Ph.D JURISANDHYA BRAIK BORDOLOI 2022 ACS

SOIL ORGANIC CARBON FRACTIONS UNDER DIFFERENT LAND USES IN DYSTRUDEPTS OF NAGALAND

Thesis

submitted to

NAGALAND UNIVERSITY

in partial fulfillment of requirements for the Degree

of

Doctor of Philosophy

in

Agricultural Chemistry and Soil Science

by

JURISANDHYA BARIK BORDOLOI

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Nagaland

2022

Dedicated to my loving family

DECLARATION

I, Mrs. Jurisandhya Barik Bordoloi, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university / institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science.

Date: 23/02/2022

Place: Medziphema

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CERTIFICATE – I

This is to certify that the thesis entitled **"Soil Organic Carbon Fractions under Different Land Uses in Dystrudepts of Nagaland"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science is the record of research work carried out by Mrs. Jurisandhya Barik Bordoloi Registration No. Ph.D./ACSS/00114 under my personal supervision and guidance.

The results of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRICULTURAL CHEMISTRY AND SOIL SCIENCE

This is to certify that the thesis entitled "Soil Organic Carbon Fractions under Different Land Uses in Dystrudepts of Nagaland" submitted by Jurisandhya Barik Bordoloi, Admission. No. Ph-223/17, Registration. No. Ph.D./ACSS/00114 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science has been examined by the Advisory Board and External examiner on ..20..06..2022...

The performance of the student has been found Satisfactory/~~Unsatisfactory~~.

Member	Signature
1. Prof Y. K. Sharma (Supervisor)	........20.6.22
2. Dr. V. K. Sharma (External examiner)	Sharma 20/06/2022 ....
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Date: 23|02|2022
Place: Medziphema

(Jurisandhya Barik Bordoloi)

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LIST OF ABBREVIATIONS

β	: Beta
BD	: Bulk Density
CMI	: Carbon management index
cmol	: Centimole
cfu	: Colony forming unit
°C	: Degree celsius
DHA	: Dehydrogenase activity
et al.	: *et allia* (and others/ co-workers)
e.g.	: for example
Exch. Ca	: Exchangeable calcium
Exch. Mg	: Exchangeable magnesium
Fig	: Figure
GSA	: Glucosidase activity
g	: Gram
>	: Greater than
i.e.	: Id est (that is)
kg	: Kilogram
LUS	: Land use system
<	: Less than
msl	: Mean sea level
Mg	: Mega gram
Mg m^{-3}	: Mega gram per cubic metre
m	: Metre
µg	: Microgram
µg g^{-1}	: Microgram per gram
mg kg^{-1}	: Milligram per kilogram
mm	: Milli meter
M	: Molarity
viz.	: Namely

N	: Nitrogen
N	: Normality
No.	: Number
OC	: Organic carbon
OM	: Organic matter
PNP	: Para nitrophenol (*p*-nitrophenol)
PD	: Particle Density
%	: Percent
g^{-1}	: Per gram
ha^{-1}	: Per hectare
h^{-1}	: Per hour
kg^{-1}	: Per kilogram
POXC	: Permanganate oxidizable carbon
PHA	: Phosphatase activity
P	: Phosphorus
K	: Potassium
SASRD	: School of Agricultural Sciences and Rural Development
Sl	: Serial
SBR	: Soil basal respiration
SMBC	: Soil microbial biomass carbon
SOC	: Soil organic carbon
S	: Sulphur
TOC	: Total organic carbon
TPF	: Triphenyl formazan
TTC	: Triphenyl tetrazolium chloride

ABSTRACT

The study was conducted in the Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema, Nagaland for assessing the impact of three prevalent land use systems (LUS); *viz.* forest (natural), pineapple and paddy (lowland) on overall soil health and quality of Medziphema block. The study sites were located between 25.69347° N to 25.76559° N latitudes and 93.82366° E to 93.88039° E longitudes. All together 432 numbers of geo-referenced surface (0–0.25 m) and sub-surface (0.25–0.50 m) soil samples were collected from eight different villages during pre-monsoon (May), monsoon (August) and post-monsoon (November) season of 2018. Samples were analysed for physico-chemical properties, fertility status, biological parameters, carbon fractions, soil organic carbon stock (SOC stock) and carbon management index (CMI). Results of the investigation revealed that forest LUS has better soil fertility status with higher content of available nutrients in surface soil with significant seasonal variation. Monsoon season exhibited significantly higher soil biological attributes *viz.* microbial biomass carbon (MBC), dehydrogenase (DHA), beta glucosidase (GSA) and acid phosphatase (PHA) enzyme activities as well as bacterial population in forest and pineapple LUS; maximum being recorded in surface soil of forest LUS (549.46 μg g^{-1}, 17.42 μg TPF g^{-1} h^{-1}, 71.78 μg PNP g^{-1} h^{-1} and 151.43 μg PNP g^{-1} h^{-1} MBC, DHA, GSA and PHA respectively). Land use systems had strikingly significant impact on the quantity of soil carbon fractions. Significantly higher amount of organic carbon (OC) (18.68 g kg^{-1}), total organic carbon (TOC) (22.67 g kg^{-1}) and permanganate oxidizable carbon (POXC) (0.543 g kg^{-1}) were recorded in post-monsoon season under forest LUS. POXC, which is considered as the labile or active fraction of carbon, was estimated at 2.1%, 1.9% and 1.5% of total organic carbon in forest, pineapple and paddy LUS respectively. Maximum (54.68 Mg ha^{-1}) SOC stock was recorded in the soils of forest LUS while, paddy LUS exhibited the least SOC stock (40.43 Mg ha^{-1}) during post-monsoon season in surface soils. Pineapple LUS recorded higher value of CMI (78.94) in comparison to paddy LUS (CMI 49.02) across depth and seasons of sampling. Carbon fractions and SOC stock under different LUS were interpolated in location maps obtained through ArcGIS 10.8.1 software to assess the spatial variability and spread across the study area in different seasons. Interpolation results indicated spatial dynamics of organic carbon fractions under different LUS in different seasons of the experimental year.

