works in every situation. This has increased soil fertility, crop yield and productivity, nutrient cycling, the development and modification of microclimates, and much more (Amundson *et al*., 2015).

Agroforestry practises have spread in central and eastern UP in recent years as a result of large-scale adoption, particularly on marginal and degraded soils. UP is not only the most populous state, but it also contributes significantly to India's national food grain stock. Eastern UP is gradually implementing agroforestry, which is distinguished by a subsistence agriculture zone with low crop intensity and irrigation capability. Instead of monocropping, the state's Eastern Plains and North Eastern Tarai zones should implement proper agroforestry systems such as agri-silviculture, silvi-horticulture, agri-silvi-horticulture, and silvo-pastoral systems (Rana *et al*., 2007). The most common system used by large and medium farmers in this region is fruit tree-based agroforestry. In their farmlands, the majority of farmers grow vegetables and fruits such as *Artocarpus heterophyllus* (jackfruit), *Psidium guajava* (guava), banana, and numerous citrus fruits. The principal woody perennials integrated with agricultural crops by farmers in agri-silviculture systems include eucalyptus, shisham, and poplar.

Guava (*Psidium guajava L.*) is a popular tropical fruit grown in many tropical and subtropical areas. It is endemic to tropical America and belongs to the Myrtaceae family. It is grown in India on a total area of 0.13 million hectares in Uttar Pradesh (the greatest area and output), Bihar, M.P., Maharashtra, A.P., and other states. In 2016, India was the world's top producer of guavas, accounting for 41% of the global production. Guava is a fast-growing evergreen tree that can reach heights of 3-10 m and develops low drop branches and root suckers from the base.

Custard apple (*Annona squamosa* L.) is also known as Sita Phal. It is found across the tropics and is regarded as a desert fruit that is typically consumed fresh. The vitamin C concentration is significant (approximately 42 mg/100 g) and slightly higher than that of grapefruit. The tree makes great firewood. The green fruits, seeds, and leaves contain vermicidal and insecticidal qualities. It can be utilised as a shade tree and is also good for cultivating with short-term arable crops.

The presence of trees improves soil fertility and quality by accumulating nutrients and organic matter in the soil and reducing losses of soil and thereby improving soil physical, chemical, and biological qualities. Agroforestry systems offer a significant potential to boost productivity of marginal and degraded lands and Trees have a more diverse impact on soil qualities than crops due to their longer maturity time. This is due to increased biomass accumulation and the large root systems of trees (Young, 2005). furthermore, the improvements in soil qualities may be gradual, but the end result is a better soil medium for maintaining plant growth and increased soil productivity. Furthermore, there is it increase in plant nutrient cycling, which leads to a reduction in nutrient loss beyond the soil's nutrient-absorbing zone (Patra, 2013).

Gairola and colleagues (2011) stated that Trees are well known for preserving soil organic matter and nutrient cycling by incorporating litter and root wastes into Through litter fall and root turn over, tree plantations have a major impact on the physical, chemical, and biological aspects of the soil. A large amount of organic matter and nutrients are added to the soil depending on the species planted, decomposition rate, plantation age, season, and spacing (Holland and Coleman, 1987; Mohsin et al., 1996; Munoz and Beer, 2001). Because of their deep root structure, trees have the ability to take nutrients from and below the rooting zone of typical crops. These nutrients are also brought to the soil surface by trees. Under, soil organic carbon and nutrient content are generally higher, and soil characteristics are improved, compared to nearby open lands

(Mathew *et al*., 1997) Soil organic matter operate as a sink and source of carbon in the atmosphere depending on how it changes.

Although C:N:P:K ratios are often measured in key compartments of agroecosystems, Once possible explanation is that fertiliser inputs have lowered nutrient interactions by modifying their potential limiting effects on biological processes. For example, since agricultural soils in industrialised countries have been enriched with P fertilisation for decades, there is very little evidence to suggest P limiting of processes of C and N transformations in soils (Ringeval *et al*. 2014). Thus, a "decoupling" of N and P cycles was seen in fertilised agroecosystems (Yuan and Chen 2015). Decoupling is defined by a reduction in biological interactions, which may increase N and/or P losses to the environment (air, soil, water, etc.) and have a negative impact on the ecosystem services connected with agricultural land.

Keeping these in view, the present investigation ***"Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system"*** was implemented at Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, India, with the following objectives:

1. To study the physico-chemical properties of soil under agri-horti system.
2. to study the nutrient concentration of soil under custard apple and guava based agri-horti system.
3. To assess the nutrient stoichiometry of soil under agri-horti system.

Chapter II

REVIEW OF LITERATURE

Agroforestry is the process of bringing trees into farms to increase land performance and increase people's livelihoods for both developed and emerging nations. Planting trees and crops enhance soil fertility, minimizes soil erosion, controls waterlogging, boosts local biodiversity, reduces fuel demand on natural forests, and provides food for cattle. It has the potential to improve the system's resistance to the negative effects of climate change. Under the following subheads, this chapter has attempted to give a review of studies on the nutrient acquisition in custard apple and guava based agri-horti system.

2.1 Effect of agri-horti system on soil physicochemical properties

2.1.1 Soil physical properties

- Bulk density (BD)
- Particle density (PD)
- Soil Porosity

2.1.2 Soil chemical properties

- Soil Organic Carbon (SOC)
- Soil pH
- Soil Electrical Conductivity (EC)
- Available Nitrogen (N)
- Available Phosphorous (P)
- Available Potassium (K)
- Available micronutrients (Fe, Zn)

2.2 Effect of agri-horti system on soil nutrient Stoichiometry

2.3 Effect of agri-horti system on Biomass accumulation

2.4 Effect of agri-horti system on CO_2 sequestration

2.5 Interaction effect of Agroforestry systems with soil depth

2.1 Effect of agri-horti system on soil physicochemical properties

2.1.1 Soil physical properties

2.1.1.1 Soil BD (g cm^{-3})

Kaur *et al.* (2021) investigated the nutrient status in the lower Satluj basin of the Shiwalik foothills Himalaya, India,under different ecological system. To examine the physicochemical parameters of soil, 120 soil samples were taken at four soil depths: 0–15, 15–30, 30–45, and 45–60 cm. The soil's BD ranged from 1.30 to 1.59 g cm^{-3}, according to the trial.

Choudhary *et al*. (2020) collected soil samples from three blocks at two different depths in Rajasthan's Rajsamand districts and the results showed that BD ranged from 1.09 to 1.30 g cm^{-3}.

Pandey *et al.* (2018) investigated soil physical properties in a Mollisol at G.B Pant University in Pantnagar. According to the findings, the BD ranged from 1.29 to 1.43 g cm^{-3}.

Bana and Uthappa (2015) Changed tree density, and soil depth and their interactions all had a major impact on soil bulk density. The soil bulk density (g/cm3) dropped as tree density increased, with solo cropping having a considerably higher (1.51 g cm^{-3}) soil bulk density than the tree-based system at all density classes.

Dutta *et al*. (2017) studied in four villages at Nagaland's Longleng district to determine soil physicochemical parameters. The average BD and PD were 1.18 to 1.51 g cm^{-3}and 2.2 to 2.34 g cm^{-3}, respectively.

Maqbool *et al.* (2017) evaluated seven land-use systems in Ganderbal district, Jammu and Kashmir, to analyse soil physicochemical parameters. Woodland, horticulture, pastures, wastelands, agri-horticulture, irrigated agriculture, and unirrigated agriculture. (1.57 g cm^{-3}) > wastelands (1.52 g cm^{-3}) > agri-horticulture (1.44 g cm^{-3}) > horticulture (1.43 g cm^{-3}) > agriculture irrigated (1.42 g cm-3) > pastures (1.31 g cm^{-3}) > forestry (1.31 g cm^{-3}) > forestry (1.31 g cm^{-3}) (1.28 g cm^{-3}).

Salve *et al.* (2018) studied soil physical parameters under various land-use systems and found that the agri-silviculture system had a greater bulk density (1.34 g cm^{-3}). The maximum bulk density (1.47 g cm^{-3}) was found at a depth of 15-30 cm, while the smallest bulk density (1.20 g cm^{-3}) was found at a depth of 0-15 cm. The agri-horticulture system recorded a higher particle density (2.49 g cm^{-3}). Under the agri-silviculture system, the pore space percent was much higher (46.99 percent).

Singh *et al.* (2018) studied at the impact of different agroforestry systems on soil properties and found that *Melia azedarach* (1.37, 1.40, and 1.44 g cm^{-3}) based agroforestry fields had the highest bulk density for all soil depths (0-15, 15-30, and 30-60 cm), while *Populus deltoids* had the lowest (1.25, 1.27, and 1.28 g cm^{-3}).

2.1.1.2 Soil PD (g cm^{-3})

Kaur *et al.* (2021) collected 120 soil samples They examined the soil nutrient quality located in the Shiwalik foothills of the Himalaya. The soil particle density ranged from 2.60 to 2.69 g cm^{-3}.

Choudhary *et al.* (2020) examined the physical parameters of soil in three Rajasthani blocks. Soil samples were taken from three different blocks at two different depths: 0-15 cm and 15-30 cm. According to the findings, particle density ranged from 1.90 to 2.90 mg $^{m-3}$.

Singh *et al.* (2017) experimented with the Majhwa block of Mirzapur, Uttar Pradesh's Vindhyan region. Six villages provided 480 samples, which were taken from the surface (0-20 cm) and subsurface (20-40 cm). Surface and subsurface soil particle densities were 2.44 and 2.48 mg $^{m-3}$, respectively.

Deb *et al.* (2014) investigated the physical and chemical parameters of soils in a hilly terrain area in South Sikkim. Thirty-five soil samples were obtained from various places, ranging in depth from 0 to 20 cm. The particle density ranged from 2.05-2.77 g/cm^{-3}, according to the findings.

2.1.1.3 Soil Porosity

Sharrow *et al.* (2007) Soil in the silvopastures had 7% lower total porosity than those in adjacent forests in 2002. Most of the difference in total porosity was air-filled pores. Average water infiltration rate was 38% less in silvopastures than in forests, however total water stored in the top 6 cm of soil at field capacity was similar, total porosity, and air-filled pore space was similar for forests, pastures, and silvopastures after 2 years without livestock grazing.

Wang *et al.* (2017) The intercropping system had continuous improvement on soil porosity in each soil layer, but mainly in the 0-20 and 20-40 cm soil layer, and the ratio of capillary porosity was also improved.

Carvalho *et al.* (2004) The soil under agroforestry exhibited a superior quality compared to the same soil cultivated by a conventional system, reflected by smaller soil density, higher porosity, lesser resistance to penetration and higher aggregate stability.

Ketema *et al.* (2014) With the objectives of assessing variations in selected soil properties, two tillage types: agroforestry-based conservation tillage (AFCST) and maize based conventional tillage (MCVT) under three age categories (5, 10 and 15-years) were selected in Chichu and Haroresa Kebels, Dilla Zuria, Ethiopia. A total of 48 composite soil samples (4 replication × 2 tillage types × 3 age categories × 2 soil depth layers: 0–10 cm and 10–20 cm) were collected to analyze texture and soil organic carbon (SOC%). The results showed that clay and sand textural fractions significantly varied ($p < 0.001$, $p = 0.002$, respectively) with age of land management. Soil bulk density, soil moisture content (SMC), total porosity (P_t) and soil organic carbon (SOC) varied significantly with tillage types ($p < 0.001$) and soil depth ($p < 0.001$). Water infiltration (rate and cumulative) significantly varied ($p < 0.001$) with tillage types: higher in the AFCST than in the MCVT.

2.1.2 Soil chemical properties

2.1.2.1 Available SOC

Kurien *et al.* (2021) compared the SOC pools of native forests with monoculture tree plantations (teak, eucalyptus, and rubber) in Kerala's Kollam district. Soil samples were taken from the depth of 50 cm. SOC concentrations varied from 41.89 to 54.09 g kg^{-1} (0–10 cm) and decreased with depth up to 30.11 to 32.98 g kg^{-1} (40–50 cm), according to the findings. Natural forest (225.34 t ha^{-1}) had the highest SOC pool, followed by rubber (203.48 t ha^{-1}), eucalyptus (196.21 t ha^{-1}), and teak plantation (194.61 t ha^{-1}).

Naik *et al.* (2017) studied the decomposition of leaf litter and the definite pattern of nutrient immobilization and mineralization in guava, mango, and litchi leaf litters. Litchi orchard (6.15 g kg^{-1}) had the highest organic carbon content, followed by mango (6.12 g kg^{-1}) and guava (6.12 g kg^{-1}) (6.00 g kg^{-1}). Mango had the highest annual decomposition constant (k) rate (3.22), followed by guava (1.33) and litchi (1.33). (0.62). The slower rate of decomposition of litchi litter compared to mango and guava litter was owing to the higher percentage of lignocellulose in litchi leaf litter (85 percent).

Singh *et al.* (2018) conducted a study in the Giri catchment of Himachal Pradesh, Himalaya, and discovered that agri-horticulture systems had significantly higher mean

SOC (2.22 percent) than other systems. When compared to other height ranges, the bulk density of soil was substantially higher at elevation E3 (1.28 g cm^{-3}). Grassland had the highest mean maximum soil organic carbon density (53.45 t C ha^{-1}), followed by agrihorti-silviculture (52.57 t C ha^{-1}), agri-horticulture (51.88 t C ha^{-1}), agri-silvi-horticulture (51.18 t C ha^{-1}), and agrisilviculture (50.01 t C ha^{-1}).

According to Basavaraja *et al*. (2007) organic carbon percentage was highest (1.61 percent) at the surface (0-15 cm) and decreased to 0.92 percent at 60-90 cm depth in the *Prosopis juliflora*-based agroforestry system, while it ranged from 0.78 percent at the surface (0-15 cm) to 0.44 percent at 60-90 cm depth in the control system (without trees).

Mandal *et al.* (2012) investigated the organic carbon stock in soil profiles in the Deras command of Odisha province, India, using several cropping systems such as rice-rice, rice-fallow, rice-groundnut, guava, and mango orchard. The rice fallow system had the highest value of soil organic carbon storage (16.80 Mg/ha), while the guava orchard had the lowest (11.81 Mg/ha). SOC in mango orchards is 16.08 Mg ha^{-1} in 15-30 cm and 8.74 Mg/ha in rice-rice systems. SOC levels in guava and mango orchards were 54.71 Mg/ha and 68.53 Mg/ha at depths of 0-90cm, respectively.

Sahoo *et al.* (2019) investigated the soil organic carbon stock and its distribution at various depths of the soil profile in Mizoram and compared different land use types. The forest had the highest total carbon (3.05 percent), followed by present jhum (2.19 percent) and grassland (1.45 percent). The inorganic carbon contents in these soils ranged from 0.14 to 0.31 percent. Except for soil in plantations, the forest had the highest total SOC (2.75 percent), however, the outcome was not equal (p0.05) (1.38 percent). The average total SOC content (percent) dropped in the following sequence in the various land use types: Agroforestry > Wet Rice Cultivation > Jhum Fallow > Plantation > Grassland > Forest > Current Jhum Regardless of land use regime, soil organic carbon was higher on the surface and reduced as soil depth increased.

Zade *et al.* (2020) experimented with Maharashtra's Parbhani district to investigate carbon storage and distribution at different depths under various horticultural cropping methods. The results showed that soil organic carbon (SOC) in the horticultural cropping system decreased with depth (30-60 cm), ranging from 21.60 Mg ha^{-1} (0-30 cm) to 25.86 Mg ha^{-1} (30-60 cm). The value of soil organic carbon in mango orchards was higher regardless of soil depth, followed by orange and pomegranate orchards. Soil inorganic carbon followed the opposite pattern as soil organic carbon, with a larger value of SIC concentration reported in deep soil (30-60cm) than in surface soil (0-30 cm). At both depths (0-30 cm and 30-60 cm), SOC and SIC were favourably linked with total organic carbon and, respectively.

Selvaraj *et al.* (2016) conducted a study in Tamil Nadu's southern agro-climatic zone and discovered that the value of soil organic carbon content at the depth of 0-20 cm depth was higher in Teak plantations (0.69 to 1.11 percent) across all plantation ages (5 to 20 years), followed by mango (0.64 to 0.85 percent), sapota (0.36 to 1.07 percent), and coconut (0.36 to 1.07 percent) (0.57 to 0.81 percent). In all agroforestry and orchards, topsoil has a higher SOC than subsurface soil.

Prakash *et al.* (2018) investigated the soil organic carbon in (different cropping systems and poplar-based agroforestry systems). Soil organic carbon (SOC) in poplar-based agroforestry was much greater than in other land-use systems.

Gupta *et al.* (2014) investigated SOC from various land use management systems, andreported that. Forests contained the most SOC stock (37.61 tonnes ha^{-1}), followed by plantations (27.26 tonnes ha^{-1}), horticulture (27.96 tonnes ha^{-1}), and agriculture and agro-forestry (17.72 tonnes ha^{-1}) (10.84 tonnes ha^{-1}). Citrus lemonum (lemon) has the highest SOC stock, while Aegle marmelos had the lowest (bel). Soil under trees can sequester three times more organic carbon than agroforestry, while horticulture and plantation can keep twice as much organic carbon. Orchard species include Mangifera indica, Ziziphus mauritiana, and P. *guajava* can hold nearly one and a half times more SOC stock than *A. marmelos.*

Stefano *et al*. (2018) evaluated changes in SOC at four levels of the soil profile after agroforestry conversion: 0-15, 0-30, 0-60, and 0-100. At depths of 0-15 and 0-30 cm, the soil organic carbon store decreased by up to 26% and 24%, respectively, due to a change in soil use from forest to agroforestry. Agriculture > Agroforestry > Forestry > Agrisilviculture>Agrisilviculture was the sequence of soil organic carbon. As land use moved from simple to complex, the organic carbon storage in the soil increased.

Mali *et al.* (2016) investigated soil variability in mango plantations in India's Eastern Plateau and Hill area. The SOC content was higher in the surface soil, ranging from 0.21 to 0.91 percent, and decreased significantly with depth, with values ranging from 0-30 cm (0.51 percent), 30-60 cm (0.40 percent), and 60-90 cm (0.91 percent) (0.31 percent).

Mandal *et al.* (2018) tested the effect of three agricultural land uses (cropland, horticultural land, and uncultivated land) on soil fertility status in the south-western plains of Punjab. The horticultural land had the highest soil SOC concentration in both surface (8.91 g/kg soil) and sub-surface soil (5.75 g/kg soil), according to the findings.

Maqbool *et al.* (2017) investigated the soil physicochemical parameters of the 7 land use system (native forest, horticulture, pastures, wastelands, agri-horticulture, agriculture irrigated, and agriculture unirrigated). SOC was found to be highest in woods (23.68 g kg^{-1}), followed by pasture (20.80 g kg^{-1}), and lowest in wastelands (3.80 g kg^{-1}), followed by irrigated agriculture (4.35 g kg^{-1}).

2.1.2.2 Soil pH

Kumar *et al.* (2020) studied several different land use system in a research farm in Rajasthan's Jaisalmer district. The pH of soils ranges between 8.7-9; with the greatest pH being found in field crop soils.

Agarwal *et al.* (2014) found constant application of nitrogen alone as urea lowered soil pH by 0.8 units over 38 years in a soyabean-wheat system. They also reported that FYM (15 t ha^{-1} yr-1) supplementation stabilised soil pH and maintained a greater soil organic carbon status.

Sujatha *et al*. (2016) discovered that intercropping medicinal and aromatic plants improved soil pH in an arecanut-based planting system. In 2004, the soil pH was 5.6, and it was 0.3 to 0.9 units higher in 2007. At the end of the trial, the organic carbon content of the soil varied dramatically due to intercropping of medicinal and aromatic crops. The organic carbon content of the soil rose in medicinal and aromatic plants.

Jadhao *et al*. (2019) investigated eight typical pedon representing pomegranate growing soils in Maharashtra's Solapur area. Soil pH ranges from 7.7 and 8.3, increasing with depth.

Sirohi *et al.* (2017) studied soil pH in a Poplar-based agroforestry system with various spacings. In comparison to wider spacings, the lowest value of soil pH (7.5) was obtained after harvesting the wheat crop in April of 2015.