Cumulative carbon mineralization in terms of soil basal respiration (SBR, μg CO_2-C g^{-1} h^{-1}) was significantly higher in forest LUS (97.68) followed by pineapple LUS (49.44) and paddy LUS (33.89) over three seasons and two depths. Weekly CO_2 mineralization exhibited a similar pattern for all three land uses starting with an initial peak at second week of incubation followed by a gradual decline up to 56 days with a static phase in between. Significant correlations among soil quality attributes were obtained for all the three LUS. The present investigation revealed pineapple LUS as a carbon sequestering LUS and necessitates extensive future research works to find out similar location specific LUS for sustainable agricultural production and management of soil health in Dimapur district in particular and Nagaland state as a whole.

Key words: LUS, sampling season, physico-chemical properties, biological properties, carbon fractions, SOC stock, CMI, Nagaland.

CHAPTER I

INTRODUCTION

INTRODUCTION

Soil organic matter plays key role in crop productivity as it is directly or indirectly responsible for making physico-chemical as well as biological environment of the soil suitable for the crop growth. Soil organic matter (SOM) is the central indicator of soil quality and health which is strongly affected by agricultural management practices (Lal *et al.*, 1995). Qualitative and quantitative changes of soil physico-chemical and biological properties are very common under different land use systems. The effects of various land use systems on soil health are mainly due to accumulation of soil organic matter. SOM is considered as the most complex and least understood component of soil, because it is comprised of plant, microbial, and animal bodies in various stages of disintegration and a mixture of heterogeneous organic substances closely associated with the inorganic constituents (Christensen, 1992). It has beneficial effects on soil physical (structural stabilization), chemical and biological properties (acts as substrate and supply of nutrients for microbes) and thus influences the productive capacity of soils (Verma *et al*., 2013; Wang *et al.*, 2017). Soil organic carbon (SOC) has recently gained prominence in assessment of soil quality since it compoundly affects chemical, physical and biological aspects of soil (Sainepo *et al.*, 2018). Depletion of organic matter causes a loss in water holding capacity, poor aggregation, acceleration in soil erosion, poor retention of applied nutrients, reduced soil biological and enzyme activities (Ghani *et al.*, 2003). There is considerable concern that if SOM or SOC concentrations in soils are allowed to decrease too much, the productive capacity of agriculture will be then compromised by deterioration in soil physical properties and by impairment of soil nutrient cycling mechanisms (Bauer and Black 1994, Loveland and Webb, 2003). Loveland and Webb (2003) suggested that a major threshold is 2% SOC (*i.e.* 3.4% SOM) in temperate regions, below which potentially serious decline in soil quality will occur. Therefore, periodic monitoring and assessment of soil organic matter and soil organic carbon is the basic need for sustainable agricultural production. Maintenance and improvement of SOM quality and quantity are the most essential criteria for sustainable soil management (Campbell and Paustian, 2015).

Soil organic matter is a heterogeneous mixture of materials ranging from fresh plant and microbial residues to relatively inert humic compounds, with turnover rates measured in millennia. There are several pools and fractions of SOM with varying degrees of decomposition and stability, and these fractions may be useful in the study of short-term as well as long-term influences of land use and management on SOC dynamics (Ramesh *et al*., 2019). The labile fraction consists of material in transition between fresh plant residues and stabilized organic matter. On the other hand, stabilized fraction of SOM is composed of organic materials that are highly resistant to microbial decomposition (Verma *et al*., 2013). Both labile and non-labile / stabilized forms of SOC constitute total organic carbon (TOC) and have different degrees of sensitivity to various land use changes and management practices. Several studies have reported that labile fractions, such as the light fraction organic carbon (LFOC) (Six *et al.*, 2002), particulate organic carbon (POC) (Cambardella and Elliot, 1992), readily oxidized carbon (Blair *et al.*, 1995) are quickly changed and restored. Hence, labile SOC fractions can serve as sensitive indicators to study the effect of land use change and management practices on soil quality and SOM changes in the short-term compared to TOC. These indicators can serve as early sensitive indicators of the overall SOC stock change (Blair *et al*., 1995; Sharma *et al*., 2014; Li *et al*., 2016). The labile fractions of soil carbon are important to study as these fractions fuel the soils food web and therefore greatly influence nutrient cycles and many biologically related soil properties (Weil *et al*., 2003). The labile fractions of soil carbon are often termed as active carbon pool and are distinctly different from the passive / recalcitrant / stabilized carbon pool. Labile fraction of soil organic carbon (SOC) is very important for maintenance of soil fertility as well as to assess the impact of land use systems on soil health and quality. Soil labile carbon is the most active carbon with rapid turnover rates, and it changes substantially after disturbance and management (Coleman *et al*., 1996). Several studies attempted to identify labile pools of SOC which are more sensitive to changes in agricultural management practices and land uses. Soil organic carbon oxidized by 0.333*M* $KMnO_4$ has been considered as useful index of labile soil carbon that is more sensitive to changes in cultivation or management practices. Since the continuity of carbon supply depends on both the total pool size and lability, Blair *et al.* (1995) introduced the concept of carbon management index (CMI), computation of which is done on the basis of labile and non-labile carbon. Here, non-labile carbon is calculated as the difference between total carbon and labile carbon. This index compares the changes that occur in total and labile carbon as a result of agricultural practices and land uses with an emphasis on the changes in labile carbon pool.

There are several controlling factors that govern the total stock of carbon in soil profile. Land use and management practices are one of them. Recently, the influence of land use change and management practices on SOC dynamics has gained scientific attention as alteration in land cover, land use, and management practices can significantly impact global carbon pools and fluxes (Sharma *et al*., 2014; Wijesekara *et al*., 2017). Changes in soil quality and land productivity over time and space can be brought about by land use change by altering the structure and functioning of ecosystems and bio-geochemical cycles (Braimoh and Vlek, 2004). Conversion of natural lands (forest, grassland) to cultivated lands decreases the SOC level (Ma *et al*., 2016; Wang *et al*., 2017). Spaccini *et al*. (2006) reported a progressive decrease in humic substance concentrations in soils that were converted from forest to arable farming. Such decrease is commonly attributed to microbial oxidation of the organic materials previously protected in the soil aggregates destroyed by cultivation. There was evidence of decrease in SOC stocks when a forest was converted to cropland and when pasture was converted to cropland (Don *et al*., 2011). On the other hand, conversion of fallow lands to cropland, horticultural land and agroforestry could increase the log-term build up of SOC stocks and fractions due to greater organic matter inputs through supplementation of above and belowground biomass to the soil (Ramesh *et al*., 2013, 2015). Horticultural lands have been given little attention with respect to soil organic carbon dynamics and global warming mitigation potential although horticultural land uses have comparable capacity to store carbon with that of natural forest. In addition to enhancing soil attributes and good soil health, cultivation of perennial horticulture crops helps in sequestering more organic carbon and CO_2 compared to annual crops (Ramesh *et al*., 2019). Increased tillage intensity in many conventional tillage systems such as lowland paddy cultivation system for instance, decreases total carbon, particularly active carbon and increases catabolism of carbon by disrupting soil aggregates and exposure of aggregate protected carbon to microbial attack (Mikha and Rice, 2004). Traditional land management practices and intensive tillage practices on continuous basis have resulted in loss of SOC and, thus, degradation in soil physical, chemical, and biological characteristics (Srinivasarao *et al*., 2013).

Temperature influences carbon dynamics; modify degree of SOC build up and SOC disintegration by regulating microbial activity. Therefore, seasonal changes in organic matter as well as fractions of organic carbon in soil can be visible under different land use systems owing to the differential temperature in different seasons. Soil depth influences contents of total, particulate and mineral-associated soil organic carbon fractions. Jamala and Oke (2013) reported highest total organic carbon (TOC) content under the natural forest (1.94%) and lowest in the crop land (1.46%) in surface soils (0–15 cm).

Soil carbon dynamics in arable soil is mediated by the soil microbial activity (population, mass as well as respiration) and soil enzymes produced by them. Microbiological activity of soil directly influences the soil quality in general and soil fertility in particular. Soil microbiological activity or enzymes activity plays a key role in nutrient transformation because it has direct impact on soil organic matter mineralization (Verma *et al*., 2017). Microbes are very sensitive to land use change. The substrate quality of an ecosystem plays an important role in the population of microbes; those in turn regulate the microbial decomposition and hence SOC build up. Microbial biomass carbon in the soil contributed around 1–3% carbon to the total soil organic carbon (Dilly *et al.*, 2003).

Measurement of soil CO_2 respiration is a means to gauge biological soil fertility. Soil basal respiration is defined as the steady rate of respiration in soil, which originates from the mineralization of organic matter (Pell *et al*., 2006), and is estimated either on the basis of CO_2 evolution or O_2 uptake (Dilly and Zyakun, 2008). Traditionally basal respiration is quantified using alkali trap and titration method. This has been widely used for many years to quantify the impact of various treatments and management inputs on soil microbial activity (Haney *et al*., 2008). The measurement of soil basal respiration has been applied across a variety of research studies and both soil microbial respiration and the mineralization of organic matter are commonly accepted as a key indicator for measuring changes to soil quality (Creamer *et al.*, 2014).