Mali *et al.* (2016) investigated soil characteristics in India's eastern plateau region. Soil samples were taken at 90 places in the mango orchards at three different depths (0-30, 30-60, and 60-90 cm). Soil pH, for example, is highly reliant on location and exhibits substantial spatial fluctuation in the surface layer.

Lana *et al.* (2018) studied the influence of native and exotic trees on soil fertility in the Brazilian savannah habitat. Chemical parameters such as pH, K, and base saturation were found to be greater largely in the upper layers (0-2cm) due to enhanced soil organic matter addition, litter decomposition, and increased nutrient availability due to increased cation exchange capacity.

Rathore *et al.* (2013) observed a decrease in soil pH in fruit-centered agrihorticultural system than the initial values that were taken before the creation of the fruit orchard.

Naik *et al.* (2017) conducted a study at the ICAR Ranchi Research Station in Jharkhand on different fruit orchards of 7-year-old mango, litchi, and guava and discovered that the decrease in soil pH was greater in the litchi orchard (pH 4.67), followed by mango (pH 4.68), and guava (pH 4.71) due to heavy litterfall and root biomass in the litchi orchard.

Behera *et al.* (2015) examined the coefficient of variance values of oil palm field at the surface (17.1) and subsurface (19.5) for the soil pH.

Mali *et al*. (2016) discovered that the pH of soil varied from 4.08 to 7.78 depending on the soil layer. The pH value on the surface profile ranged from 4.08 to 6.61. (0-30 cm). The mean pH value increased from 6.61 in the upper layer of the soil profile to 7.65 in the lower depth of the soil profile. The investigation was carried out in India's southern plateau.

Sarvade *et al.* (2014) studied soil characteristics as influenced by several agri-silviculture systems in the Terai Region of Northern India and reported that tree species have a substantial influence on soil pH. Lower pH in agroforestry systems leads to increased aboveground biomass, cation absorption, and organic acid generation by the tree component of agroforestry systems.

Dhotare *et al.* (2019) investigated the soil's nutritional status and chemical characteristics, 44 surface soil samples were taken from 0-20 cm deep. The pH of the soil was found to be between 7.8 and 8.6.

Notaro *et al.* (2014) did a study on agroforestry land in the Brazilian state of Pernambuco and found substantially lower pH values in forest systems. Regardless of treatment, topsoil (0-10 cm) has a greater pH value than soil at the lower level (10-20 cm).

Verma *et al*. (2019) collected soil samples from Prayagraj (Allahabad), Uttar Pradesh. They were tested in the lab to determine the physicochemical qualities of soil. The pH value ranged from 7.35-8.12, atdiffrent land use system.

Bhatt (2013) carried out research in the central Nepal region. Soil pH was shown to increase with depth. In topsoil, improved agroforestry had significantly lower soil pH values than natural forest and traditional agroforestry (0-15 cm).

Baishya and Sharma (2017) investigated soil physicochemical parameters under various agro-ecosystems in Assam's Kamrup area. Soil samples were taken at depths of

0-15 cm and 15-30 cm. At a depth of 0-15 cm, the pH value ranges from 4.64 to 5.98, while at 15-30 cm, it ranges from 4.27 to 5.30.

Jain *et al.* (2014) investigated the physicochemical parameters of farming soil in Gujarat's Lunawada Taluk. The pH of the soil samples ranged from 6.5-7.8 in the experiment, which involved 15 soil samples obtained from several communities.

2.1.2.3 Soil EC (dsm^{-1})

Dhotare *et al*. (2019) looked at judging soil chemical characteristics and available nutrient status in Akola, Maharashtra, and found that soil EC ranged from 0.13 to 0.38 dsm^{-1}.

Tigga *et al.* (2017) experimented to investigate the soil attributes of the land use system of Sarguja District, Chhattisgarh. The physicochemical parameters of the soil were examined in this study. The following were the results of the observation: The pH ranged from 6.9 to 6.08, indicating that it is acidic. The E.C value ranged from 0.335 to 0.142, which is typical.

Alaie and Gupta (2019) studied soil samples to identify their physicochemical state. One hundred and eighty soil samples were taken from several LUSs in the area of Doda at a depth of 0-15 cm. Electrical Conductivity varied between 0.08 and 0.31 dsm^{-1} under forest, 0.18 and 0.77 dsm^{-1} under barren land, 0.11-0.45 dsm^{-1} under agricultural, and 0.10-0.35 dsm^{-1} under horticulture, according to the results.

Kumar *et al*. (2017) evaluated soil fertility in Himachal Pradesh's Mid-Himalayan area. The soil samples were taken from irrigated regions in 32% of the cases, and the rest were taken from fields depending on seasonal precipitation. In the experimental field, the value of EC ranged from 0.049 to 0.793 dsm^{-1}.

Kadam *et al*. (2016) took sixty samples of soil from an experimental field in Maharashtra's Deulgaon Raja region and experimented with soil analysis. Soil samples had EC values ranging from 0.30-0.46 dsm^{-1}.

2.1.2.4 Primary Macro-nutrients in soil (N, P, and K)

Yadav *et al*. (2020) conducted an experiment in Alwar district, Rajasthan, to assess the available N, P, and K status of the soil. Soil samples were taken at two depths, 0-15 cm, and 15-30 cm, from three blocks in the Alwar district. N ranges from 87.5 to 184.1 kg ha^{-1}, P from 25 to 39 kg ha^{-1}, and K from 169 to 298 kg ha^{-1}, according to the study.

S.N. Singh *et al.* (2017) Soil samples were obtained from various localities in Mirzapur's Manhwa Block. The results revealed that the accessible N content in surface (0-20 cm) soils were higher than in subsurface soils (20-40 cm). The mean accessible N content in surface soils (0-20 cm) was 306 kg ha^{-1}, while it was 241 kg ha^{-1} in subsurface soil (20-40 cm).

Shivkumar *et al.* (2020) investigated the availability of important nutrients in the soil of Karnataka's central Western Ghat. Manmade systems (paddy; horticulture: coffee, areca nut, tea, and banana); forest plantations (acacia and teak); and natural systems (acacia and teak) all had soil samples taken from 0-15 cm and 15-30 cm depth (Evergreen, semi-evergreen and grassland). Surface soil had a much higher accessible nitrogen concentration (394.55 kg ha^{-1}) than subsurface soil, according to the findings (330.57 kg ha^{-1}). Coffee (435.82 kg ha^{-1}) had the highest accessible nitrogen level among manufactured LUSs, followed by soils under banana trees (404.40 kg ha^{-1}). Similarly, the available nitrogen content in a natural system ranged from 294.97 to 376.55 kg ha^{-1}, with a low in grassland and a high in the semi-evergreen forest. Soils under coffee (29.31 kg ha^{-1}) had the highest accessible P content, followed by evergreen forest (28.37 kg ha^{-1}), semi-evergreen (27.26 kg ha^{-1}), and other systems. But on the other side, grassland had the least amount of available P. (20.28 kg ha^{-1}). Paddy soils had an accessible K content of 299.42 kg ha-1, which was much lower than other systems but comparable to grassland (311.01 kg ha^{-1}), acacia (321.01 kg ha^{-1}), and teak systems (329.86 kg ha^{-1}).

Sirohi and Bangarwa (2017) studied the impact of varied spacings in a Poplar-based agroforestry system Under varying spacings of the Poplar-based agroforestry system, significantly high accessible soil N, P, and K were obtained in all treatments from their initial values. After wheat harvesting, 54 m spacing yielded the maximum accessible soil N (366.3 kg/ha), P (21.4 kg/ha), and K (355.3 kg/ha) compared to 102 m, 182 m, and lone cropping.

Chauhan *et al.* (2018) evaluated the nutrient content of the soil under Melia and Dalbergia plantations and found that the Melia azedarach system had higher accessible N (156.9 kg/ha), P (28.3 kg/ha), and K (170.1 kg/ha) content than the *Dalbergia sissoo* system.

Rahangdale *et al.* (2018) investigated the effects of various land-use systems on soil nutrient concentration. They found that available N, P, and K were much higher in the Eucalyptus pigeon pea agri-silviculture system than in the moong-wheat conventional cropping land-use system. As the depth of the soil was increased, the soil parameters gradually declined.

Salve *et al*. (2018) investigated nutrient analyses in the agri-horticulture system (AH), agri-silviculture system (AS), and agri-horti-silviculture system (AHS) and found that soil extractable phosphorous (0.81 mg/100g) was higher in the agri-silviculture system than in the other two systems. With increased soil depth, many chemical characteristics were shown to decrease.

Selvaraj *et al.* (2016) found available N content in 5- to the 20-year-old tree planted soil samples varied from 80 to 103 (milligram kg ha^{-1}) in mango, 91 to 105 (milligram kg ha^{-1}) in sapota, 82 to 126 (milligram kg ha^{-1}) in teak, and 85 to 117 (milligram kg ha^{-1}) in coconut. Teak plantations have the highest nitrogen concentration, as shown by the maximum carbon storage in soil. Higher litterfall and decomposition contribute to an increase in soil nitrogen content.)

Mali *et al.* (2016) found total N content was classed as 'poor,' and total nitrogen concentration declined dramatically as soil depth increased. The coefficient of variation (CV) of total N was larger in the lower depth (25.7 percent) than in the surface layer (15.8 percent), but the CV of total N in the soil as a whole was mild. When compared to the subsurface layer, the surface layer had a 24.7 percent higher total nitrogen content (60-90 cm). The mean nitrogen concentration at depths of 0-30 cm was 126.1 kg/ha^{-1}, while depths of 30-60 cm and 60-90 cm were 111.3 kg/ha and 103.1 kg/ha, respectively. This is most likely owing to the fact that the accumulation of the organic residues was the higher upper horizon of the soil profile than in the deeper layers.

Naik *et al*. (2017) investigated the rate of litter decomposition and its impact on the soil's physicochemical and biological qualities. Litchi leaf litter has a high lignin content and a delayed breakdown rate. Mango leaf litter has the lowest Lignin: N ratio (13.9), allowing for fast decomposition. The rate of nitrogen released from the litter was observed to be quick and higher during the first month of decomposition. The available nitrogen content in the soil of litchi and mango orchards was found to be 247 kg/ha and 254 kg/ha, respectively. The available nitrogen content and lignin level (33 percent) were greater in litchi leaf litter, which attributed to a slower decay rate, whereas the fast decomposition rate in mango leaf litter may be attributed to a low lignin content of 17.2 percent.

Pandey *et al.* (2018) investigated by measuring soil physical parameters under various LUSs. The study was conducted under several LUSs, including rice-wheat–green gramme, rice–pea (vegetable)–maize, rice–potato–okra, rice–berseem + oat + mustard (fodder)– maize + cowpea (fodder), maize–wheat–cowpea, sorghum (fodder)–yellow Sarson–black gramme, guava + The amount of available soil N ranged from 148.02 to

311.09 kg ha^{-1}, available soil P from 14.29 to 25.97 kg ha^{-1}, and available soil K from 153.66 to 259.62 kg ha^{-1}

Dameshwar *et al.* (2018) investigated the soil physicochemical parameters of the Kasdol block in Matya village, Chattisgarh, and collected soil samples from a depth of 15-20 cm. The available nitrogen in soil samples ranged from 99.47 to 281.4 kg ha^{-1}, with an average of 152.8 kg ha^{-1}. P levels in soil samples ranged from 4.75 to 18.5 kg ha^{-1}, with an average of 10.4 kg ha-1, while K levels in soil samples ranged from 145.0 to 585.5 kg ha^{-1}, with an average of 280.4 kg ha^{-1}.

Kaur and Za (2017) investigated the impact of LUSs on soil physicochemical parameters in Punjab's lower Shiwalik foothills. Four LUSs had soil samples collected (cropland, forestry, agroforestry, and grassland). The available N, P, and K ranged from 37.78 to 234.78 and 40.48 to 264.47 kg ha^{-1}, respectively, 3.81 to 21.44 and 3.19 to 18.56, 15.83 286.67 and 6.66 to 149.17 kg ha^{-1}.

Paul *et al.* (2018) investigated the phosphorus (P) fractions in several land use management systems (namely, organic farming, apple orchard maize–wheat, uncultivated land, and undisturbed oak woodland of the Indian Himalayas). Total phosphorous showed no significant change. The value of accessible P was highest in oak forests and lowest in uncultivated land. The highest organic phosphorus level was found in apple orchards. The degradation of P pools was seen as a result of farming.

Prakash *et al.* (2018) studied the impact of various agricultural systems and land use on the soil P fraction. The Agroforestry system had the highest total P content (569 mg P/kg) and the lowest (449 mg P/kg) cropping systems. Due to increased fertilisation, the rice-wheat cropping system had a much larger value of accessible P than the agroforestry system. The largest percentage of inorganic phosphorus was found in sole cropping systems (92.2-94.6 percent of total P). Agroforestry systems boost the availability of phosphorous by accumulating organic P.

Naik *et al*. (2017) in a mango, guava, and litchi fruit orchard, it was observed that mango has the highest P-decomposition rate constant (4.11) followed by guava (2.13) and litchi (2.11). (2.13). (1.09). Mango litters have the highest rate of P mineralization (68%), followed by guava (44.1%) and litchi (44.1%). (44.1 percent). (27 percent). As a result, the available phosphorous content in the soil of litchi, guava, and mango orchards was determined to be 24.5 kg ha^{-1}, 21.3 kg ha^{-1}, and 31.7 kg ha^{-1}, respectively.

Mali *et al.* (2016) investigated the spatial variability of the mango orchard and discovered that the available phosphorus content reduced as one moved down the soil profile. It was lowest at 60-90 cm depth (3.03 kilogram/ha) and rose at 30-60 cm and 0-30 cm depths, with mean values ranging from 3.83 kg ha-1 to 4.80 kg/ha. When compared to the surface layer, the available phosphorous content in the deeper layer (CV = 97.8 percent) was significantly varied. The available phosphorus concentration is also affected by soil pH and total organic carbon.

Naik *et al*. (2017) found mango has the highest K-decomposition rate constant (4.66), whereas litchi has the lowest (1.63). In mango, guava, and litchi leaf litter, the average potassium-mineralization rate was 26.8, 19.6, and 11.3 percent, respectively. Litchi, Guava, and Mango orchards had available potassium content of 350 kg/ha, 355 kg/ha, and 341 kg/ha, respectively.

Mali *et al*. (2016) found that the potassium content decreased from the surface to the subsurface. The surface soil had 270.5 kg ha^{-1} of K, while the deeper layer had 225.0 kg ha^{-1}. The soil's moderate k content (CV=24.4 to 26.5 percent) was mostly attributed to non-uniform management practises.

Ashok *et al*. (2017) studied the soil physicochemical parameters under various horticulture land-use schemes in Hiriyur Taluk, Chitradurga district. A total of 120 composite soil samples were collected from six horticultural LUSs (coconut, areca nut, pomegranate, banana, onion, and chili). When compared to other land-use systems, coconut LUS had the most available N (365.28 kg ha-1) and onion LUS had the least available N (365.28 kg ha^{-1}) (245.57 kg ha^{-1}). The coconut LUS had the highest available P (32.66 kg ha^{-1}) while the chilli LUS had the lowest available P. (24.24 kg ha^{-1}). The coconut LUS had the highest available K (325.20 kg ha^{-1}) and the lowest available K (325.20 kg ha^{-1}) of all the LUSs (266.82 kg ha^{-1}).

Chandak *et al.* (2017) investigated the soil physicochemical parameters collected from four villages in Gujarat's Kadi city. Five soil samples were taken from each community. The available P-value ranged from 7.77 kg ha^{-1} to 23.31 kg ha^{-1}, whereas the available K value ranged from 188.48 kg ha^{-1} to 243.04 kg ha^{-1}, according to the results.

Sahu *et al*. (2016) conducted an experiment in Bhawanipatna, Odisha, India, to evaluate the physicochemical parameters of soil under four LUSs (forest land, grazing land, sugarcane field, and rice field). The NPK assessment results were variable and were in the following order: pasture land (82 mg/kg) > sugarcane field (75.33 mg/kg) > rice field (55 mg/kg) > forest land (38.33 mg/kg), rice field (99.83 mg/kg) > sugarcane field (88.33 mg/kg) > forest land (59 mg/kg) > pasture land (51.67 mg/kg), and sugarcane field (0.078 mg/g).

Jain *et al.* (2014) analyzed the soils in Gujarat's Lunawada Taluka. Soil samples were obtained from ten different communities and physicochemical characteristics were determined. The N value ranged from 0.03 percent to 0.07 percent, P from 12 to 100 kg ha^{-1}, and K from 132 to 914 kg ha^{-1}, according to the findings.

2.6 Effect of agri-horti system on soil nutrient Stoichiometry

Li *et al.* (2019) Five typical agroforestry systems were investigated: *Citrus sinensis* (L.) Osbeck system (CO), *Citrus sinensis* (L.) Osbeck system (CI), *Citrus sinensis* (L.) Osbeck system (CA), *Citrus sinensis* (L.) Osbeck system (CZ), and Citrus sinensis (L.) Osbeck system (CS). Tree-cropping systems (CI, CA, CZ, and CS) had significantly greater soil C, N, P, and K concentrations, as well as a lower clay percentage and bulk density than the CO system. The nutrient ratios varied unevenly among five agroforestry systems. N content, N:K ratio, bulk density, and total porosity varied with soil depth. Significant connections were found between soil nutrient contents and stoichiometry and physical characteristics. In the 0-10 cm soil depth, the N:P ratio was 69.78 and 78.55 percent lower than the Chinese and global averages, indicating that severe N limitation occurred in the agroforestry systems. Rational N fertilisation and tree-cropping system allocation are critical for the long-term development of agroforestry.

Qiao *et al.* (2020) The C: N, N:P, and C:P ratios all dropped as soil depth increased. The intensity of bivariate correlations between C, N, and P, on the other hand, converged from the top to the deepest soil layer. From 0-20 to 40-60 cm depths, decreasing C-N (R2 as 0.84, 0.80, and 0.76) and increasing C-P (R2 as 0.11, 0.26, and 0.31) correlations drove vertical convergence. Converging bivariate correlations between C, N, and P along increasing soil depth imply that distinct nutritional components play depth-dependent roles in soil C cycling.

Griffiths *et al.* (2012) Soil and biomass CNP increased at higher P fertiliser, and there was a significant, positive correlation with both microbial biomass P and biomass C, except when the microbial biomass was over-saturated with P at the highest level of P fertilisation. Despite considerable variations in soil nutrient ratios, the molar ratios of C:N:P in the microbial biomass remained stable (homeostatic). Except in soil with no added P, where C and P were the principal limiting nutrients, microbial development was mainly limited by C and N. However, C, N, and P did not explain all of the growth limitations on the soils with no added P.

Zhang *et al.* (2019) The results demonstrated that NPK additions alone caused a reduction in soil pH and exacerbated acidification, whereas M additions might buffer the acidification. The manure additions resulted in a reasonably steady C:N ratio, a low C:P ratio, and a high C:S ratio, but reduced functional ratios of ln (-GLU + -GLU + -GAL + -GAL): ln (urease + PR); ln (GLU + GAL): (PM + PD); and ln (GLU + GAL): ln (AS), implying high P.

Ashraf *et al.* (2019) found significantly negative relationships were also found between SOC and N mineralization and soil C:P and N:P ratios, as well as SMBC:SMBP and SMBN:SMBP stoichiometry in microbial biomass. However, after a certain point, the availability of N and P had little effect on qCO_2 (0.69-0.72 mg CO_2-C g^{-1} MBC h^{-1}).

Shasha *et al.* (2020) Observed that the NPK treatment with residue return at 5.0 Mg ha^{-1} significantly increased the C: N, C:P, and N:P ratios in the soil while decreasing the C: N and C:P ratios in the soil microbial biomass. As a result, NPK fertiliser treatment paired with residue return at 5.0 Mg ha^{-1} could increase SOC content via microorganism stoichiometric plasticity. Residue return and fertilisation improved soil C pools by directly changing the microbial stoichiometry of C-limited biomass.

2.1.2.5 Available micronutrients (Fe, Zn) in soil

Kashiwar *et al*. (2018) conducted research in the Rajiv Gandhi South Campus Barkachha, Mirzapur, Uttar Pradesh, India, in the central Vindhyan plateau region. A total of 260 soil samples were collected from depths ranging from 0 to 15cm. According to the data, the available Fe and Zn values ranged from 19.2 to 38.12 mg kg^{-1} and 0.23 to 0.9 mg kg^{-1}, respectively.