Nagaland, a state in North-East India is known for its hilly terrain. To circumvent the difficulties of farming in undulating topography, the local communities have developed unique indigenous farming systems based on local resources, which facilitate conservation as well as effective and efficient use of natural resources (Chase and Singh, 2014). However, repeated use of land for cultivating crops without proper management practices and conversion of forest land to cultivable land offer threat to the inherent fertility of the age old production systems in general and soil organic carbon in particular. Although limited information on the effects of traditional land use systems on the selected indicators of soil fertility is available for Nagaland soils, the information on the different fractions of soil organic carbon under various land use systems are scarce. Dynamics of carbon under different land uses in relation season, space and soil depth is also studied little. Hence, the present investigation entitled "Soil organic carbon fractions under different land uses in Dystrudepts of Nagaland" has been undertaken with the following objectives:

1. To study the organic carbon fractions and soil carbon stock under different land uses
2. To study the carbon dynamics under different land uses
3. To evaluate the carbon mineralization pattern under different land uses

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The productivity and sustainability of soil depends on dynamic equilibrium among its physical, chemical, and biological properties. Among different soil properties, soil organic matter (SOM) or soil organic carbon (SOC) is a vital indicator of soil quality and the amount of SOC strongly affects other soil physicochemical and biological properties. There are several controlling factors that affect the total amount of SOC in the soil profile. Land use or land management practice is one of them. Land use change can cause changes in soil quality and land productivity over time and space by influencing SOC content and thus other soil physico-chemical and biological properties. It is important to elucidate the effects of land use systems on SOC and other soil properties to determine spatial and temporal trends of the same whether these properties are being maintained at levels sufficient to sustain current land use and future agricultural development. The present review focuses on dynamics of soil organic carbon, its fraction and carbon stock under various LUS. Attempt has also been made to review the dynamics of soil physicochemical and biological properties as affected by LUS. Review on research works conducted all over the world on carbon mineralization pattern under different LUS has also been presented.

2.1. Physico-chemical properties of soil under different land uses

Kizilkaya and Dengiz (2010) have reported that soil pH tends to increase in the cultivated lands. The pH values of the natural forest, pasture and cultivated lands varied significantly from 6.03 to 7.71. Natural forest and pasture soils were more acidic than those of the cultivated sites. They have observed slight increase in soil pH with soil depth due to accumulation of basic cations in cultivated lands. They have also reported that land use change and subsequent tillage practices resulted in significant decrease in organic matter, total porosity, total nitrogen and soil aggregates stability. Natural forestland has high organic matter led to low bulk density and increasing total porosity. However, amount of total porosity in cultivated lands diminished due to tillage causing compaction. A significant change in bulk density among cultivated, pasture and natural forest soils was evident in their study. Depending upon the increase in bulk density and disruption of pores by cultivation, total porosity decreased accordingly. They have reported high clay content in cultivated land compared to forest and pasture lands.

Fageria *et al*. (2011) mentioned that the pH of acidic soils increased and alkaline soils decreased because of flooding. The main changes occur in flooded or waterlogged rice soils are decreases in oxidation-reduction or redox potential and increases in iron (Fe^{2+}) and manganese (Mn^{2+}) concentrations because of the reductions of Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+}.

Moges *et al*. (2013) have studied the effect of land uses on soil quality indicators, and reported high mean clay fraction under farm land followed by open grazing lands and the least in the protected forestland. Higher clay content was recorded in the 10–20 cm soil layers across all land use types. They have revealed high BD in lower soil layers than top surface soil indicating the tendency of bulk density to increase with depth due to the effects of weight of the overlying soil and the decrease in soil organic matter content in sub-surface soil.

Salim *et al*. (2015) revealed the least pH values under natural forest because of high organic matter content and undisturbed nature of the natural forest soils as compared to plantation and grassland. The accumulation of plant litters and high amount of humus in forest soils is responsible for decrease soil pH through slow decomposition. Soils become more acidic (the minimum pH was recorded in rainfall season) because of warm temperature and high rainfall as under such conditions, soils quickly weather and basic cations are leached from soil profile, leaving behind more stable materials rich in Fe and Al oxides.

Sahu *et al*. (2016) have reported maximum pH under forestlands and minimum in rice fields. They have also reported low pH values during monsoon season compared to pre and post monsoon season under forest land, pasture land, sugarcane field and rice field while studying physico-chemical properties of soil under different land use practices in Odisha, India.

Dutta *et al*. (2017) have revealed the textural class of soils under low land LUS as 'clay' to 'clay loam' and orchard as 'sandy clay loam' while studying the erodibility status of soils under different land uses in Chiephobozou sub-division of Kohima district, Nagaland.

Bizuhoraho *et al*. (2018) have reported the highest soil pH in the cultivated land with a pH value of 5.3 and the lowest pH in forestland with a pH value of 4.0 while studying the effect of land use systems on soil properties in Rwanda. They have also reported the highest BD value (1.617 g cm^{-3}) in cultivated land use and the lowest BD in the forest land use (0.983 g cm^{-3}). They opined that the decrease in the BD was due to the accumulation of higher organic matter from the added organic amendments.

Jiao *et al*. (2020) reported the high sand content in forestland uses while studying variation of soil organic carbon and physical properties in relation to land uses in the Yellow River Delta, China. According to this group of scientists, soil bulk density and porosity are functions of SOM, soil particle size and aggregate stability and soil particle density. Reduction in SOM would cause the increase of BD and the decrease of porosity, consequently reducing soil infiltration and water and air storage capacities. Their findings also revealed that arable lands exhibit high BD which might be the result of combined influence of the ploughing in tillage layer, roots distribution and decreased SOC and soil aggregation augmented by repeated events of sowing and harvesting.

2.2. Soil fertility parameters under different land uses

Nitrogen:

Onweremadu (2007) studied distribution of soil nutrients among seven (7) different land uses and has reported significantly higher amount of soil nutrients under uncultivated lands *viz.* grass land, wood land and shrub land compared to other land uses. He has opined that cultivation decreases soil available nutrient status as cultivated lands are vulnerable to runoff losses, leaching, eluviations, colluviation and volatilization loss of available soil nutrients.

Moges *et al.* (2013) conducted a study to compare soil quality within culturally protected forest areas and adjacent grassland, grazing land, and farmland in Abo-Wonsho, Southern Ethiopia. They have reported relatively higher total nitrogen in the protected forest followed by the grazing land than in other land use types as expected because organic carbon was also high in the soils of protected forest since most soil nitrogen is bound in organic carbon.

Chase and Singh (2014) studied status of soil fertility in three traditional land use systems of Khonoma village, Nagaland. They have reported highest amount of nitrogen in natural foest. The order of availability of nitrogen was: natural forest (202.55) > *Jhum* fallow (159.49) > paddy field (47.34); which was significantly different among the three land use type at $p<0.05$. Very less amount of N (47.34 kg ha^{-1}) in paddy fields was attributed to the negligible number of trees grown, leading to lesser availability of SOM. Also burning of biomass and debris, a common practice in paddy fields reduces N stocks.

Salim *et al.* (2015) conducted a study to investigate the seasonal changes of the nutrients in the soil under different land uses *i.e.*, natural forest, plantation and grassland of Jhilmil Jheel wetland, situated in Haridwar district of Uttrakhand. The results revealed that the total nitrogen in the soils under natural forest in autumn season was higher followed by winter, spring and the least as observed in summer. The same trend also observed under plantation.

The results exhibited maximum content of total nitrogen in natural forest during autumn season and the minimum was observed in grassland in the summer season.

Maqbool *et al.* (2017) while comparing physico-chemical properties and nutrient status of soil under forest and agricultural land uses in Ganderbal district, J & K have revealed significantly higher available nitrogen in forest then agricultural land use which may be because of high OM and overall high turnout of nitrogen during decomposition in forests. Available phosphorus was also found high in forests soil, which was attributed to high content of OM that releases organic anions on decomposition and form chelates with Fe and Al and makes the P available.

Khanday *et al*. (2018) studied depth wise distribution of available nutrients of soils of horticultural crop growing areas of Ganderbal district of Kashmir valley. They have reported maximum amount of available N in surface horizons which decreased with increase in soil depth. According to them, the possible reason of this may be decreasing trend of organic carbon with depth.

Tellen and Yerima (2018) characterized the soils under, and assesses the effects of different land use systems *viz.* natural forest, natural savanna, grazing land, afforested land, farmland and eucalyptus plantation on selected soil physico-chemical properties in the North West region of Cameroon. They have reported low content of total nitrogen in farms, probably because of the poor nitrogen retention ability of the soils under farmland uses and the loss of organic matter which is a source of nitrogen. The soils under natural forest land cover systems exhibited the highest mean soil total nitrogen content (0.28%) in the surface soil layer, while those under savanna land use had the lowest values (0.19%). Low nitrogen content under savanna cover was attributed to human activities including burning and grazing, which greatly influenced the soil organic matter and hence soil nitrogen content.

Maqbool *et al.* (2020) have reported the higher available nitrogen in surface soils which showed a linear decreasing trend with an increase in soil depth in three different altitudes in HDP (High Density Planting) apple orchards under MM 106 rootstock of north Kashmir.

Phosphorus:

Fatubarin and Olojugba (2014) reported higher available phosphorus in dry season (January) and at the beginning of rainy season (May) and remain low at the peak of the rainy season (September) while studying effect of rainfall season on the chemical properties of the forest soil of a Southern Guinea Savanna ecosystem in Nigeria.

Salim *et al.* (2015) studied the seasonal changes of the nutrients in the soils under different land uses *i.e.*, natural forest, plantation and grassland of Jhilmil Jheel wetland. The result revealed that the available phosphorous under natural forest in winter season was higher followed by spring, autumn and the least was in summer. Under plantation, it was higher in winter season followed by autumn, summer and least was in spring respectively. Under grassland, it followed the same trend as natural forest. The results showed that the maximum value of phosphorous was observed in natural forest during winter season and the minimum was observed under grassland during summer season. It may be due to more accumulation of minerals in winter season. Less amount of available phosphorus occurred in autumn (rainy season) because of leaching due to rain and soil erosion.

Maqbool *et al.* (2017) also have reported increased phosphorus content under forest LUS than agriculture LUS. However, they didn't get significance difference in phosphorous content between the two LUS may be due to the application of Di ammonium phosphate (DAP) fertilizer on the cultivated land may have resulted in the increase of phosphorus in the agricultural soil too. High content of OM in case of forests which also releases organic anions on decomposition and form chelates with Fe and Al and make the P available.