Riyabati and Sarangthem (2017) investigated the distribution of micronutrients in the surface soils of Jhum and Terrace soils in Churachandpur District.The value of DTPA-Fe ranged from 15.403 to 81.897 mg kg^{-1}, while the value of DTPA-Zn ranged from 0.203 to 1.9 mg kg^{-1}.

Athokpam *et al.* (2013) tested on macro and micronutrients of specific soils in Senapati district, Manipur, to investigate their condition and relationship (India). Surface dirt (0 to 30 cm) was collected for the experiment. The experimental values for DTPA-extractable Zn and Fe were 2.36 and 766.03 mg kg^{-1}, respectively.

B. Yadav (2011) investigated the micronutrient content of soils under legume crops in the dry region of Western Rajasthan. Six hundred fifty-two soil samples were collected from farmer's fields to assess the state of DTPA-extractable micronutrients and soil properties. According to the data, Fe and Zn levels in soil ranged from 2.5 to 6.5 mg kg^{-1} and 0.29 to 3.9 mg kg^{-1}, respectively.

Jadhao *et al*. (2019) studied eight typical pedon representing some pomegranate growing soils of Solapur District of Maharashtra. The available Zn ranged from 0.19 to 1.7 mg kg^{-1}, available Fe ranged from 12.1 to 19.6 mg kg^{-1}.

Shivakumar *et al*. (2013) the paddy system has the maximum DTPA zinc availability (1.81 mg kg^{-1}), followed by coffee (1.51 mg kg^{-1}), areca nut (1.36 mg kg^{-1}), and banana (1.27 mg kg^{-1}). The soil of the grassland system contained a significantly lower level of Zn that was readily available (0.93 mg kg^{-1}).

2.2 Biomass accumulation of different land-use systems

Subba *et al.* (2018) examined the variation in carbon stocks in backyard gardens in the northern West Bengal region, which included the districts of Jalpaiguri, which is a part of Cooch Behar, and the Siliguri sub-division of Darjeeling. The amount of plant biomass C was largest in extensive gardens (60.38 Mg/ha), whereas small gardens were projected to have the highest SOC (46.85 Mg/ha). Singh and Sahoo (2018) carried out experimental studies to compare the CO2 sequestration capability of two major land uses, namely shifting agriculture and home gardens of Mizoram. The findings showed that biomass in home gardens varied from 116.8 to 278.5 Mg ha^{-1} and from 60.0 to 95.2 Mg ha^{-1} in shifting agriculture fallows. Comparatively, the biomass carbon in home gardens and shifting agriculture varied from 59.0 to 140.0 Mg C ha^{-1} and 31.6 to 49.1 Mg C ha^{-1}, respectively.

Chisanga et al. (2018) performed an experiment on dry temperate land-use systems (L.U.S.) in the Kinnur district of Himachal Pradesh, India, in order to calculate the variation in biomass and carbon stocks between different LUSs. There were six LUSs: agricultural, horticulture, agri-horti-silviculture, silvopasture, and bare land. The silvopasture land-use system was shown to have greatest mean aboveground biomass (84.65 t ha^{-1}), belowground biomass (19.50 t ha^{-1}), and total biomass (104.10 t ha^{-1}). Silvopasture > Agri-Horti-silviculture > agrihorticulture > horticulture > agriculture > barren land ranked first in terms of total biomass output among the various LUSs.

Pandey et al. (2017) conducted a study on the grounds of the V.C.S.G. College of Horticulture in Pauri Garhwal, Uttarakhand, to determine Kafal's capacity for sequestering carbon (Myrica esculenta). The analysis revealed a buildup of tree biomass of 112.59 t/ha above ground and 71.4 t/ha below ground. In Kafal, 1.839 Mg C ha^{-1} yr^{-1} of CO_2 was net annually sequestered.

Gautam and Mandal (2016) investigated the dynamics of carbon and biomass in a humid tropical forest in eastern Nepal. According to the findings, an undisturbed forest stand had a total stand biomass of 960.4 Mg ha-1, whereas a disturbed forest stand had a total stand biomass of 449.1. In an undisturbed forest stand, the biomass (Mg ha^{-1}) of trees, shrubs, and herbs was 948.0, 4.4, and 1.4, respectively, but in a disturbed forest stand, it was 438.4, 6.1and 1.2, respectively.

2.3 CO_2 sequestration

Hammad *et al.* (2020) experimented with comparing the C sequestration capability of various LUSs, such as forestlands, croplands, agroforests, and orchards. In order to determine the soil's physical and chemical characteristics as well as the biomass and carbon contents of the above- and belowground plants, The aboveground biomass of forest land had the largest capacity for sequestering carbon (64.54 Mg ha^{-1}), while farmland had the lowest (33.50 Mg ha^{-1}).

Bhagya *et al.* (2017) conducted a field experiment At the ICAR-CPCRI in Kasaragod, Kerala in a coconut garden with seven-year-old fruit crops. They calculated that coconut + Jamun systems sequestered the most carbon (140.06 t/ha), followed by coconut + mango systems (138.91 t/ha), and coconut + garcinia (131.72 t/ha). Under coconut monocrop, it was just 98.2 C t/ha.

Khaki *et al.* (2016) investigated in Himachal Pradesh's Poanta valley. The six agroforestry systems that were chosen were the hortipastoral system (HP) (Mango + natural grasses), the silvi-pastoral system (SP) (Dalbergia sissoo + natural grasses), the agri-silviculture system (AS) (Sal + wheat), the horti-silvipastoral (HSP) (Mango + Poplar + natural grasses), the pure forest (F) (pure grasses). The total SOC pool for the various agroforestry systems was distributed as follows: PF (1373.7 Mg/ha), HSP (719.6 Mg/ha), AS (697.3 Mg/ha), NG (696.5 Mg/ha), HP (646 Mg/ha), and SP (599.10 Mg/ha) in decreasing order.

Rizvi *et al.* (2016) carried out an experiment in four districts of Gujarat to estimate net C sequestered in existing agroforestry systems. The result showed that net C sequestered over a simulated period of 30 years in four districts was found to be 2.70, 6.26, 1.61, and 1.50 Mg C ha^{-1}, respectively.

Goswami *et al.* (2014) conducted study In eight land-use systems in the Kwalkhad Watershed of the middle Himalayan area of Himachal Pradesh, India, to assess the C sequestration and C credits. The results of the experiment demonstrated that the agrisilvihorticulture (ASH) system and the agrihortisilviculture (AHS) system sequestered C at rates of 14.78 Mg ha^{-1} and 14.45 Mg ha^{-1}, respectively.

2.5 Interaction effect of Agroforestry systems with soil depth

Schorth *et al. (*2001) Tree crop-based land use systems are more efficient in maintaining soil fertility than annual cropping systems. Certain tree crop plantations have remained productive for many decades, whereas homegardens have existed in the same place for centuries. However, cases of fertility decline under tree crops, including multistrata agroforestry systems, have also been reported, and research on the causal factors (both socioeconomic and biophysical) is needed.

Palm *et al.* (1995) Tree biomass containing sufficient nutrients to meet crop demand is not enough, the nutrients must be supplied in synchrony to crop needs. Nutrient release patterns from organic materials are, in part, determined by their chemical composition, or quality. Leguminous materials release nitrogen immediately, unless they contain high levels of lignin or polyphenols. Nonlegumes and litter of both legumes and nonlegumes generally immobilize N initially.

Ilany *et al.* (2010) The monoculture plantations were more susceptible than agroforestry sites to a decline in soil nutrient status over time, particularly with respect to Ca, eCEC, N and C for both soil depths. P concentrations were below detection limits for all sites, potentially reflecting the high P-fixing capacity of the kaolinic soils of this region. While agroforestry systems may be better at maintaining soil quality over time, significant growth increase of *I. paraguariensis* was apparent only for the monoculture sites.

Singh *et al.* (2007) The sites selected for the study were farmers' fields located villages around Ludhiana city, which is the main poplar growing belt in Ludhiana district of Punjab. It was observed the soil OC was significantly greater in older (6.83 g kg-1) than the younger (5.35 g kg-1) plantations. Available macronutrients in soil increased at successive sampling times. The average Zn concentration at final sampling was 17% lower compared to initial sampling, whereas the other micronutrients tended to increase during April 2002 to October 2003 and the increase was higher in four year old plantations than one year due to higher inputs of organic matter.

Chapter III

MATERIAL AND METHODS

The current study was carried out at Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha Mirzapur, Uttar Pradesh, India, and was named ***"Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system"*** This section includes a brief description of the materials utilised and the methods used during the research endeavour.

3.1 Location of the experimental site

Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, is the study area for this project. It is located in the Vindhyan region of the district Mirzapur (UP). It is situated at 25.0579°N latitude and 82.5997°E longitudes, with an elevation of 80 metres and a mean altitude of 145 metres above sea level. The physography of agricultural land is undulating, covering 2763 acres and supporting a variety of crops including agricultural, horticultural, medicinal, and aromatic crops. This area is mostly rainfed and falls within agro-climatic zone III-A (semi-arid eastern plain zone). figure 1 depicts the location of the experimental site.

3.2 Cultivated crop

This region comes under agro-climatic zone III-A (semi-arid eastern plain zone). Major cultivated crops are *Triticum aestivum* (wheat), *Oryza sativa* (paddy) under irrigated conditions and wheat, *Cicer arietinum* (gram), *Pennisetum glaucum* (bajra), *Cajanus cajan* (arhar), *Brassica juncea* (mustard), *Linum usitatissimum* (linseed), *Hordeum vulgare* (barley), paddy under rainfed conditions. Horticultural crops, i.e., *Mangifera indica* (mango), *Psidium guajava* (guava), *Annona reticulata* (custard apple), *Aegle marmelos* (bael), *Citrus sp.* (citrus), vegetables *Brassica oleracea var capitata* (cabbage), *Pisum sativum* (pea) are cultivated in this region.

3.3 Climate

Mirzapur has a semi-arid climate with minimal rainfall and moderate humidity. Winter (November-February), summer (April-mid June), and rainy (late June to October) seasons are the most common in this area. Summers are hot and dry, while winters are mild and pleasant. January and May are the coldest and hottest months, respectively. The weather starts to warm up around February and reaches its peak in May. The highest temperature was 40.2 degrees Celsius in May, while the lowest temperature was 10.2 degrees Celsius in January. Due to the southwest monsoon, 85 percent of the yearly precipitation falls during the rainy season (late June to October). Winter showers are common from December through the middle of February.

3.4 Climate and weather

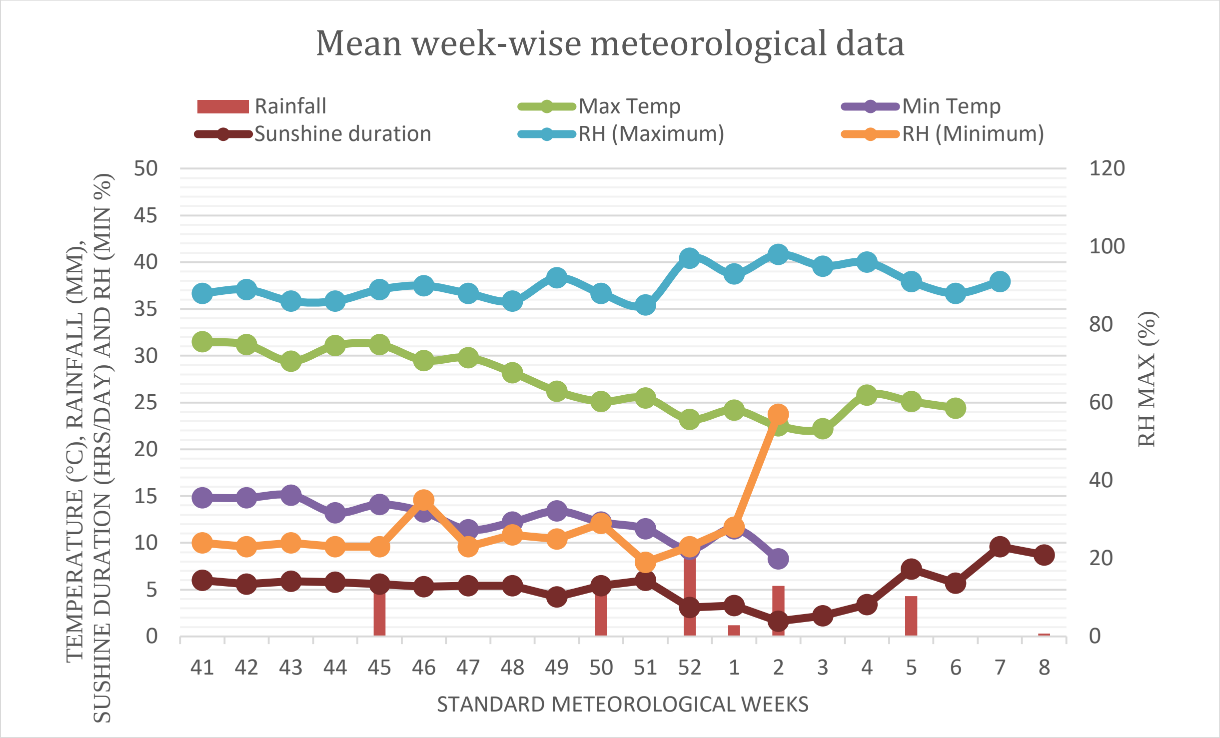
Barkachha's climate is typically semi-arid to sub-humid, with temperature extremes in both winter and summer, moderate humidity, and very little precipitation.

Table 3.1 Mean weather data (2022) of Mirzapur district Uttar Pradesh

Month	**Rainfall (mm)**	**Temperature (^{0}c)**		**Relative Humidity (%)**	
		Min.	**Max.**	**Min.**	**Max.**
January	15	10.2	22.4	54.5	96.6
February	19	13.4	26.7	41.4	94.3
March	10	18.1	32.9	28.6	91.3
April	6	23.4	38.9	40.4	94.3
May	9	27.1	40.2	50.8	96.6
June	137	28.3	37.6	54.8	95.7
July	299	26.5	32.1	56.5	98.5
August	256	25.9	31.4	61-9	98.8
September	175	25	31.3	60.9	97.1
October	41	21.1	30.9	48.2	97.1
November	5	16.1	28.1	44.6	93.1
December	6	11.6	23.8	42.2	97.4

Source: Observatory Krishi Vigyan Kendra, R.G.S.C. BHU, Mirzapur

Fig. 1: Standard week wise meteorological data during crop season *Rabi*, 2021-22



3.5 Experimental Details

The field experiment was carried out in two different land-use systems. The experimental trial was laid out in Randomized Block Design (Factorial) with five treatments and three replications. Details of the experiment are presented in Table 3.2

Design	R B D (Factorial)
No. of treatment	10
No. of replication	3
1. Agroforestry system	
(a) Custard apple-based Agri-Horti system	
(b) Guava-based Agri-Horti system	
2. Depth of soil (cm)	
(a.) D1	0-15 cm
(b.) D2	15-30 cm
(c.) D3	30-45 cm
(d.) D4	45-60 cm
(e.) D5	60-75 cm

3.6 Soil samples collection and preparation

3.6.1 Location of collection

The research has been carried out at Banaras Hindu University's Rajiv Gandhi South Campus in Barkachha, which covers 2763 acres in the Vindhyan plateau with a diverse land use pattern. Thirty soil samples were obtained for the experiment from two agri-horti (custard apple and guava) based LUSs on the RGSC campus.

3.6.2 Method of soil collection and samples preparation

Using a spade, needles, debris, and pebbles were initially removed from the sampling area. Following that, soil samples were obtained from the research area at depths of 0-15 cm, 15- 30 cm, 30-45 cm, 45-60 cm, and 60-75 cm using a core sampler to evaluate Physical and chemical analysis. After that, soil samples were brought to the lab and air-dried for 7 days in the shade by spreading them out on a clean sheet of paper. The clods of the soil samples were broken with a wooden mallet after air drying, and the materials were sieved using a 2 mm sieve. After processing, collect the material and store it in a clean polythene bag with suitable labelling for laboratory examination.

Fig 3.1 Soil sample collection

Fig 3.15: Soil Samples of different agri-horti systems

Table 3.3 Details of methods of soil physicochemical properties analysis

Soil properties	Method employed
a. Physical	
Soil BD (g/cm^3)	Core sample (Black *et al.*,1965)
Soil PD (g/cm^3)	Pycnometer (Black *et al.*,1965)
Soil porosity (%)	Danielson and Southerland (1986).
b. Chemical	
pH (1:2.5, soil and water ratio)	Glass electrode digital pH meter (Jackson, 1973)
EC (1:2.5, Soil:Water suspension) (dsm^{-1} at 25 ^{0}C)	Systronics Electrical conductivity meter (Jackson, 1973)
Available SOC (%)	Walkley and Black rapid titration method (Piper, 1966)
Available N (kg ha^{-1})	Modified alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	0.03 N NH_4F + 0.25 N HCL (Bray and Kurtz, 1945)
Available K_2O (kg ha^{-1})	1N neutral ammonium acetate method (Jackson, 1973)
Available micronutrient (Fe, Zn) (ppm)	Extracted using 0.005 M diethylene triamine Penta acetic acid (DTPA), 0.01M calcium chloride dehydrate, and 0.1M triethanol at pH 7.3 (Lindsay and Norvell, 1978) atomic absorption spectrophotometer

3.7 Analysis of soil samples

The soils' physical and chemical parameters were investigated using the methods outlined in the following section. Procedures used in the laboratory are listed in a table format.

3.7.1 Soil pH

A 1:2.5 soil-water suspension was prepared (10 g soil in 25 mL distilled water), and the pH was measured using a glass electrode digital pH metre (Chopra and Kanwar, 1982).

3.7.2 Soil EC (dsm^{-1})

The electrical conductivity of the soil was estimated using the same soil water solution that was used to determine the pH. The soil suspension was allowed to settle for a period of time until the supernatant became transparent. The EC was then measured at room temperature using the Conductivity Bridge. The following formula was used to convert the scale reading (mhos cm^{-1}) to dsm^{-1} (Chopra and Kanwar,1982)

$$EC\ (dsm^{-1}) = \text{Scale reading} \times 1000 \times \text{cell constant}$$

3.7.3 Soil BD (g/cm^3)

A cylindrical core sampler was inserted into the soil to a depth of 0-15 cm, 15- 30 cm, 30-45 cm, 45-60 cm, and 60-75 cm to measure BD. The oven-dry weight of the soil was determined by transferring the soil from the sampler to a previously weighted moisture box and drying it at 105°C for 18-24 hours. The oven-dry weight of the soil was divided by the volume of the soil to get the BD. (Blake,1965).

$$BD\ (g/cm^3) = \text{weight of oven dry soil} / \text{volume of the soil}\ (cm^3)$$

3.7.4 Soil PD (g/cm^3)

The soil PD was determined using a Pycnometer, as indicated by Black (1965). A clean and dry pycnometer was first taken and weighed on a weighing scale. The pycnometer was then filled with water and the weight obtained. Then 10 g of dirt and 15 ml of water were combined in a beaker and heated for a few minutes to remove the air. The suspension was then transferred to the pycnometer, which was then filled to the full with water and weighed with the stopper. Then, using the formulas, PD was estimated.

$$PD\ (g/cm^3) = 10/\ (W_2 + 10) - W_3$$

- Mass of empty, clean, dry pycnometer (g) = W_1
- Mass of pycnometer (W_1) + water (g) = W_2
- Mass of pycnometer (W_1) + water + soil (Ws) = W_3
- Mass of soil (Ws) = 10g

3.7.5 Soil Porosity

Soil porosity is the fraction or the percent pore space of the total soil porosity. Soil porosity was determined by the method described by Danielson and Southerland (1986). Soil porosity was calculated by using the following formula:

$$\text{Porosity (\%)} = 1 - \frac{\text{Bulk density}}{\text{particle Density}} \times 100$$

3.7.6 Available SOC (%)

OC was estimated by Walkley and Black's (1934) method. Took 1 gm soil in a 500 ml conical flask for the analysis of SOC. Pipette out 10 mL of 1N $K_2Cr_2O_7$ and add it to the flask content and mix thoroughly with them. Then add 20 ml concentrated H_2SO_4 with a measuring cylinder into a flask and swirl it gently. Now keep the flask for 30 minutes. After that, add 200 ml distilled water with a measuring cylinder and rotate the flask to mix them, and it gave yellow color. Fill the burette with 0.5 N Ferrous ammonium sulphate (FAS) solutions. Add a pinch of sodium fluoride (NaF) into the flask content. After that, add 1 ml of diphenylamine indicator into the flask content and mix well. Immediately, titrate the flask content with 0.5 N ferrous ammonium sulphate solution. During titration, the blue colour appeared after this add drop by drop ferrous ammonium sulphate till the color changes from blue to green. Simultaneously blank (without soil) was also done. Then after, pour 1 mL of diphenylamine indicator into the flask and well mix. Titrate the flask contents with a 0.5 N ferrous ammonium sulphate solution right away. When the blue colour appears during titration, add ferrous ammonium sulphate drop by drop until the colour changes from blue to green. Simultaneously, a blank (no dirt) was created.

$$\text{Organic 'C' in soil (\%)} = \frac{0.5\,(B - T) \times 0.003 \times 100}{2 \times \text{wt. of soil}}$$

Where, B = Volume of 0.5 N FAS solution used for blank titration.

T = volume of 0.5 N FAS solution used for sample titration.

Nutrient	Low	Medium	High
Organic C (%)	< 0.5	0.5 – 0.75	> 0.75

3.7.7 Available N (kg/ha)

The alkaline permanganate method was used to determine the amount of accessible nitrogen in the soil (Subbiah and Asija, 1956). 5 g of soil sample was placed in a Kjeldahl flask with 25 mL of KMnO4 solution, and then 5 mL of distilled water was added to the flask with the use of a measuring cylinder to wash off any adhering soil and $KMnO_4$. After that, 20 mL of boric acid solution was placed in a conical flask with a capacity of 250 mL, and the exit tube (Delivery tube) was dipped in the boric acid solution. In the Kjeldahl flask, add 25 mL of NaOH. For 9 minutes, distil the contents. The reddish-purple tint of boric acid turns green after the distillation process is completed. Remove the flask and titrate it with 0.02 N H2SO4 until the solution turns reddish-purple in colour (the original colour of boric acid solution). As a burette reading, write down the endpoint. Simultaneously, I drew a blank.

$$\text{Available N (kg ha}^{-1}\text{)} = (S - B) \times 125.44$$

Where ,

S = Sample titration reading

B= Blank titration reading

Nutrient	Low	Medium	High
Available N (kg/ha)	< 280	280 – 560	>560

3.7.8 Available P (kg/ha)

Olsen's approach was used to determine the soil's accessible P concentration (Olsen, 1954). 2.5 g of soil, a pinch of Darco G-60, and 40 mL of Olsen's reagent (0.5 M NaHCO3) were put to a 100 mL conical flask. The suspension was then filtered through Whatman No. 1 filter paper after being shaken for 30 minutes on a mechanical shaker. In a 25 mL volumetric flask, 10 mL of filtrate was transferred and 2-3 drops of p-nitrophenol indicator were added. After adding 2.5M H2SO4 dropwise till the solution became colourless, the colour of the solution turned yellow. Reagent B was then made by mixing 200 mL reagent A with 1.056 g ascorbic acid. 4 mL of reagent B was added, followed by distilled water to make up the volume. After waiting 10 minutes for the blue colour to emerge, take an absorbance reading at 660 nm with a spectrophotometer.

Nutrient	Low	Medium	High
Available P (kg/ha)	< 12.5	12.5 – 25	> 25

3.7.9 Available K (kg/ha)

A flame photometer (1 N ammonium acetate extract) method was used to evaluate the available K level in soil (Hanway and Heidal, 1952). 5 g of soil was put to a 100 ml conical flask for this. Then 25 mL of 1 N ammonium acetate solution was added, followed by 5 minutes of shaking. A flame photometer was used to measure the K concentration in the filtrate, which was filtered through Whatman No. 1 filter paper.

Available K_2O (kg ha^{-1}) = C x 10 x 1.

Where,

C is the concentration of K in the sample

Nutrient	High	Medium	Low
Available K (kg/ha)	< 135	135-335	>335

3.7.10 Available micronutrients

Estimation of Zn and Fe were done by using 1.967 gm Diethylene Triamine Penta Acetic acid (DTPA), 1.47 gm Calcium chloride, and 13.3 ml Triethanolamine in 800 ml distilled water, adjusting the pH to 7.3 with dilute HCl and made up the volume to one litre (Lindsay and Norvell, 1978). 10 g soil was taken in a 100 ml conical flask, and a 20 mL DTPA solution was added. Flask has shaken at speed 120 cycles per min for 2 hours. Filter through Whatman no-42 filter paper and took the reading on atomic absorption spectrophotometer.

Element concentration (ppm) = AAS reading × 2

Table 3.4 Rating for available micronutrients

S. No	Nutrient	Critical limits*(mg kg-1)	Reference
1.	Zinc	0.6	Lindsay and Norvell (1978)
2.	Iron	4.5	Lindsay and Norvell (1978)

3.8 Tree components

3.8.1 Tree Height (m)

The tree height was recorded for the tree falling in the plot (50 x 10 m^2) with the help of Ravi Altimeter.

3.8.2 Tree diameter at breast height (DBH) in cm

The tree trunk's diameter at breast height (1.37 cm from ground level) was measured in centimetres with the help of measuring tape and a tree calliper.

3.8.3 Volume of selected tree species (m^3)

When volume equation was not available for the selected tree species, to find out the Volume of selected tree species, Pressler's (1865) and Bitlerlich's (1984) formula was used.

$$f = 2h_1 / 3h$$

where,

f = form factor

h_1 = height at which diameter is half of DBH

h = total height

Volume was calculated by Pressler's formula (1865)

$$V = f \times h \times g$$

where,

V = volume

f = form factor

h = total height

g = basal area = πr^2 or $\pi\ (DBH/2)^2$

where,

r = radius

DBH = diameter at breast height

3.8.4 Wood specific gravity

Specific gravity was determined from the available literature. When the specific gravity values were not available, the stem cores were taken to find out specific gravity used to assess the biomass of the stem using the maximum moisture method (Smith, 1954).

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

$$\text{Mass} = \text{Average specific gravity of stem wood} \times \text{volume}$$

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

$$Y = \exp\{-1.996+2.32 \times \ln(D)\}$$

Where,

Y = above ground biomass (kg)

D = Diameter at breast height

ln = Natural log

3.9 Tree biomass

3.9.1 Branch biomass

Total numbers of branches irrespective of size were counted on each sample tree and categorized based on basal diameter into three groups, *viz*., < 6cm, 6-10cm, and >10 cm. The 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.

$$\text{Bdwi} = \text{Btwi}/(1+\text{Mcbdi})$$

where,

Btwi = Oven dry weight of the branch

Bdwi = Fresh/green weight of branches

Mcbdi = Moisture content of branch on a dry weight basis

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

$$\text{Bbt} = n1bw1 + n2bw2 + n3bw3 \sum nibwi$$

where,

BBt = Branch biomass (fresh/dry) per tree

Ni = Number of branches in the ith branch group

Bwi = Average weight of branch of the ith group

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

3.9.2 Above ground biomass of trees

The above-ground tree biomass was the sum of branch biomass and leaf biomass.

3.9.3 Below ground biomass of trees

The below-ground biomass of tree roots was calculated by multiplying the above-ground biomass by a factor of 0.26 (Cairns et al. 1997).

Below-ground biomass of trees = Above-ground biomass of trees x 0.26.

3.9.4 Total tree biomass

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

3.9.5 Total carbon in trees

The tree biomass was converted into a carbon fraction by a factor of 0.5 (IPCC, 2006).

Total carbon in trees = Total biomass × 0.5

3.10 Fruit tree biomass estimation

Diameter-dry biomass-based equations were developed for the estimation of fruit tree biomass. Around 20 trees were selected for each fruit tree crop. Each selected tree was then divided into secondary branches and the main stem. The diameter of the basal portion (with tree caliper) and fresh weight of each branch were determined in the field with the help of balance. The dry weight of branches was estimated using the following equation (Chidumaya, 1990).

Bdwi = Bdwi/(1+Mcbdi)

Where,

Btwi = Oven dry weight of the branch

Btwi = (Fresh weight of branches)/(green weight of branches)

Mcbdi = Moisture content of branch on a dry weight basis

After estimating the dry biomass of each secondary branch, a non-linear regression equation between the diameter and dry biomass of the branches was developed. This regression equation was used to estimate the dry weight of secondary branches of the sample trees from the sample plot (Chidumaya, 1990).

$$\text{Dry weight of the sample tree} = \text{biomass of the main stem log} \\ + \text{cumulative weight of all the secondary branches}$$

Biomass of the main stem log was determined as below:

The following formula calculated the volume of the main stem:

The volume of the main stem = $(S_1+S_2)/2 \times l$

Smalian's formula (Khanna and Chaturvedi 1986)

Where,

S_1 = Basal area of the lower portion

S_2 = Basal area of the upper portion

l = Length of the main stem

Biomass of the main stem of the sample tree = volume of the main stem × specific gravity

Biomass of the sample tree = biomass of the main stem + sum biomass of all the

3.11 C Stock and Sequestrated CO_2 estimation of (Tree)

3.11.1 C stock (Tree)

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

C stock = Biomass × 0.5

3.11.2 Sequestrated CO_2 estimation

Sequestrated CO_2 was estimated as per the formula suggested by Pearson et al. (2007)

CO_2 sequestered = Biomass C stock×3.67

3.12 Carbon credits

One ton of net sequestered or mitigated CO_2 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 CO_2-eq values of retained biomass in the respective system. The eligible carbon credits were calculated from the net sequestered or mitigated CO_2 in the tree or crop biomass only.

Carbon credit was calculated as per the following formula is given by (Mukherjee and Ghosh, 2014):

Carbon credit (t/ha/yr) = Rate (t/ha/yr) x US $ x Indian rupees

Rate x 40 US $ x 79.26 Indian rupees (Dated: 011/07/2022)

One ton CO_2 sequestered per year = One carbon credit

3.13 Nutrient Stoichiometry

In nutrient stoichiometry, nitrogen, phosphorous and potassium content in soil of different agri-horti system to be calculated by the following formula.

Nutrient Stoichiometry = Nutrient content (N) in soil / Nutrient content (P) in soil

EXPERIMENTAL FINDINGS

The results were recorded during the investigation entitled ***"Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system"*** conducted at Rajiv Gandhi South Campus, Banaras Hindu University, Mirzapur are presented in this chapter under the following headings. The trial was conducted with two different agri-horti system with three-time replicated in Randomized Block Design (RBD Factorial). The observations revealed the quantity of BD, PD, Porosity, pH EC, SOC N, P, K, Zn, Fe, nutrient stoichiometry, biomass accumulation, CO_2 sequestration potential, carbon stock of 12 years old horticulture tree of 2022 and carbon credit under different agri-horti system.

4.1 Effect of custard apple and guava based agri-horti system on soil physical properties

4.1.1 Soil BD (g/cc)

The data presented in table (4.1) Agri-horti system recorded non-significant on bulk density. However, maximum bulk density (1.64 g/cc) was recorded with guava based agri-horti system. Bulk density was significantly influenced by depth of the soil. The maximum value (1.84 g/cc$_)$ of bulk density was recorded with guava based agri-horti system at the depth of 60-75 cm. The minimum value (1.45 g/cc) was recorded with 0-15 cm at custard apple based agri-horti system.

4.1.2 Soil PD (g/cc)

The data presented in table (4.2) Agri-horti system recorded non-significant on Particle density. However, maximum Particle density (2.66 g/cc) was recorded with guava based agri-horti system. Particle density was significantly influenced by depth of the soil. The maximum value (2.87 g/cc) of Particle density was recorded at the depth of 60-75 cm in guava based agri-horti system. The minimum value (2.46 g/cc) was recorded with 0-15 cm at custard apple based agri-horti system.

4.1.3 Porosity (%)

The data presented in table (4.3) Agri-horti system recorded non-significant on Porosity. However, maximum Porosity (39.18 %) was recorded with guava based agri-horti system. Porosity was significantly influenced by depth of the soil. The maximum value (40.91%) of Porosity was recorded at the depth of 0-15 cm in custard apple based agri-horti system. The minimum value (30.48%) was recorded with 60-75 cm at guava based agri-horti system.

4.2 Effect of custard apple and guava based agri-horti system on soil chemical properties

4.2.1 Soil pH

The data presented in table (4.4) Agri-horti system recorded non-significant on pH. However, maximum pH (5.48) was recorded with guava based agri-horti system. pH was significantly influenced by depth of the soil. The maximum value (5.87) of pH was recorded at the depth of 60-75 cm in guava based agri-horti system. The minimum value (4.91) was recorded with 0-15 cm at custard apple based agri-horti system.

4.2.2 EC (ds/m)

The data presented in table (4.5) Agri-horti system recorded non-significant on EC. However, maximum EC (0.12 ds/m) was recorded with custard apple based agri-horti system. EC was significantly influenced by depth of the soil. The maximum value (0.16 ds/m) of EC was recorded at the depth of 0-15 cm in custard apple based agri-horti system. The minimum value (0.07 ds/m) was recorded with 60-75 cm at guava based agri-horti system.

4.2.3 Available SOC (%)

The data presented in table (4.6) Agri-horti system recorded non-significant on SOC. However, maximum bulk density (0.51 (%) was recorded with custard apple based agri-horti system. SOC was significantly influenced by depth of the soil. The maximum value (0.60%) of SOC was recorded at the depth of 0-15 cm cm in custard apple based agri-horti system. The minimum value (0.41 %) was recorded with 60-75 cm at guava based agri-horti system.

4.2.4 Available N (kg/ha)

The data presented in table (4.7) Agri-horti system recorded non-significant on N. However, maximum N (187.44 kg/ha) was recorded with guava based agri-horti system. N was significantly influenced by depth of the soil. The maximum value (226.51 kg/ha) of N was recorded at the depth of 0-15 cm in guava based agri-horti system The minimum value (139.81 kg/ha) was recorded with 60-75 cm at custard apple based agri-horti system.

4.2.5 Available Phosphorus (kg/ha)

The data presented in table (4.8) Agri-horti system recorded non-significant on Phosphorus. However, maximum Phosphorus (17.38 kg/ha) was recorded with guava based agri-horti system. Phosphorus was significantly influenced by depth of the soil. The maximum value (21.17 kg/ha) of Phosphorus was recorded at the depth of 0-15 cm in guava based agri-horti system. The minimum value (11.21 kg/ha) was recorded with 60-75 cm at custard apple based agri-horti system.

4.2.6 Available potassium (kg/ha)

The data presented in table (4.9) Agri-horti system recorded non-significant on potassium. However, maximum potassium (173.22 kg/ha) was recorded with guava based agri-horti system. potassium was significantly influenced by depth of the soil. The maximum value (217.23 kg/ha) of potassium was recorded with guava based agri-horti system at the depth of 0-15 cm in guava based agri-horti system. The minimum value (113.64 kg/ha) was recorded with 60-75 cm at custard apple based agri-horti system.

4.2.7 Available Fe (mg/kg)

The data presented in table (4.10) Agri-horti system recorded non-significant on Fe. However, maximum Fe (2.27 g/kg) was recorded with guava based agri-horti system. Fe was significantly influenced by depth of the soil. The maximum value (2.70 g/kg$_)$ of Fe was recorded at the depth of 0-15 cm in guava based agri-horti system. The minimum value (1.58 g/kg) was recorded with 60-75 cm at custard apple based agri-horti system.

4.2.7 Available Zn (mg/kg)

The data presented in table (4.11) Agri-horti system recorded non-significant on Zn. However, maximum Zn (0.30 g/kg) was recorded with guava based agri-horti system. Zn was significantly influenced by depth of the soil. The maximum value (0.36 g/kg) of Zn was recorded at the depth of 0-15 cm in guava based agri-horti system The minimum value (0.22 g/kg) was recorded with 60-75 cm at custard apple based agri-horti system.

4.3 Effect of custard apple and guava based agri-horti system on soil Stoichiometry

4.3.1 N:P ratio

The data presented in table (4.12) Agri-horti system recorded non-significant on N:P ratio. However, maximum N:P ratio (10.48) was recorded with custard apple based agri-horti system. N:P ratio was significantly influenced by depth of the soil. The maximum value (10.71) of N:P ratio was recorded at the depth of 0-15 cm in custard apple based agri-horti system. The minimum value (10.44) was recorded with 60-75 cm at guava based agri-horti system.

4.3.2 P:K ratio

The data presented in table (4.13) Agri-horti system recorded non-significant on P:K ratio. However, maximum P:K ratio (0.103) was recorded with custard apple based agri-horti system. P:K ratio was significantly influenced by depth of the soil. The maximum value (0.113) of P:K ratio was recorded with custard apple based agri-horti system at the depth of 60-75 cm in custard apple based agri-horti system. The minimum value (0.097) was recorded with 0-15 cm at guava based agri-horti system.

4.3.3 N:K ratio

The data presented in table (4.14) Agri-horti system recorded non-significant on N:K ratio. However, maximum N:K ratio (1.10) was recorded with custard apple based agri-horti system. N:K ratio was significantly influenced by depth of the soil. The maximum value (1.23) of N:K ratio was recorded at the depth of 60-75 cm in custard apple based agri-horti system The minimum value (1.04) was recorded with 0-15 cm at custard apple based agri-horti system.

4.3.4 K:P ratio

The data presented in table (4.15) Agri-horti system recorded non-significant on K:P ratio. However, maximum K:P ratio (9.92) was recorded with custard apple based agri-horti system. K:P ratio was significantly influenced by depth of the soil. The maximum value (10.28) of K:P ratio was recorded with custard apple based agri-horti system at the depth of 0-15 cm in custard apple based agri-horti system. The minimum value (8.89) was recorded with 60-75 cm at guava based agri-horti system.

4.3.5 P:N ratio

The data presented in table (4.16) Agri-horti system recorded non-significant on P:N ratio. However, maximum P:N ratio (0.094) was recorded with custard apple based based agri-horti system. P:N ratio was significantly influenced by depth of the soil. The maximum value (0.096) of P:N ratio was recorded with custard apple based agri-horti system at the depth of 0-15 cm in custard apple based agri-horti system. The minimum value (0.089) was recorded with 60-75 cm at guava based agri-horti system.

4.4 Effect of agri-horti system on biomass accumulation and rate of biomass accumulation of (12 year old) custard apple and guava based agri-horti system of 2022

The data presented in table (4.17) showed that biomass accumulation was significantly influenced under agro-horti system. The maximum biomass accumulation 27.96 t/ha, and 2.33t/ha/yr were recorded in the Custard apple based agri-horti system at the total and rate, respectively, Moreover, the minimum biomass accumulation of 21.68 t/ha, and 1.81 t/ha/yr was recorded in guava based agri-horti system, statistically total, and rate, respectively.

4.5 Effect of agri-horti system on C stock and rate of C stock of (12 years) old custard apple and guava based agri-horti system of 2022

The data presented in table (4.18) showed that C stock and rate of C stock of (13 years old fruit trees of 2022) was significantly influenced under agri-horti system. The maximum C stock of (12 years old fruit trees of 2022) 13.98 t/ha, and 1.16 t/ha/yr was recorded in the Custard apple based agri-horti system at the total, and rate. respectively, Moreover, the minimum C stock 10.84t/ha, and 0.90 t/ha/yr was recorded in Guava based agri-horti system, statistically total, and rate, respectively.

4.6 Effect of agri-horti system on CO_2 sequestration and rate of CO_2 sequestration of (12 years old) custard apple and guava based agri-horti system of 2022

The data presented in table (4.19) showed that CO_2 sequestration and rate of CO_2 sequestration of (12 years old custard apple and guava based agri-horti system of 2022) was significantly influenced under agri-horti system. The maximum CO_2 sequestration potential of (12 years old custard apple and guava based agri-horti system of 2022) 51.31 t/ha, and 4.28 t/ha/yr was recorded in the Custard apple based agri-horti system at the total, and rate, respectively Moreover, the minimum biomass accumulation 39.79 t/ha, and 3.32 t/ha/yr was recorded in Guava-based agri-horti system, at the total, and rate, respectively.