Bini *et al*. (2015) have reported high available phosphorus in pre-monsoon than post-monsoon and monsoon season under agricultural lands while studying the seasonal variations in soil edaphic and chemical factors of agricultural and grassland habitats of Central Travancore, Kerela.

Khanday *et al.* (2018) reported maximum amount of available phosphorus in surface layers and it exhibited a decreasing trend with an increase in soil depth, which may be due to variation in amount of organic matter and soil reaction. The lower phosphorus content in sub-surface was attributed to the fixation of P by clay-minerals and oxides of iron and aluminium.

Hoque *et al.* (2020) conducted an experiment soil samples from seven land use types to observe the effect of soil depth on soil properties under various land use systems. They have revealed more available phosphorus content under banana orchard than rice field while studying vertical distribution of soil nutrients under different land use systems in Bangladesh. They have also reported a decreasing trend of available phosphorus content with increasing depths.

Maximum available phosphorus was recorded in surface layers of HDP apple orchards under MM 106 rootstock of north Kashmir and it exhibited a decreasing trend with an increase in soil depth, which may be due to variation in amount of organic matter and soil reaction (Maqbool *et al*., 2020).

Potassium:

Chase and Singh (2014) have reported maximum exchangeable K under *Jhum* fallow followed by natural forest and least in paddy field. They have revealed the possibility of natural build up of K fertility because of litter fall from trees in *Jhum* fallows and natural forests. The low level of K in paddy field was attributed to poor recycling of nutrients from crop and grass residues due to grazing of livestock on crop residues remaining on the land after harvest as well as removal of residues under Nagaland condition.

Salim *et al.* (2015) also reported higher available K in natural forest than plantation and grassland. They have revealed that more the organic matter more is the accumulation of minerals in the soil.

Maqbool *et al*. (2017) reported more available K in forest soil than agricultural lands while comparing physicochemical properties and nutrient status of soils of forest and agricultural land uses in Ganderbal, J&K.

Khanday *et al.* (2018) have reported the highest available K in the surface horizons that exhibited more or less a decreasing trend with depth. This was attributed to more intense weathering, release of liable K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary raise of ground water.

Das *et al.* (2019) assessed the soil K pools under major land use systems of Assam, *viz.* mulberry, sugarcane, tea and rice-mustard under three depths (0–15, 15–30 and 30–60 cm) and reported that soils of rice-mustard land use system is low in both Exch-K and NEK and requires adequate K fertilization. Whereas; both Exch-K and NEK were higher in the forest soils as compared to rice-mustard soils in the three soil depths.

Yadav *et al.* (2019) have reported high mean value of available potassium (363.0 kg ha^{-1}) in pre-monsoon season than post-monsoon season (358.25 kg ha^{-1}), with the least available potassium in monsoon season while studying seasonal variation of soil chemical characteristics at Manjri Farm, Pune. They have revealed that, in rainy season the potassium present in soil is easily dissolved in water and eroded off and solubility of potassium in rainy season is higher than in dry season.

Amgain *et al.* (2020) conducted a study to determine depth-wise soil parameters distribution in the apple growing areas of Gharpajhog Rural Municipality, Mustang, Nepal. The result of the study revealed variation in the extractable potassium content in different depths. It varied from 17.34 to 300.24 mg kg^{-1} in 0–20 cm soil depth with a mean of 95.91 ±5.8 mg kg^{-1}. The extractable potassium in 20–40 cm varied from 0.05 to 296 mg kg^{-1} with a mean value of 45.83 ±5.8 mg kg^{-1}. Similarly, in 40–60 cm depths the extractable potassium was ranged from 0.05 to 118.51 mg kg^{-1} with a mean value 29.63±5.8 mg kg^{-1}. In general, the mean extractable potassium was found maximum in upper surface and decreasing with depth. This was attributed to release of liable K from organic residues as well as application of external fertilizers.

Khan *et al.* (2020) have studied the depth wise distribution of available nutrients of soils of Langate Block of Kupwara district, Kashmir valley and reported higher amount of potassium in surface soils, which was due to greater exposure of these minerals to weathering agencies at surface than sub-soils.

Negasa (2020) conducted a study to assess the effects of land use types on selected soil properties in Meja watershed, central highlands of Ethiopia and reported higher exchangeable K content in cultivated soils compared to eucalyptus plantation and grasslands.

Sulphur:

Majumdar and Patil (2016) carried out an investigation to study the forms and distribution sulphur in surface soils of three land use systems *viz.* agriculture, forest and horticulture in Singhanhalli-Bogur micro-watershed and reported less available S in paddy land use compared to forest and orchard (mango) land use.

Padhan *et al*. (2016) studied the effects of land use pattern on distribution of sulphur fractions in soil and reported that mineralization of organic S depends upon many factors and it varies from land use to land use and also the type of crop species in a particular land use. The highest amount of available S was reported in the surface layer of orchard soil and the lowest amount in the lower depth (0.4–0.6 m) of rice-green gram land use during their study. The maximum availability of S in orchard land use was attributed to higher mineralization of organic S as the microbial activity was more pronounced owing to higher biomass addition. Continuous cropping that removed greater amount of S was the reason for lower availability of S in rice-rice and rice- green gram land use. They have also reported declining trend of available S content along the depth irrespective of all the land uses pertaining to their study.