4.7 Effect of agri-horti system on Carbon credit of (12 years old) custard apple and guava based agri-horti system of 2022

The data presented in table (4.20) showed that carbon credit of (12 years old custard apple and guava based agri-horti system of 2022) was significantly influenced under agri-horti system. The maximum carbon credit of (12 years old custard apple and guava based agri-horti system of 2022) was 12416 ₹/ha/yr recorded in the Custard apple based agri-horti system. Moreover, minimum carbon credit 9629 ₹ /ha/yr was recorded in guava based agri-horti system.

4.1 Effect of custard apple and guava based agri-horti system on soil physical properties

Table 4.1 Effect of custard apple and guava based agri-horti system on soil BD at different depth of soil

Soil Depth	Bulk density (g/cm^3)	
	Agri-Horti System	
	Custard apple based Agri-Horti System	Guava based Agri-Horti System
0-15 cm	1.45	1.48
15-30 cm	1.51	1.54
30-45 cm	1.59	1.62
45-60 cm	1.69	1.72
60-75 cm	1.79	1.84
Mean	1.61	1.64
SEm±		
Soil depth	0.05	
Agri-horti system	0.03	
CD(P=0.05)		
Soil depth	0.16	
Agri-horti system	NS	

Graph 4.1 Effect of custard apple and guava based agri-horti system on soil BD at different depth of soil

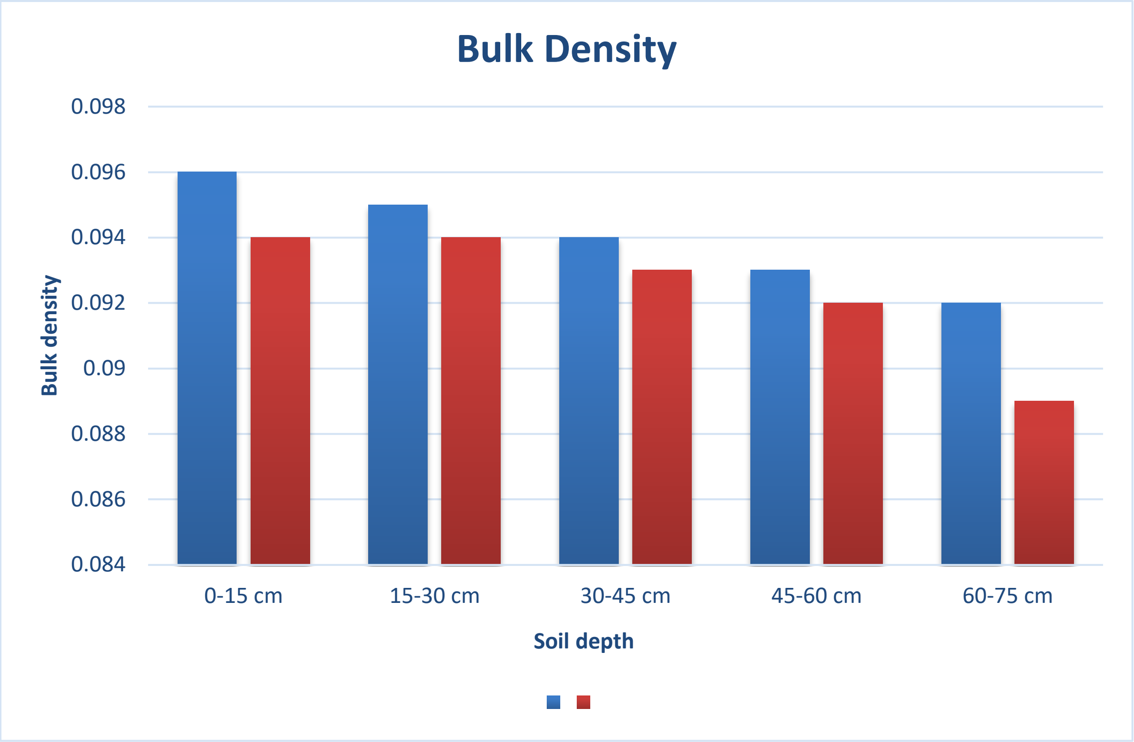


Table 4.2 Effect of custard apple and guava based agri-horti system on soil PD at different depth of soil

Soil Depth	**Particle density (g/cm^3)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	2.46	2.47
15-30 cm	2.53	2.56
30-45 cm	2.63	2.65
45-60 cm	2.73	2.76
60-75 cm	2.84	2.87
Mean	2.64	2.66
SEm±		
Soil depth	0.09	
Agri-horti system	0.06	
CD(P=0.05)		
Soil depth	0.27	
Agri-horti system	NS	

Graph 4.2 Effect of custard apple and guava based agri-horti system on soil PD at different depth of soil

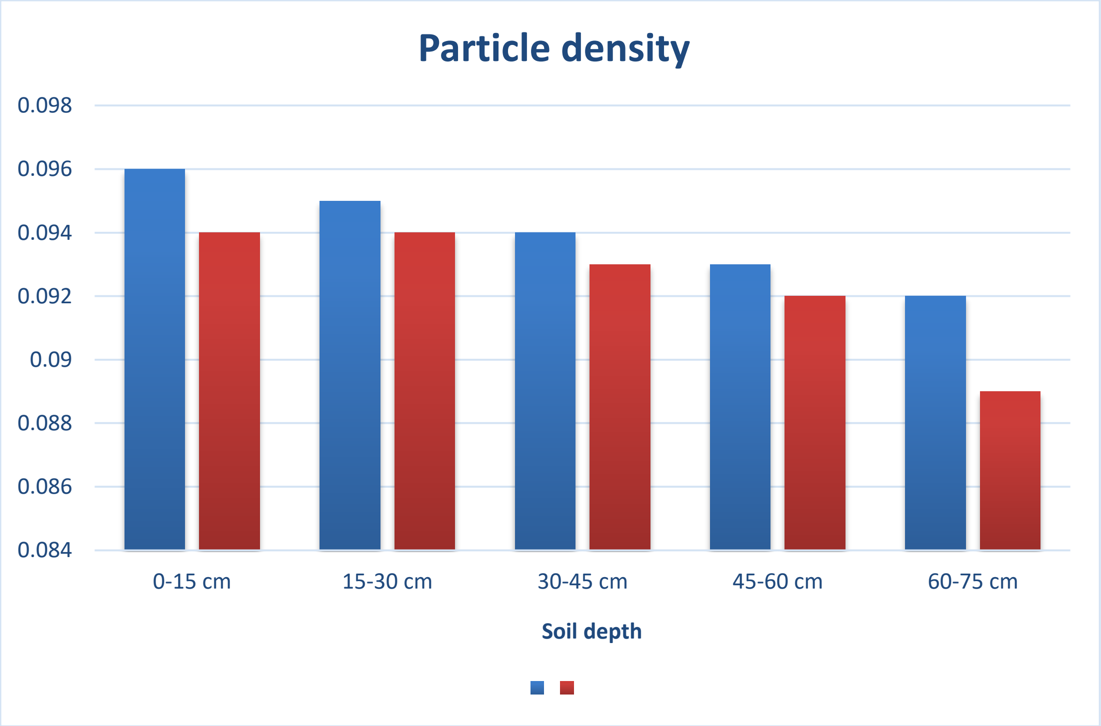
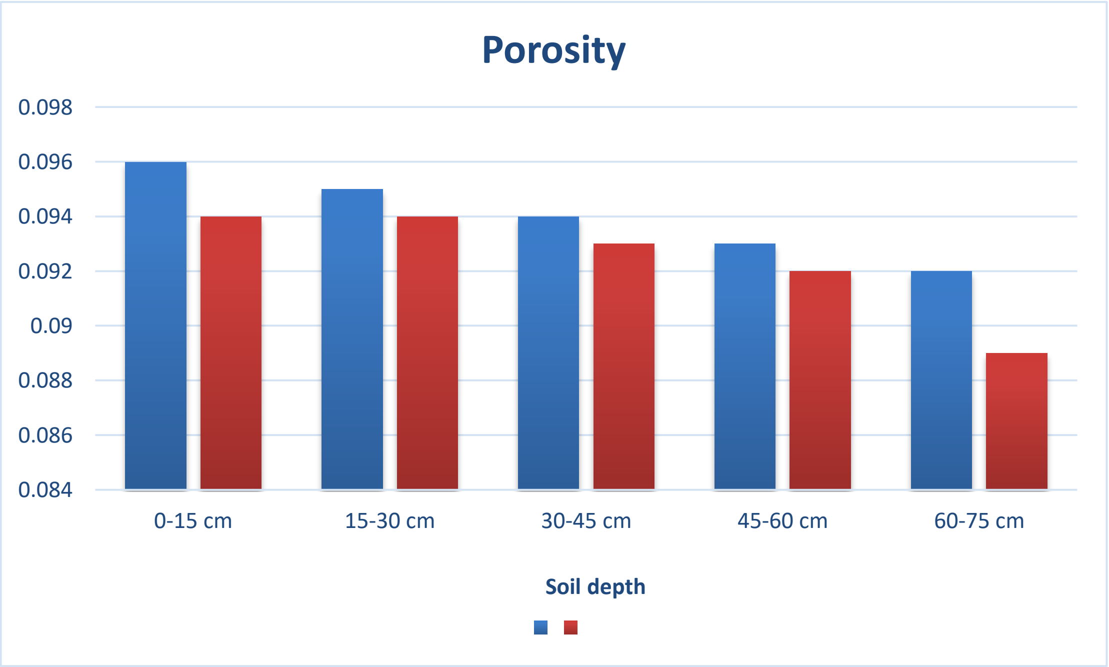


Table 4.3 Effect of custard apple and guava based agri-horti system on soil Porosity at different depth of soil

Soil Depth	**Porosity (%)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	40.91	40.33
15-30 cm	40.25	39.81
30-45 cm	39.47	38.85
45-60 cm	38.29	37.56
60-75 cm	36.97	35.86
Mean	39.18	30.48
SEm±		
Soil depth	0.99	
Agri-horti system	0.62	
CD(P=0.05)		
Soil depth	2.93	
Agri-horti system	NS	

Graph 4.3 Effect of custard apple and guava based agri-horti system on soil Porosity at different depth of soil



4.2 Effect of custard apple and guava based agri-horti system on soil chemical properties

Table 4.4 Effect of custard apple and guava based agri-horti system on soil pH at different depth of soil

Soil Depth	**pH**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	4.91	4.98
15-30 cm	5.17	5.26
30-45 cm	5.47	5.61
45-60 cm	5.53	5.69
60-75 cm	5.66	5.87
Mean	5.34	5.48
SEm±		
Soil depth	0.07	
Agri-horti system	0.04	
CD(P=0.05)		
Soil depth	0.20	
Agri-horti system	NS	

Graph 4.4 Effect of custard apple and guava based agri-horti system on soil pH at different depth of soil

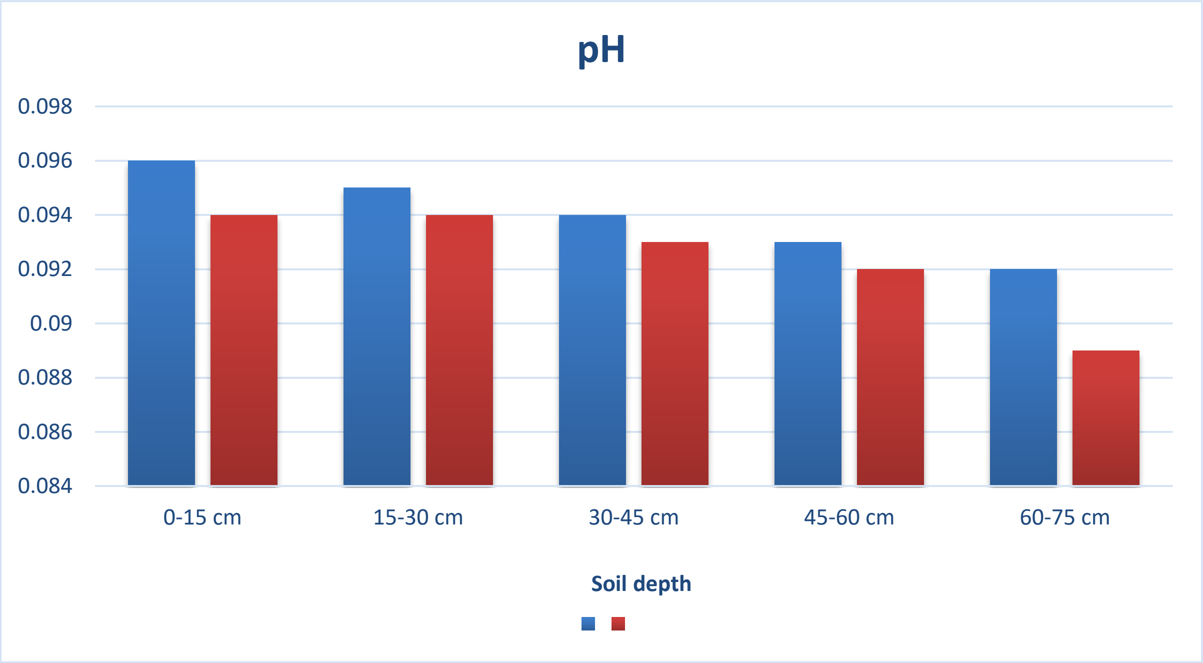


Table 4.5 Effect of custard apple and guava based agri-horti system on soil EC at different depth of soil

Soil Depth	Electrical conductivity (dsm^{-1})	
	Agri-Horti System	
	Custard apple based Agri-Horti System	Guava based Agri-Horti System
0-15 cm	0.16	0.13
15-30 cm	0.14	0.12
30-45 cm	0.12	0.10
45-60 cm	0.11	0.09
60-75 cm	0.09	0.07
Mean	0.12	0.10
SEm±		
Soil depth	0.004	
Agri-horti system	0.003	
CD(P=0.05)		
Soil depth	0.01	
Agri-horti system	NS	

Graph 4.5 Effect of custard apple and guava based agri-horti system on soil EC at different depth of soil

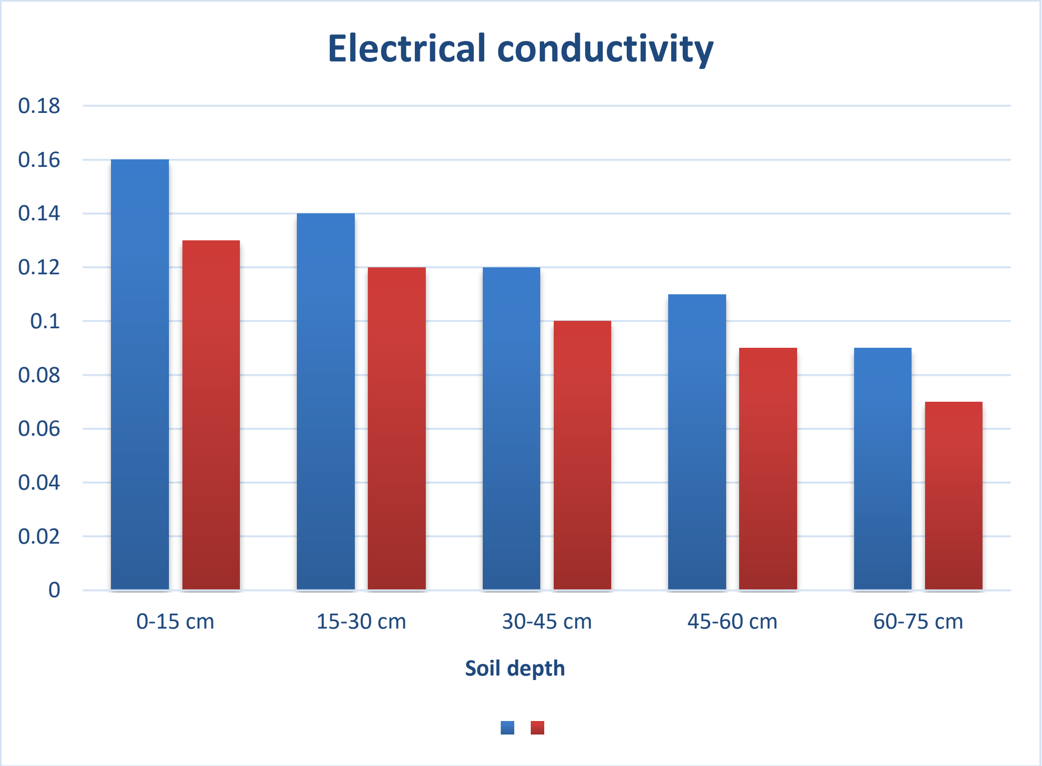


Table 4.6 Effect of custard apple and guava based agri-horti system on soil Available SOC at different depth of soil

Soil Depth	**Soil organic carbon (%)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	0.60	0.54
15-30 cm	0.57	0.52
30-45 cm	0.50	0.49
45-60 cm	0.46	0.45
60-75 cm	0.42	0.41
Mean	0.51	0.48
SEm±		
Soil depth	0.01	
Agri-horti system	0.01	
CD(P=0.05)		
Soil depth	0.04	
Agri-horti system	NS	

Graph 4.6 Effect of custard apple and guava based agri-horti system on soil Available SOC at different depth of soil

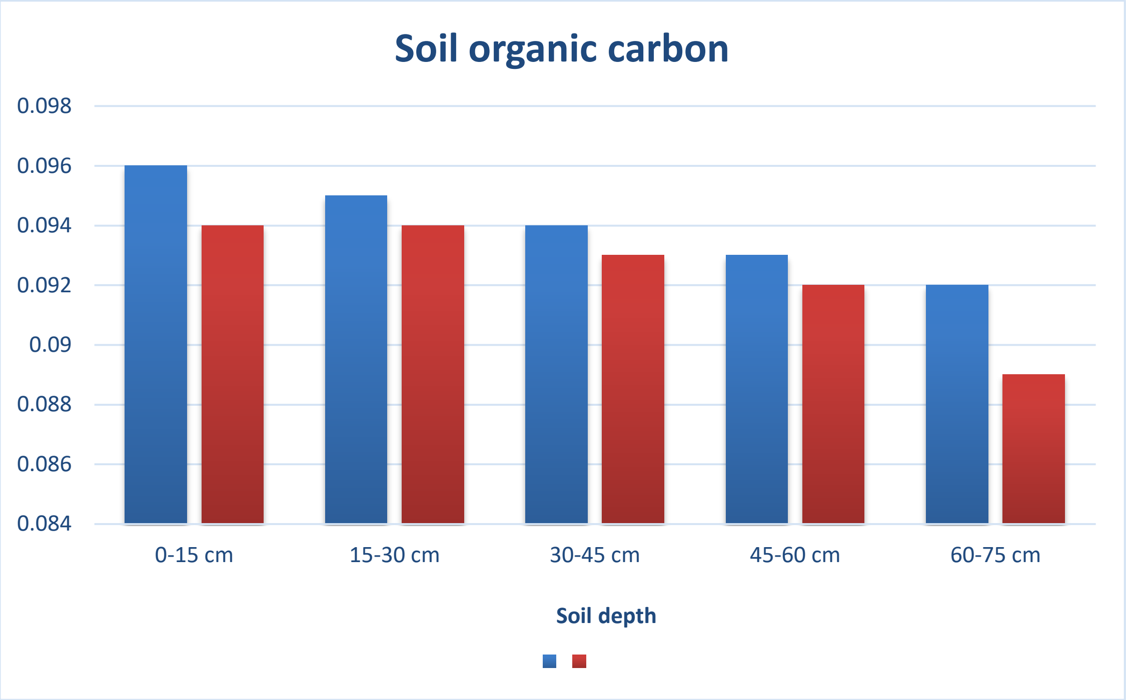


Table 4.7 Effect of custard apple and guava based agri-horti system on soil Available N at different depth of soil

Soil Depth	**Available Nitrogen (kg/ha)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	218.55	226.51
15-30 cm	202.18	209.88
30-45 cm	185.52	192.15
45-60 cm	165.63	168.92
60-75 cm	139.81	139.75
Mean	182.34	187.44
SEm±		
Soil depth	5.34	
Agri-horti system	3.38	
CD(P=0.05)		
Soil depth	15.86	
Agri-horti system	NS	

Graph 4.7 Effect of custard apple and guava based agri-horti system on soil Available N at different depth of soil

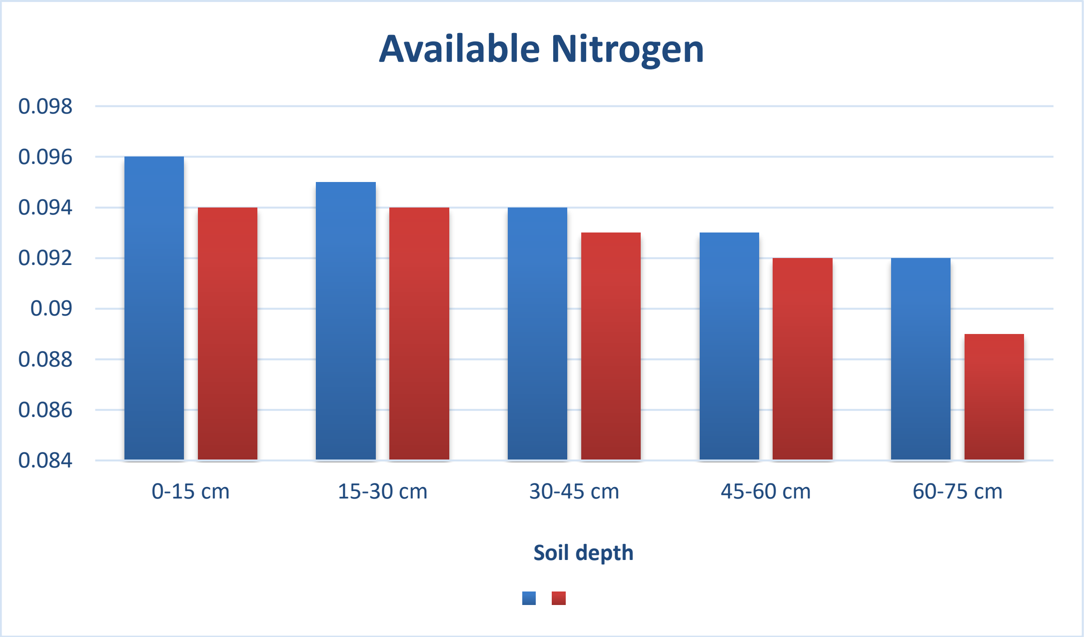


Table 4.8 Effect of custard apple and guava based agri-horti system on soil Available P at different depth of soil

Soil Depth	**Available Phosphorus (kg/ha)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	19.11	21.17
15-30 cm	17.58	19.64
30-45 cm	15.98	18.09
45-60 cm	13.79	15.54
60-75 cm	11.21	12.49
Mean	15.53	17.38
SEm±		
Soil depth	0.31	
Agri-horti system	0.19	
CD(P=0.05)		
Soil depth	0.91	
Agri-horti system	NS	

Graph 4.8 Effect of custard apple and guava based agri-horti system on soil Available P at different depth of soil

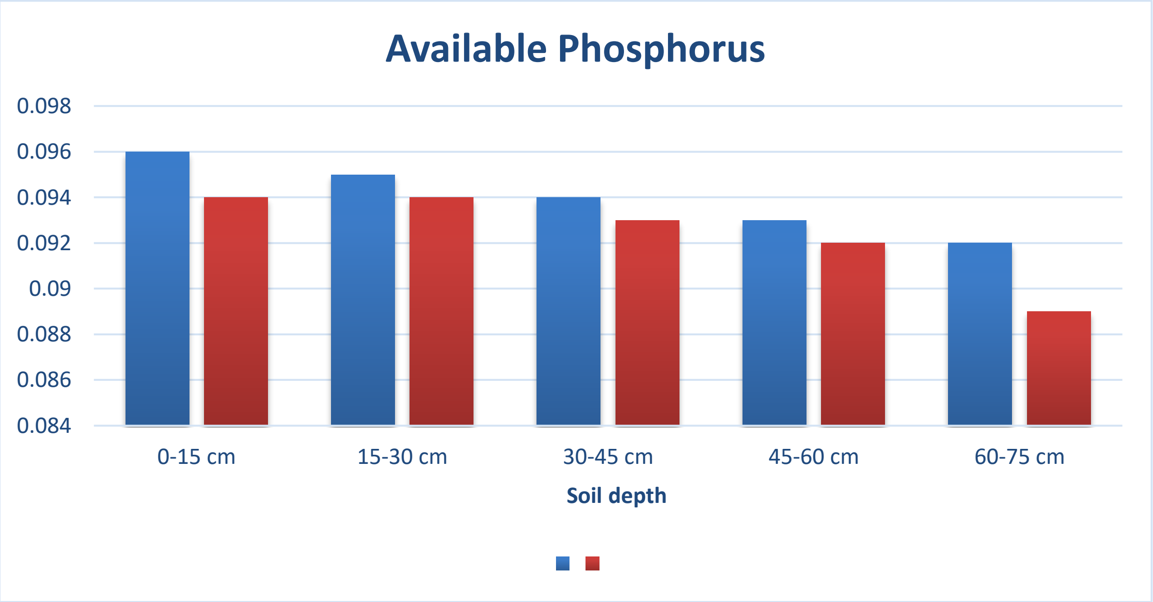


Table 4.9 Effect of custard apple and guava based agri-horti system on soil Available K at different depth of soil

Soil Depth	**Available potassium (kg/ha)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	208.05	217.23
15-30 cm	192.17	198.54
30-45 cm	174.48	179.65
45-60 cm	150.59	153.71
60-75 cm	113.64	116.98
Mean	167.79	173.22
SEm±		
Soil depth	3.96	
Agri-horti system	2.51	
CD(P=0.05)		
Soil depth	11.78	
Agri-horti system	NS	

Graph 4.9 Effect of custard apple and guava based agri-horti system on soil Available K at different depth of soil

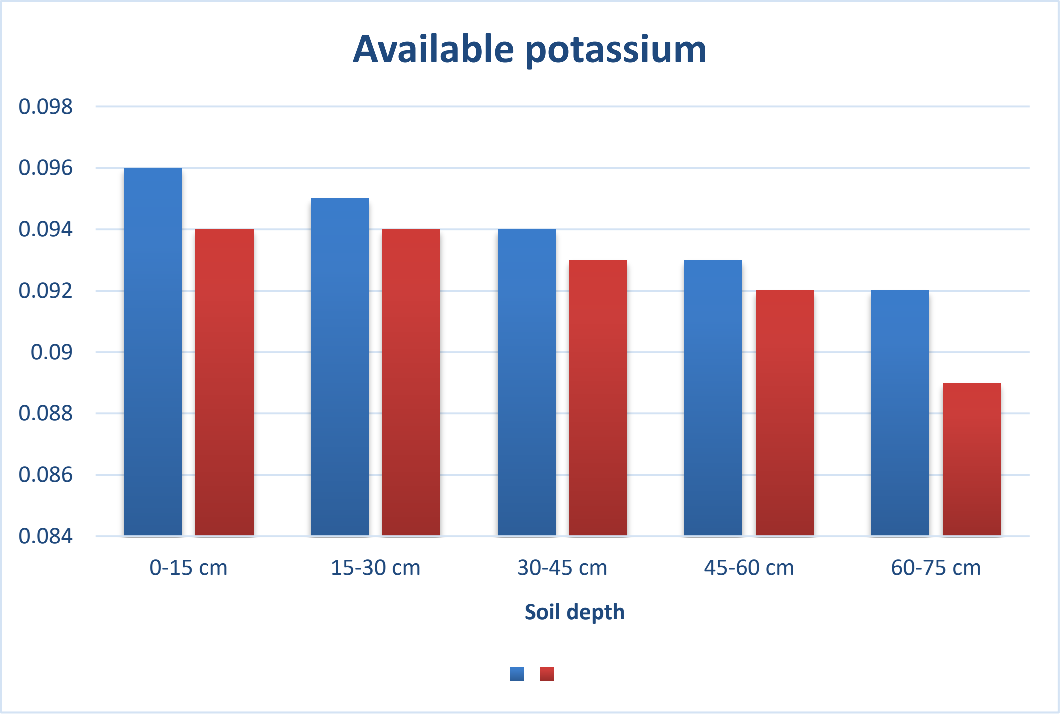


Table 4.10 Effect of custard apple and guava based agri-horti system on soil Available Fe at different depth of soil

Soil Depth	**Available Fe (g/kg)**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	2.54	2.70
15-30 cm	2.41	2.55
30-45 cm	2.09	2.23
45-60 cm	1.79	2.08
60-75 cm	1.58	1.80
Mean	2.08	2.27
SEm±		
Soil depth	0.04	
Agri-horti system	0.03	
CD(P=0.05)		
Soil depth	0.12	
Agri-horti system	NS	

Graph 4.10 Effect of custard apple and guava based agri-horti system on soil Available Fe at different depth of soil

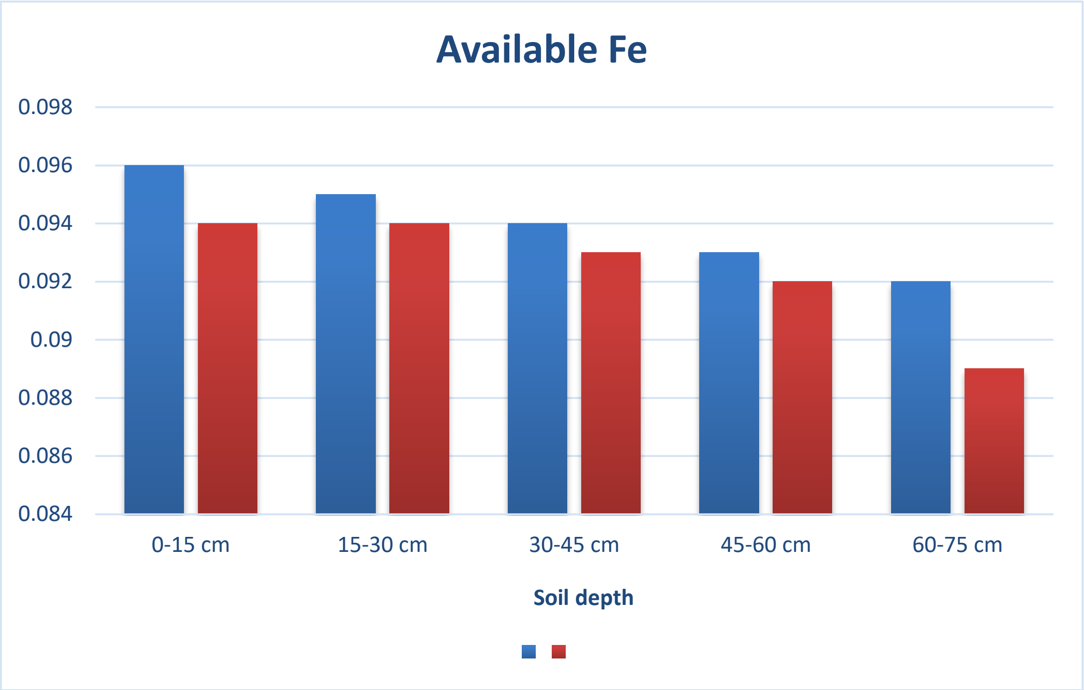
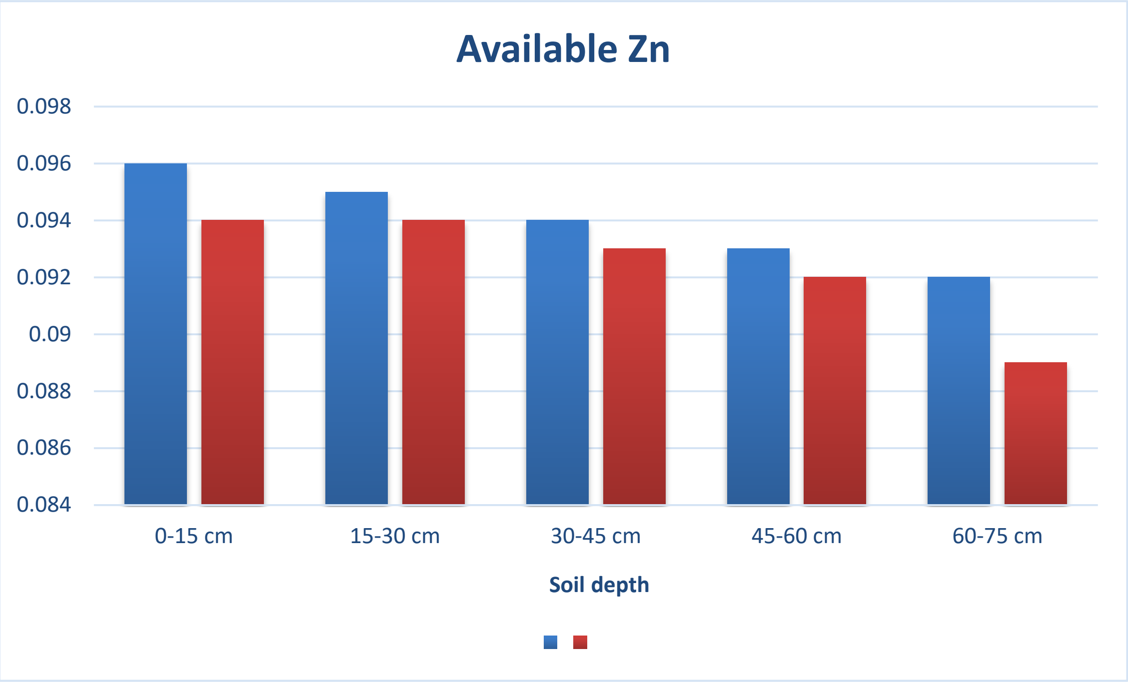


Table 4.11 Effect of custard apple and guava based agri-horti system on soil Available Zn at different depth of soil

Soil Depth	Available Zn (mg/kg)	
	Agri-Horti System	
	Custard apple based Agri-Horti System	Guava based Agri-Horti System
0-15 cm	0.34	0.36
15-30 cm	0.32	0.34
30-45 cm	0.30	0.32
45-60 cm	0.26	0.27
60-75 cm	0.22	0.23
Mean	0.29	0.30
SEm±		
Soil depth	0.005	
Agri-horti system	0.003	
CD(P=0.05)		
Soil depth	0.01	
Agri-horti system	NS	

Graph 4.11 Effect of custard apple and guava based agri-horti system on soil Available Zn at different depth of soil



4.3 Effect of custard apple and guava based agri-horti system on soil physical properties

Table 4.12 Effect of custard apple and guava based agri-horti system on soil N:P at different depth of soil

Soil Depth	N: P	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	10.71	10.59
15-30 cm	10.69	10.57
30-45 cm	10.63	10.54
45-60 cm	10.58	10.50
60-75 cm	10.55	10.47
Mean	10.48	10.44
SEm±		
Soil depth	0.31	
Agri-horti system	0.19	
CD(P=0.05)		
Soil depth	0.91	
Agri-horti system	NS	

Graph 4.12 Effect of custard apple and guava based agri-horti system on soil N:P at different depth of soil

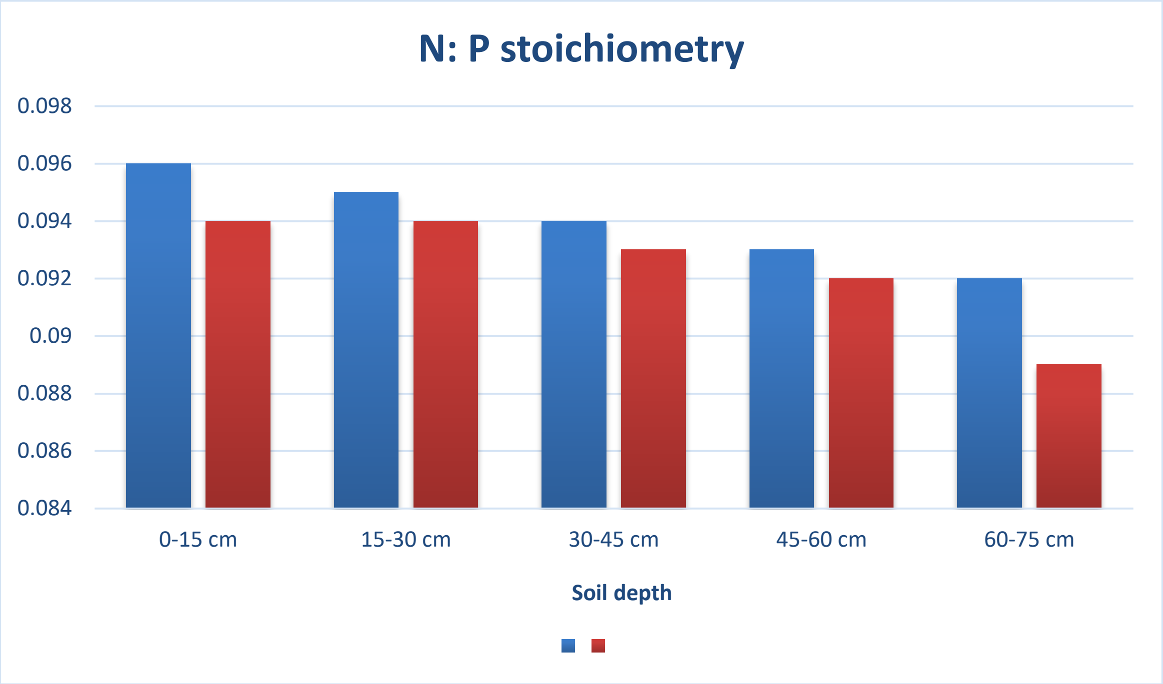


Table 4.13 Effect of custard apple and guava based agri-horti system on soil P: K at different depth of soil

Soil Depth	**P: K**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	0.100	0.097
15-30 cm	0.100	0.099
30-45 cm	0.101	0.101
45-60 cm	0.103	0.101
60-75 cm	0.113	0.107
Mean	0.103	0.101
SEm±		
Soil depth	0.003	
Agri-horti system	0.002	
CD(P=0.05)		
Soil depth	0.008	
Agri-horti system	NS	

Graph 4.13 Effect of custard apple and guava based agri-horti system on soil P: K at different depth of soil

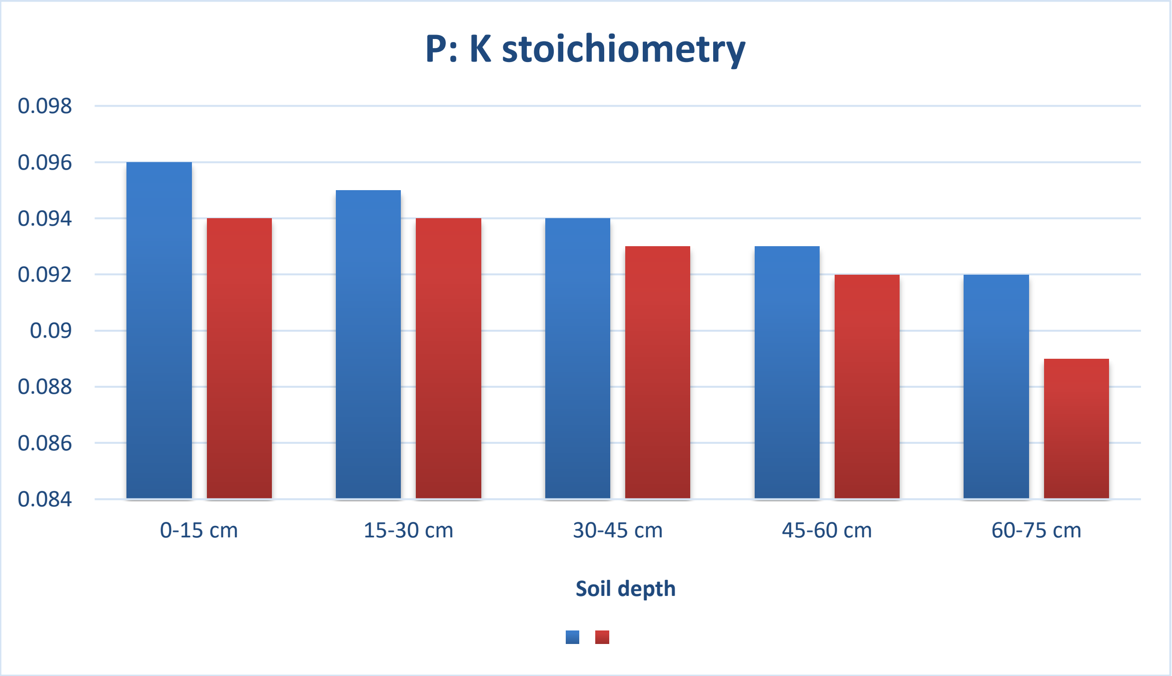


Table 4.14 Effect of custard apple and guava based agri-horti system on soil N:K at different depth of soil