Maqbool *et al.* (2017) reported high available S in forest LUS than agriculture LUS while comparing physicochemical properties and nutrient status of soils of forest and agriculture land uses in Ganderbal district of J & K.

Khanday *et al.* (2018) also reported decrease in sulphur content down the profile. According to them, the prevalence of high S content in surface horizons may be due to higher organic matter content.

Khan *et al.* (2020) have studied depth wise distribution of available nutrients in Kashmir valley and found higher available sulphur in surface horizons as compared to sub-surface horizons. The available sulphur content in surface soils varied from 8.70 to 16.43 kg ha^{-1} while as, in sub-surface soils it varied from 8.00 to 16.50 kg ha^{-1}. Available sulphur content exhibited a regular decreasing trend with the depth in all the pedons. They have revealed that possible reason of higher available sulphur in surface horizons as compared to sub-surface horizons might be due to varying land use and parent material. Moreover, soil depth, soil organic matter, sulphur mineralization and immobilization also determine the availability of sulphur in soil.

Maqbool *et al.* (2020) reported a decreasing trend of available sulphur with an increase in its vertical distribution. It may be due to increasing pH with depth and decrease of organic carbon with depth. The available sulphur in surface soils was more in comparison to sub-surface soils, which was attributed to higher amounts of organic matter content of the surface soils, as indicated by positive correlation of available sulphur with organic carbon.

Calcium and Magnesium:

Saha *et al*. (2012) however reported comparatively less Ca and Mg content in forest LUS compared to agri-horticulture land use system under Meghalaya condition. They have revealed that agroforestry intervention increased the exchangeable Ca and Mg content and the content of these nutrients decreased with increasing soil depth.

Fatubarin and Olojugba (2014) also reported similar results of increased Ex. Ca and Mg content in beginning and end of rains, while least been reported in the peak of rains (monsoon) with the distribution of exchangeable bases decreased down the depths in a study carried out in Oro forest reserve in Kwara State of Nigeria. Low exchangeable base content at higher depth might be due in part to the higher organic matter at the upper depths during the dry and beginning of rains.

Bini *et al*. (2015) have conducted a comparative study on the seasonal variations in the soil edaphic and chemical factors of agricultural and grassland habitats of central Travancore, Kerala and reported higher magnesium and calcium in grass land habitat than agricultural habitat. They have found a similar trend of availability of Exch Ca and Mg under grassland and agricultural habitat; maximum being in pre-monsoon season, followed by post-monsoon and least in the monsoon season.

Wani *et al.* (2017) reported higher calcium (2312.0 and 2284.6 ppm) and magnesium (286.24 and 273.37 ppm) content in surface and sub-surface soils in pear orchards of mid altitude in Jammu & Kashmir, India.

2.3. Soil biological properties under different land uses

Microbial biomass carbon:

Kara and Bolat (2008) conducted a study with an aim to determine the impact of different land uses (forest, pasture, and agricultural lands) on soil microbial biomass carbon and nitrogen in Bartin Province. In the study, the mean values for microbial biomass C were found as 1028.29 μg g^{-1}, 898.47 μg g^{-1}, and 485.10 μg g^{-1} in the forest, pasture and agricultural soils, respectively.

Bhuyan *et al.* (2013) carried out a study to investigate the soil microbial biomass C, N and P of major agro-ecosystems prevalent in East Siang district, Arunachal Pradesh *viz.* soybean, millets, maize and vegetable agro-ecosystem. During the study, microbial biomass C and N ranged between 199.61 and 238.35 μg g^{-1} and 15.46 and 26.55 μg g^{-1} respectively. Higher MBC content was reported in the surface soil layer than the sub-surface layer in different agro-ecosystems. Microclimatic variations and different agricultural practices were found to affect the changes in microbial biomass during their investigation.

Reza *et al.* (2014) have reported significantly greater microbial biomass carbon (MBC) and nitrogen (MBN) as well as FDA and DHA activities in the soils of the undisturbed forest than the soils under various land use practices. The MBC and MBN in the surface soil layer (0–25 cm) were found to be highest in the forest (99.0 and 20.43 mg kg^{-1}, respectively) and lowest (21.89 and 6.25 mg kg^{-1}, respectively) in the one year old *Jhum* fallow in a study conducted in lower range of Wokha district of Nagaland in North-Eastern India.

Xiangmin *et al.* (2014) conducted a study in Changbai Mountains of Northeast China to study soil carbon content, microbial biomass carbon (MBC), basal respiration and soil carbon mineralization in five selected types of land use *viz.* natural old-growth broad-leaved Korean pine mixed forest (NF); spruce plantation (SP); cropland (CL); ginseng farmland (GF); and a five-year Mongolian oak young forest (YF). They have found that the MBC contents ranged from 304.4 mg/kg in CL to1350.3 mg/kg in NF and were significantly higher in the NF soil compared with the SP, CL, GF, and YF soils. The results of study exhibited a close correlation between MBC and SOC or TN because most microorganisms are heterotrophic and their distribution and biological activity often depend on organic matter. They have revealed that the MBC content is effectively limited by SOC. The maximum value of microbial biomass was reported in wet period and the minimum value in dry period.