Soil Depth	**N: K**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	1.05	1.04
15-30 cm	1.05	1.06
30-45 cm	1.06	1.07
45-60 cm	1.11	1.10
60-75 cm	1.23	1.20
Mean	1.10	1.09
SEm±		
Soil depth	0.03	
Agri-horti system	0.02	
CD(P=0.05)		
Soil depth	0.10	
Agri-horti system	NS	

Graph 4.14 Effect of custard apple and guava based agri-horti system on soil N:K at different depth of soil

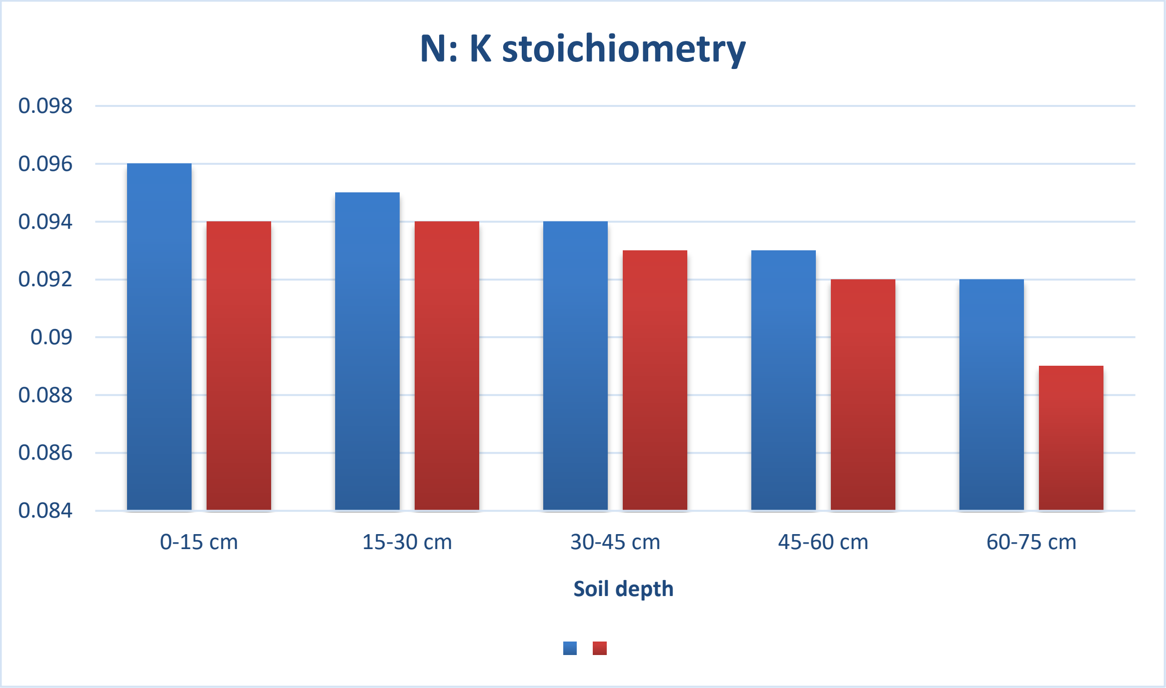


Table 4.15 Effect of custard apple and guava based agri-horti system on soil K:P at different depth of soil

Soil Depth	**K:P**	
	Agri-Horti System	
	Custard apple based Agri-Horti System	**Guava based Agri-Horti System**
0-15 cm	10.28	10.05
15-30 cm	10.12	10.04
30-45 cm	9.93	9.92
45-60 cm	9.90	9.81
60-75 cm	9.39	8.89
Mean	9.92	9.74
SEm±		
Soil depth	0.27	
Agri-horti system	0.17	
CD(P=0.05)		
Soil depth	0.79	
Agri-horti system	NS	

Graph 4.15 Effect of custard apple and guava based agri-horti system on soil K:P at different depth of soil

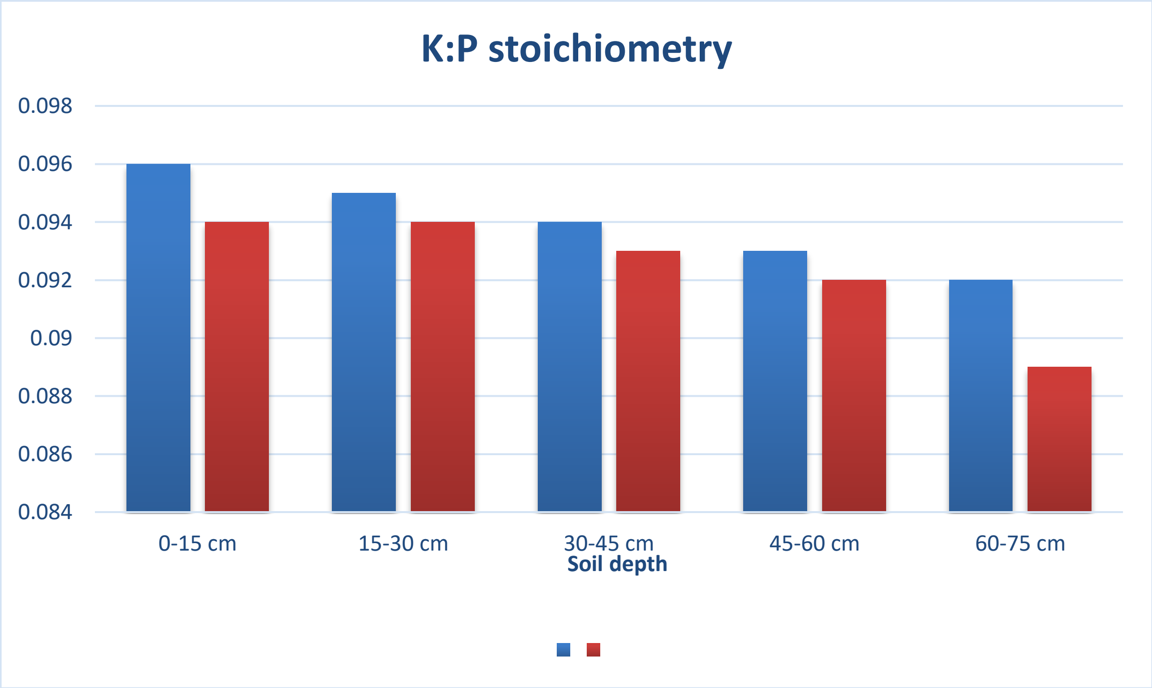
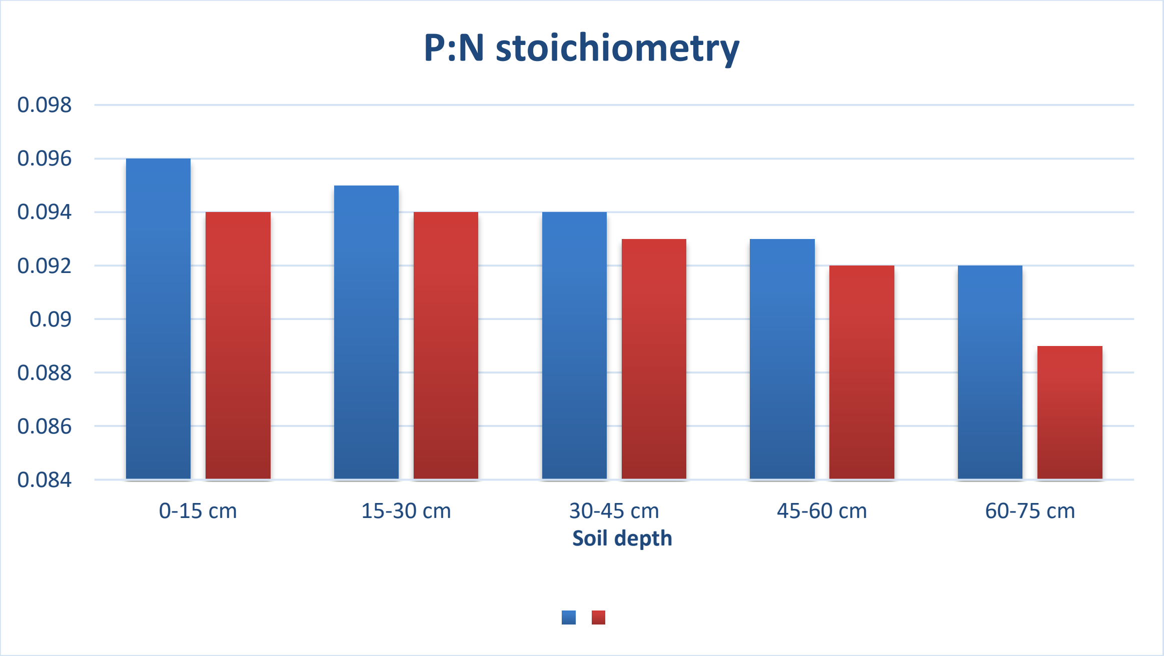


Table 4.16 Effect of custard apple and guava based agri-horti system on soil P: N at different depth of soil

Soil Depth	P: N	
	Agri-Horti System	
	Custard apple based Agri-Horti System	Guava based Agri-Horti System
0-15 cm	0.096	0.094
15-30 cm	0.095	0.094
30-45 cm	0.094	0.093
45-60 cm	0.093	0.092
60-75 cm	0.092	0.089
Mean	0.094	0.093
SEm±		
Soil depth	0.003	
Agri-horti system	0.002	
CD(P=0.05)		
Soil depth	0.008	
Agri-horti system	NS	

Graph 4.16 Effect of custard apple and guava based agri-horti system on soil P: N at different depth of soil



4.17 Detail of the 12 years old Custard apple and Guava based Agri-horti system of 2022

Sl no	Fruit tree	Tree spacing	Height	GBH	Crown diameter
1	Custard apple	5×5 m^2	4.9 m	0.17 m	4.8 m
2	Guava	7×7 m^2	5. 2m	0.20 m	5.2 m

4.18 Biomass accumulation and rate of biomass accumulation of (12 years old) Custard apple and Guava based Agri-horti system of 2022

system	**Biomass accumulation (t/ha)**			**Rate (t/ha/yr)**
	Above ground	**Below ground**	**Total**	
Custard apple	22.19	5.77	27.96	2.33
Guava	17.21	4.47	21.68	1.81

4.19 carbon stock and rate of carbon stock of (12 years old) Custard apple and Guava based Agri-horti system of 2022

Treatment	**Carbon stock (t/ha)**			**Rate (t/ha/yr)**
	Above ground	**Below ground**	**Total**	
Custard apple	11.10	2.88	13.98	1.16
Guava	8.61	2.24	10.84	0.90

4.20 CO_2 sequestration, rate of CO_2 sequestration and Carbon credit of (12 years old) Custard apple and Guava based Agri-horti system of 2022

Treatment	**CO_2 sequestration (t/ha)**			**Rate (t/ha/yr)**	**Carbon credit Rs./ha/yr**
	Above Ground	**Below ground**	**Total**		
Custard apple	40.72	10.59	51.31	4.28	13574
Guava	31.58	8.21	39.79	3.32	10529

Carbon credit was calculated as per the following formula is given by (Mukherjee and Ghosh, 2014):

Carbon credit (₹/ha/yr) = Rate (t/ha/yr) x US $ x Indian rupees

Rate x 40 US $ x 79.29 Indian rupees (date: 09/07/2022)

One ton CO_2 sequestered per year = One carbon credit

Chapter V

DISCUSSION

The results evaluated from the investigation ***"Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system"*** performed at Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur 2022. The experimental findings presented in previous chapter are discussed and explained in this chapter with appropriate reasoning.

5.1 Effect of custard apple and guava based agri-horti system on soil physical properties

It is noticeable from the presented data in table (4.1) that the soil BD was non-significantly influenced under different agri-horti system. Maximum soil BD (1.64 g/cc) was recorded under guava based agri-horti system and the minimum soil BD (1.61 g/cc) was recorded in custard apple based agri-horti system. No significant changes in BD by the fruit orchards might be due to calcareousness of the soil with very high percentage of free CaCO3 that have decreased the effect of the organic carbon improvement in lowering the soil BD. Similar results have been also reported by Laik *et al*. (2009) while studying the effect of 18-year-old forest tree species on calciorthents. Soil organic matter decreases with increase in the soil depth thus the soil is more compacted, less porous, less aggregated and restricts the root penetration in the deeper layers of the soil hence the value of bulk density significantl, increase with the soil depth. Ghimire and Bana (2015) also reported significantly higher BD in sub-surface soil (15-30 cm) than that of surface soil (0-15 cm) under poplar basedagroforestry system.

5.1.2 Particle density (g/cm^3)

It is noticeable from the presented data in table (4.2) that the soil PD was non-significantly influenced under different agri-horti system. Maximum soil PD (2.66 g/cc) was recorded under guava based agri-horti system and the minimum soil PD (2.64 g/cc) was recorded in custard apple based agri-horti system. Because soil PD values are static and unaffected by soil organic carbon, they remain constant across different land use systems. Rathore (1993), Sharma (2000), Ram *et al*. (2010), Vedari and Naidu (2018), and Laxaman *et al*. all reported the same kind of outcome (2019).

5.1.3 Porosity %

It is noticeable from the presented data in table (4.3) that the soil Porosity was non-significantly influenced under different agri-horti system. Maximum soil Porosity (39.18%) was recorded under custard apple based agri-horti system and the minimum soil Porosity (38.48%) was recorded in guava based agri-horti system.Moreover, the quality and quantity of leaf litter introduced by the vegetation and the distribution and penetration of the roots into the soil might also contribute to the improvement of the soil physical properties and soil structure. A previous study conducted in this region by Pang *et al*. (2009) also suggested that the rubber-Flemingia macrophylla agroforestry system could decrease soil bulk density and then improve soil porosity.

5.2 Effect of custard apple and guava based agri-horti system on soil chemical properties

5.2.1 Soil pH

It is noticeable from the presented data in table (4.4) that the soil pH was non-significantly influenced under different agri-horti system. Maximum soil pH (5.48) was recorded under guava based agri-horti system and the minimum soil pH (5.35) was recorded in custard apple based agri-horti system. Soil pH is affected by organic acid production, leaf litter composition and the above ground biomass (Sarvade *et al*.., 2014), accumulation of exchangeable bases in the subsurface and higher weak acid on the surface of the soil (Rathod and Devar, 2003). Rathore *et al.* (2011) reported that non-significant reduction in the soil pH under Aonla orchard may be due to heavy litter fall, high acid content in the fruit cultivars. The reduction in the soil pH might be due to the root exudates and dead root biomass. In the subsequent years with the growth of the trees, the decomposition of the leaf litter releases the weak organic acid that lowers the pH of the soil (Das *et al.*, 2008). In the study conducted by Young (1997), reason for the reduction in the pH in case of sodicity might be due to the reduction in the sodium saturation of exchange complex. As roots of the trees uptake calcium and magnesium ion from the deeper layers, these ions are recycled in the litters that subsequently replace the sodium ion in the exchange complex, thereby causing reduction in the soil pH.

5.2.2 Electrical conductivity (dsm^{-1})

It is noticeable from the presented data in table (4.5) that the soil EC was non-significantly influenced under different agri-horti system. Maximum soil EC (0.12 ds/m) was recorded under custard apple based agri-horti system and the minimum soil (EC 0.10 ds/m) was recorded in guava based agri-horti system. Reduction in the EC as compared to the custard apple based agri-horti system might be due to deep and extensive root systems of the custard tree that enable the uptake of soluble salt from the soil and slightly reduce the concentration of soluble salt in the soil solution. It might be also due to higher root density which upon decomposition contributed to the organic matter and improved the physical properties of the soil. A similar finding has also been showing by Meena *et al.* 2020.

5.2.3 Available Nitrogen (kg/ha)

It is noticeable from the presented data in table (4.6) that the soil N was non-significantly influenced under different agri-horti system. Maximum soil N (187.44 kg/ha) was recorded under guava based agri-horti system and the minimum soil N (182.34 kg/ha) was recorded in custard apple based agri-horti system. The greater availability of N on the surface might be due to higher SOC status on the surface soil. In the present investigation it was observed with increase in the soil depth soil organic carbon decreased. Okunwo *et al.* (2012) stated that soil organic matter acts as the reservoir of the total nitrogen nutrient and hence, available N is higher in surface soil. Dalal *et al*. (2015) reported highest available N at top soil in Guava + Khejri + wheat in agroforestry model whereas minimum was found in sole cropping systems and decreasedwith increase in soil depths. Available nitrogen increased under the plantations may be due toincrease in the microbial biomass, conversion of organic form of nitrogen to available formby the process of mineralization, decomposition of leaf litter, fine roots and nutrients release from the residual reserves of the soil (Das and Chaturvedi 2003; Laik *et al.* 2009).

5.2.4 Available Phosphorus (kg/ha)

It is noticeable from the presented data in table (4.7) that the soil P was non-significantly influenced under different agri-horti system. Maximum soil P (17.38 kg/ha) was recorded under guava based agri-horti system and the minimum soil P (15.53 kg/ha) was recorded in custard apple based agri-horti system. Accumulated litter fall on the soil surface provide source of energy and food to the microorganisms and hence create the favourable soil environment for their multiplication. Greater addition of organic residues to the soil decomposes to release organic acids. These organic acids solubilize the insoluble complex formed by calcium namely dicalcium phosphate, tricalcium phosphate and hydroxyl apatite with increasing basicity (Ca/P) ratio to soluble form that is assimilated by the trees and microorganisms. Laik *et al.* (2009) also explained that during the decomposition of organic matter, organic acids are released that enhance the phosphorous release by the reduction of metal ions binding to the phosphate through the chelation and also the functional groups of the acids compete with the phosphate for the exchange sites.

5.2.5 Available potassium (kg/ha)

It is noticeable from the presented data in table (4.8) that the soil K was non-significantly influenced under different agri-horti system. Maximum soil K (173.22 kg/ha) was recorded under guava based agri-horti system and the minimum soil K (167.79 kg/ha) was recorded in custard apple based agri-horti system. Higher amount of soil available K and their variation under the orchards may be due to the variation in quantity and quality of litter fall (Das and Chaturvedi 2003). Potassium is not a constituent of the soil organic matter or plant constituent. Hence, the soil organic matter is not the direct supplier of the potassium. But it modifies the soil physical environment that increases the cation exchange capacity of the soil and reduces the leaching loss of potassium through the deeper layers of the soil and hence increases its availability. Gupta and Sharma (2009) argued that the physical and chemical conditions under the influence of tree canopy, canopy capture of precipitation input and minimum leaching losses of nutrient under the plantation may be attributed the gain of potassium in the soil.

5.2.6 Available SOC %

It is noticeable from the presented data in table (4.9) that the soil SOC was non-significantly influenced under different agri-horti system. Maximum soil SOC (0.49%) was recorded under custard apple based agri-horti system and the minimum soil SOC (0.48%) was recorded in guava based agri-horti system.Trees have extensive root systems which can grow deep into the mineral soil. The root-derived C inputs are critical sources for the SOC pool in deeper soil horizons (Kell 2012). Specifically, root-derived C is more likely to be stabilized in the soil by physicochemical interactions with soil particles than shoot-derived C (Rasse *et al*. 2005). hus, agroforestry systems store more C in deeper soil layers near trees than away from trees (Nair *et al*. 2010). However, quantitative information about belowground C inputs in agroforestry systems is scanty (Schroth and Zech 1995).

5.2.7 Available Fe and Zn (g/kg)

It is noticeable from the presented data in table (4.10 and 4.11) that the soil Fe and Zn was non-significantly influenced under different agri-horti system. Maximum soil Fe and Zn (2.27and 0.30) was recorded under guava based agri-horti system and the minimum soil Fe and Zn (2.08 and 0.29) was recorded in custard apple based agri-horti system. Variation in available micronutrients in different orchards may be due to variation in quality of litter and quantity of litterfall on soil surface. Extensive root systems of the trees extract nutrient from the deeper layers of the soil and add to the top soil through litterfall and fine root biomass. The micronutrient cations form chelates with organic molecules that enhance the availability of micronutrient in the soil (Lindsay, 1979). Decreasing trend in the DTPA-Zn with the increase in the depth might be due to the formation of insoluble complex of zinc and higher quantity of calcium content as Ca-zincate and higher pH (Chandrasekhar *et al.* 2014). The interaction effect of fruit orchards with the depth of soil was non-significant in relation to available Zn and Mn. Significant increase in the micronutrient status under plantations were in accordance with the result obtained by past workers Singh *et al.* (2007) and Yadav *et al.* (2008), who observed tree litter fall returns a good amount of Zn, Fe, Mn and Cu. In thepresent study SOC showed significant and positive correlation with the DTPA extractable Fe,Zn ,Cu,and Mn.

5.3 Effect of custard apple and guava based agri-horti system on nutrient stoichiometry of soil N:P, P: K, N: K, K: P and P: N

It is noticeable from the presented data in table (4.12 to 4.16) that the soil N:P, P: K, N: K, K: P,and P: N was non-significantly influenced under different agri-horti system. Maximum soil N:P, P: K, N: K, K: P,and P: N (10.48, 0.103, 1.10, 9.92, and 0.094) was recorded under guava based agri-horti system and the minimum soil N:P, P: K, N: K, K: P,and P: N (10.44, 0.101, 1.09, 9.74 and 0.093) was recorded in custard apple based agri-horti system. Results showed that the custard apple based agri-horti system had relatively higher C, N, P and K concentrations than that in the guava based agri-horti system system, indicating that soil nutrients were more effectively accumulated under custard apple based agri-horti system. This may be due to the greater plant production resulted from more developed root system and high litter fall due to bigger size of custard apple tree. Generally, the agri-horti system may supply more abundant above and below ground litterfall and provide more root exudates and root litters, resulting in higher inputs of nutrients into the soils (Jordi *et al*. 2012; Udawatta *et al*. 2014). Gao *et al*. (2014) suggested that multiple-species systems had higher soil microorganisms and enzymes activities, which both enhanced the decomposition rates and thus increased the soil carbon and nutrient contents.

5.5 Effect of custard apple and guava based agri-horti system at different depth on soil physical properties of soil

5.5.1 Bulk density (g/cm^3)

It is noticeable from the presented data in table (4.1) that the soil BD was significantly influenced under different depth of soil. Maximum soil BD (1.83 g/cm^3) was recorded under at the depth of 60-75 cm. cm and the minimum soil BD (1.48 g/cm^3) was recorded at the depth of 0-15 cm. The BD was followed a increasing trend with increase in depth, this might be due to more compaction of soil at lower depths. The BD value of soil samples was found significantly lower at 0-15 cm depth and higher value of BD was found at 60-75 cm in both agri-horti systems, this might be due to the low organic matter content was responsible for increased bulk density. Such type of results was also reported by Shrestha (2008), Ahukaemere and Akpan (2012) and Rasool *et al*. (2014).

5.5.2 Particle density (g/cm^3)

It is noticeable from the presented data in table (4.2) that the soil PD was significantly influenced under different depth of soil. Maximum soil PD (2.86 g/cm$^{3)}$ was recorded under at the depth of 60-75 cm. cm and the minimum soil PD (2.47 g/cm$^{3)}$ was recorded at the depth of 0-15 cm. The soils under study area further evident from the data exhibited an increasing trend with the depth of soil. In general lower value of particle density was observed in upper most depths of soil which might be due to relatively nature and amount of minerals present in the study area (Sangwan, 1978).

5.2.3 Porosity (%)

It is noticeable from the presented data in table (4.3) that the soil Porosity was significantly influenced under different depth of soil. Maximum soil Porosity (40.09%**)** was recorded under at the depth of 0-15 cm. cm and the minimum soil Porosity (35.95%) was recorded at the depth of 60-75 cm. The soils under study showed an decreasing trend with the increase in depth of soils under different agri-horti systems because porosity per cent and organic carbon are positively and significantly correlated to each other and another reason might be due to their coarse texture, presence of calcium carbonate in the study area (Sharma et al. 1993). Such type of results also reported by Yadav *et al*. (1995), Sharma and Kumar (2003), Vedari and Naidu (2018) and Laxaman *et al*. (2019).

5.3 Effect of custard apple and guava based agri-horti system at different depth on soil chemical properties of soil

5.3.1 Soil pH

It is noticeable from the presented data in table (4.4) that the soil pH was significantly influenced under different depth of soil. Maximum soil pH (5.65) was recorded under at the depth of 60-75 cm and the minimum soil pH (4.99) was recorded at the depth of 0-15 cm. It is obvious from the data that the pH value is increased with increase in depth under agri-horti systems; this might be due to leach down of calcium carbonate (Kumar *et al*., 2012). Such type of results also reported by Badabnur *et al*. (1990), Halemani *et al*. (2004) and Perie and Quimet (2008).

5.3.2 Electrical conductivity (dsm^{-1})

It is noticeable from the presented data in table (4.5) that the soil EC was significantly influenced under different depth of soil. Maximum soil EC (0.13 ds/m) was recorded under at the depth of 0-15 cm and the minimum soil EC (0.07 ds/m) was recorded at the depth of 60-75 cm. It is obvious from the data that the EC value follows decreaseing trend with increase in depth. The result showed that most of soils were light in soil texture, where in rainy season the soils reach near normal might be due to leaching of salts (Paliwal and Maliwal 1968 and Dubey *et al*.1984). Such type of results reported by Nagaraj et al. (2002) and Mandal *et al*. (2019).

5.3.3 Available Nitrogen (kg/ha)

It is noticeable from the presented data in table (4.6) that the soil N was significantly influenced under different depth of soil. Maximum soil N (222.53 kg/ha) was recorded under at the depth of 0-15 cm and the minimum soil N (139.78 kg/ha) was recorded at the depth of 60-75 cm. Among different depths, 60-75 cm soil depth contained lowest nitrogen content may be because of low soil organic carbon and which further decreased consistently with increasing soil depth under both agri-horti systems. It is further proved by correlation between available nitrogen and TOC. Such type of findings was reported by Dagar *et al*. (1995) and Malo *et al*. (2005).

5.3.4 Available Phosphorus (kg/ha)

It is noticeable from the presented data in table (4.7) that the soil P was significantly influenced under different depth of soil. Maximum soil P (20.94 kg/ha) was recorded under at the depth of 0-15 cm and the minimum soil P (12.65 kg/ha) was recorded at the depth of 60-75 cm. Available P decreased with increasing soil depth. This could be due to the reduced SOM content with increasing depth of the soil. A similar finding has also been showing by Selassie and Ayanna (2013).

5.3.4 Available potassium (kg/ha)

It is noticeable from the presented data in table (4.8) that the soil K was significantly influenced under different depth of soil. Maximum soil K (212.64 kg/ha) was recorded under at the depth of 0-15 cm and the minimum soil K (115.31 kg/ha) was recorded at the depth of 60-75 cm. In present study, the available K was rated as medium might be due to presence of potassium bearing minerals such as biotite, muscovite, and feldspar which are slowly release potassium during weathering (Kumar et al.,2013) under different land use systems. Such type of result findings also reported by Sharma (1994), Gathala *et al*. (2004), Meena (2008), Verma *et al*. (2013), Sahoo *et al*. (2019) and Laxaman *et al*. (2019).

5.3.5 Available SOC (%)

It is noticeable from the presented data in table (4.9) that the soil SOC was significantly influenced under different depth of soil. Maximum soil SOC (0.55**%)** was recorded under at the depth of 0-15 cm and the minimum soil SOC (0.41**%)** was recorded at the depth of 60-75 cm. The findings clearly show that under various land use systems, OC concentration in soils decreases as depth increases. The horticultural land had the highest OC concentration, which may be because trees were introduced there. This land use also produces a lot of biomass, which increases carbon content, as shown by the connection between OC and TOC. These findings also reported by Mandal *et al*. (2019).

5.3.6 Available Fe and Zn (mg/kg)

It is noticeable from the presented data in table (4.10 and 4.11) that the soil Fe and Zn was significantly influenced under different depth of soil. Maximum soil Fe and Zn (2.69 and 0.35) was recorded under at the depth of 0-15 cm and the minimum soil Fe and Zn (1.76 and 0.23) was recorded at the depth of 60-75 cm. The most of the soils under study area was found deficient in available zinc, iron (except upper two depths of horticultural land), as per limit suggested by (Lindsay and Norvell, 1978) might be due to that the soils are alkaline and rich in calcium carbonate so it can be precipitated as hydroxides and carbonates under alkaline soil pH, therefore, solubility and mobility are decreased resulting in reduced availability of these micronutrients (Shekhar *et al*., 2000).

5.4 Effect of custard apple and guava based agri-horti system at different depth on nutrient stoichiometry of soil

It is noticeable from the presented data in table (4.12 to 4.16) that the soil N:P, P: K, N: K, K: P, P: N ratio in nutrient stoichiometry of the soil recorded at different depths with different agri-horti system. The different ratio depends on their respective values of N, P and K The value of N, P and K is decreasing downwards. The value of N: P, K: P and P: N is decreasing with increase in depth because the value of N, P and K is decreasing downwards. The value of P: K and N: K is increasing because its reciprocal is decreasing downwards.

5.5 Biomass accumulation of (12 years old) custard apple and guava based agri-horti system of 2022

The data showed in table (4.18) showed that biomass accumulation was significantly influenced under different agri-horti system. The biomass of the selected tree species depends on soil quality, age of the tree, tree height, DBH, wood density, growth habit of species. The maximum total biomass, and rate of biomass accumulation (27.96 t/ha, and 2.33 t/ha/yr) were recorded in custard apple based agri-horti system as compare to guava based agri-horti system because of the high wood density, more age, more tree height, and improved soil quality. These results are also in close agreement with the findings of Chavan and Rasal (2012), Yadava (2012), Kanime *et al*. (2013).

5.6 C stock of (12 years old) custard apple and guava based agri-horti system of 2022

The data presented in table (4.19) showed that the C stock of 12 years old custard apple and guava based agri-horti system of 2022 was significantly influenced under different agri-horti system. The maximum C stock of 12 years old custard apple and guava based agri-horti system was recorded in the custard apple and based agri-horti system 13.98 t/ha, and 1.16 t/ha/yr at the total, and rate, respectively, because horticulture tree species have higher woody biomass with more carbon content. Carbon stock in plants is calculated by multiplying the dry weight of the different plant parts with the average carbon concentration in this particular part of a plant. After this, the carbon stock in various plant components was then summed up to obtain total carbon stock in plants. These results are also in close agreement with the finding of Yadav *et al.* (2015), Sarangle *et al.* (2018).

5.7 CO_2 Sequestration Potential (12 years old) custard apple and guava based agri-horti system of 2022

The data presented in table (4.20) showed that the CO_2 sequestration potential of 12 years old custard apple and guava based agri-horti system of 2020 was significantly influenced under different agri-horti system. The maximum CO_2 sequestration potential 51.31 t/ha, and 4.28 t/ha/yr was recorded in the custard apple based agri-horti system at the total, and rate, respectively among all the agri-horti system because the carbon sequestration potential of any land-use system depends on the tree density, age, structure, and C concentration in different components. The result corroborates the previous research findings of Swamy and Puri (2005), Kanime *et al.* (2013), Mohanty *et al.* (2017), Uthappa and Devakumar (2021).

5.8 Carbon Credit (₹ ha^{-1} yr^{-1}) 12 years old custard apple and guava based agri-horti system of 2022

The data presented in table (4.20) One ton of CO_2 fixed in biomass equals one carbon credit, and one-carbon credit value is $40. The maximum carbon credit of 12 years old tr custard apple and guava based agri-horti system was 13574 ₹/ha/yr recorded in the custard apple based agri-horti system because of maximum SOC content and biomass accumulation and the minimum carbon credit 10529 ₹/ha/yr was recorded in guava based agri-horti system. A similar finding was observed by Derwisch *et al.* (2009).

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SUMMARY AND CONCLUSION

The current research work entitled *"**Study of physico-chemical and nutrient stoichiometry of soil under Agri-horti system**"* was conducted at Agricultural Research Farm of Banaras Hindu University-South Campus, Mirzapur, Uttar Pradesh during 2021-2022. The experiment was executed with two agroforestry systems viz. custard apple based Agri-horti system and guava based Agri-horti system with three times replicated in a Randomized Block Design (RBD) factorial. For the estimation of soil physicochemical properties (BD, PD, pH, EC, SOC, available N, P, K, Fe, Zn), soil samples were collected from 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm depth. The C sequestration, C credit and stoichiometry of NPK was calculated at different soil depths. Above and below-ground biomass of trees was recorded in the two Agri-horti systems. The experimental findings were subjected to statical analysis to draw valid conclusions, which are summarized below:

- Different Agri-horti system influence the BD of the soil. The maximum BD was observed under the Guava based Agri-horti System and the minimum BD was observed under the Custard apple based Agri-horti System. Effect of depth on BD in soil found significant. Maximum BD in soil was recorded at the depth 60-75 cm in Guava based Agri-horti System while minimum was found at 0-15 cm Custard apple based Agri-horti System.
- The experimental data showed that the soil PD in the different Agri-horti system had non-significantly influenced. The maximum PD was noticed under Guava based Agri-horti System and the minimum under Custard apple based Agri-horti System. Effect of depth on PD in soil found significant. Maximum PD in soil was recorded at the depth 60-75 cm in Guava based Agri-horti System while minimum was found at 0-15 cm Guava based Agri-horti System.
- The experimental data showed that the soil Porosity in the different Agri-horti system had non-significantly influenced. The maximum Porosity was noticed under Custard apple based Agri-horti System and the minimum under guava based Agri-horti System. Effect of depth on Porosity in soil found significant. Maximum Porosity in soil

was recorded at the depth 0-15 cm in Custard apple based Agri-horti System while minimum was found at 60-75 cm Guava based Agri-horti System.

- The data revealed that different Agri-horti system non-significantly influence the soil pH. The maximum soil pH was noticed under Guava based Agri-horti System, and minimum pH was observed in Custard apple based Agri-horti System. Effect of depth on pH in soil found significant. Maximum pH in soil was recorded at the depth 60-75 cm in Guava based Agri-horti System while minimum was found at 0-15 cm Custard apple based Agri-horti System.
- The soil EC in the different Agri-horti system had non-significantly influenced. The highest EC was observed under the Custard apple based Agri-horti System, and the lowest EC was noticed under Guava based Agri-horti System. Effect of depth on EC in soil found significant. Maximum EC in soil was recorded at the depth 0-15 cm in Custard apple based Agri-horti System while minimum was found at 60-75 cm Guava based Agri-horti System.
- The SOC of different Agri-horti system non-significantly influenced value. The maximum SOC was observed under the Custard apple based Agri-horti System, and the minimum was observed under the Guava based Agri-horti System. Effect of depth on SOC in soil found significant. Maximum SOC in soil was recorded at the depth 0-15 cm in Custard apple based Agri-horti System while minimum was found at 60-75 cm Guava based Agri-horti System.
- The experimental data showed that different Agri-horti system had non-significantly influence. The N availability was maximum under the Guava based Agri-horti System and minimum under the Custard apple based Agri-horti. Effect of depth on N in soil found significant. Maximum N in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.
- The P availability of different Agri-horti system had non-significantly influenced. The highest amount of P availability was noticed under the Guava based Agri-horti System. The lowest amount of P availability was detected under the Custard apple based Agri-horti System. Effect of depth on P in soil found significant. Maximum P in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.

- The analysed data showed that the different Agri-horti system were non-significantly improved. The maximum availability of K was seen under the Guava based Agri-horti System. The minimum availability of potassium was seen under the Custard based apple Agri-horti System. Effect of depth on K in soil found significant. Maximum K in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.
- The presented result revealed that different Agri-horti system had a non-significantly influence on available Fe. The highest availability of Fe was noticed under the Guava based Agri-horti System, and the lowest availability of Fe was detected under the Custard apple based Agri-horti System. Effect of depth on Fe in soil found significant. Maximum Fe in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.
- The experiment's data revealed that different Agri-horti system had a non-significantly effect on available Zn. The highest availability of Zn was noticed under the Guava based Agri-horti System, and the lowest availability of Zn was detected under the Custard apple based Agri-horti System. Effect of depth on Zn in soil found significant. Maximum Zn in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.
- The presented result revealed that different Agri-horti system had a non-significantly influence on available N:P. The highest availability of N:P was noticed under the Custard apple based Agri-horti System, and the lowest availability of N:P was detected under the guava based Agri-horti System. Effect of depth on N:P in soil found significant. Maximum N:P in soil was recorded at the depth 0-15 cm in Guava based Agri-horti System while minimum was found at 60-75 cm Custard apple based Agri-horti System.
- The presented result revealed that different Agri-horti system had a non-significantly influence on available P: K The highest availability of P: K was noticed under the Custard apple based Agri-horti System, and the lowest availability of P: K was detected under the Guava based Agri-horti System. Effect of depth on P: K in soil found significant. Maximum P: K in soil was recorded at the depth 60-75 cm in Custard

apple based Agri-horti System while minimum was found at 0-15 cm Guava based Agri-horti System.

- The presented result revealed that different Agri-horti system had a s non-significantly influence on available N: K. The highest availability of N: K was noticed under the Custard apple based Agri-horti System, and the lowest availability of N: K was detected under the Guava based Agri-horti System. Effect of depth on N: K in soil found significant. Maximum N: K in soil was recorded at the depth 60-75 cm in Custard apple based Agri-horti System while minimum was found at 0-15 cm Guava based Agri-horti System.
- The presented result revealed that different Agri-horti system had a non-significantly influence on available K:P. The highest availability of K:P was noticed under the Custard apple based Agri-horti System, and the lowest availability of K:P was detected under the guava based Agri-horti System. Effect of depth on K:P in soil found significant. Maximum K:P in soil was recorded at the depth 0-15 cm in Custard apple based Agri-horti System while minimum was found at 60-75 cm guava based Agri-horti System.
- The presented result revealed that different Agri-horti system had a non-significantly influence on available P: N. The highest availability of P: N was noticed under the Custard apple based Agri-horti System, and the lowest availability of P: N was detected under the Guava based Agri-horti System. Effect of depth on P: N in soil found significant. Maximum P: N in soil was recorded at the depth 15-30 cm in Custard apple based Agri-horti System while minimum was found at 60-75 cm Guava based agri-horti System.
- The experimental data indicated the significant effect of different Agri-horti system on above-ground biomass accumulation, below-ground biomass accumulation, total biomass accumulation, and rate of biomass accumulation of 12 years old trees of 2022. The maximum amount of total ground biomass, and rate of biomass accumulation was observed under the Custard apple based agri-horti System. The minimum amount of total ground biomass, and rate of biomass accumulation was recorded under Guava based agri-horti System.
- The total amount, and rate of C stock of 12 years old trees of 2022 were significantly influenced by different agri-horti system. The highest total amount, and rate of C stock was noticed under the Custard apple based agri-horti System. The

lowest of total amount, and rate of carbon stock was recorded under the Guava agri-horti System.

- The different Agri-horti system significantly influence thetotal, and CO_2 sequestration rate. The maximum amount of CO_2 sequestration rate was recorded under the Custard apple based agri-horti System. The minimum total amount of CO_2 sequestrated was recorded under Guava based agri-horti System.
- The evaluated data showed that carbon credit of 12 years old trees of 2021 was significantly influenced under different agri-horti system. The maximum carbon credit was recorded in the Custard apple Based Agri-horti System. Moreover, minimum carbon credit was recorded in Guava Agri-horti System.

CONCLUSION

Physico-chemical properties of soil varied with agri-horti system and depth of soil the maximum bulk density, partical density pH was recorded with guava based agri-horti system, however porosity, EC and soil organic carbon was recorded maximum with custard apple based agri-horti system.

Bulk density, particle density, pH, increases with increasing depth of soil. However EC and soil organic carbon decreases with depth.

Nutrient content was recorded maximum with guava based agri-horti system. Further, the nutrient content was decreased with depth of soil at each agri-horti system.

The N:P:K stoichiometry recorded higher with custard apple based agri-horti system. Further, regardless of system, the N:P:K ratio decreases with depth of soil.

However, the experiment was conducted only at one year and one place, the valid conclusion may not be drawn and need further investigation.

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