Manpoong and Tripathi (2019) studied soil properties of different land use systems of Mizoram, North East India. Soil samples (0–15 cm depth) were collected from five land uses *viz.* rubber plantation (RP), oil palm plantation (OPP), bamboo forest (BF), fallow land (FL) and natural forest (NF). The result revealed maximum soil microbial biomass carbon (SMBC) in NF soils, whereas the minimum was observed in BF with values ranging from 340 mg kg^{-1} to 345 mg kg^{-1}.

Katti *et al*. (2020) reported significantly higher mean value under arecanut land use system (398.67 mg kg^{-1}) which is followed by coconut land use system (373.00 mg kg^{-1}) and maize land use system (206.00 mg kg^{-1}) at surface soil layer. SMBC was decreased with increase in depth in all the land use systems studied in the Nandipura mini-watershed. They opined that the application of manure had a positive effect on soil organic matter content, which in turn decides the SMBC.

Lepcha and Devi (2020) have reported highest annual mean microbial biomass carbon in the forest (455.03 µg g^{-1}) followed by cardamom agroforestry (392.86 µg g^{-1}) and paddy cropland (317.47 µg g^{-1}). They opined that the highest MBC in the forest is due to the production of litter and deep root systems of the tree allowing more microbial activities than other agricultural land-use systems. Further, high soil N in the natural forest and cardamom agroforestry system is due to the presence of *Alnus nepalensis* which might result in a higher microbial biomass C in these sites Microbial biomass carbon exhibited a peak value in the rainy season and lowest in the winter season supporting the fact that warm and wet weathers during the rainy season accelerated litter decomposition as microbial activities and decomposition are at peak during this season thereby increasing the immobilization of nutrients by the microbes. Also, high relative humidity during the wet period accelerates the growth of fungi which further increases microbial biomass carbon. They have also reported high MBC content in the surface soil than sub- surface soil in all the land use types.

Tomar and Baishya (2020) studied seasonality and moisture regime control soil respiration, enzyme activities, and soil microbial biomass carbon in a semi-arid forest of Delhi and reported highest MBC in monsoon season and lowest in the winter season. MBC also exhibited significant ($p < 0.05$) variation among the two depths and was observed higher in 0–10 cm than in 10–20 cm depth. The range of MBC reported as 49.8 to 484.52 μg g^{-1}.

Dehydrogenase activity:

Mukhopadhyay and Maiti (2010) reported more DHA in undisturbed soil (natural forest) than disturbed soil (mine soil). In the undisturbed sites, dehydrogenase activity was reported as 140–580 μg TPF g^{-1} 24 h^{-1}; whereas the same is reported as 10–220 μg TPF g^{-1} 24 h^{-1} in disturbed sites. They have revealed that the low DHA in mine soil resulted from damage of microflora and lack of organic matter.

Velmourougane *et al.* (2013) conducted a study in Black Soil Regions (BSR) in India with an objective to study the impacts of bio-climates, cropping systems and land use systems on the distribution of dehydrogenase activity (DHA) in different soil profiles. DHA was reported to decline with depth with the record of maximum activity within 0–30 cm soil depth. The major reason for increased DHA in the surface soil compared to the deeper soil depths was attributed to the greater availability of organic carbon, nutrients and stimulated microbial activity in the surface soil. Significant influence of cropping systems and bio-climates on DHA was recorded during their study. Significantly higher DHA was recorded in Sub-humid moist (SHm) bio-climate (2.45 μg TPF g^{-1}) followed by Semi-arid dry (SAd) (2.00 μg TPF g^{-1}) and the least in arid bio-climate (1.62 μg TPF g^{-1}). The average DHA in different bio-climates were in decreasing order of sub-humid moist > semi-arid dry > sub-humid dry > arid. Legume-based cropping system recorded higher DHA (2.32–2.88 μg TPF g^{-1}) followed by cereal-based cropping system (1.29–2.82 μg TPF g^{-1}). The average DHA in different cropping systems were in decreasing order of legume > cereals > cotton > sugarcane.

Adak *et al*. (2014) evaluated changes in soil organic carbon, dehydrogenase activity, nutrient availability and leaf nutrient concentrations in a mango orchard soil in a field experiment on a *Typic Ustocrepts* soil of subtropical region in Lucknow, India. They have reported that vermicompost, organic mulching and microbial inoculation significantly enhanced soil organic carbon content, available nutrients, dehydrogenase activity and leaf nutrient concentrations. Dehydrogenase activity was highest (1.85 μg TPF g^{-1} h^{-1}) in organically treated soils. Surface soil (0–10 cm) showed higher dehydrogenase activity (1.29 to 1.85 μg TPF g^{-1} h^{-1}) as compared to lower soil depths in all the treatments.

Reza *et al*. (2014) conducted a study in the Bhandari or lower range of Wokha district of Nagaland in North-eastern India with an aim to analyze the impact of human activities such as shifting agriculture (*Jhum*) and horticultural practices on microbial biomass and fluorescein diacetate hydrolysis (FDA) and dehydrogenase (DHA) activities in soil. They have reported varied DHA between the land uses; with greatest dehydrogenase activity under forest soil followed by arecanut and pineapple orchards and *Jhum* fellows with least DHA. They also found that the dehydrogenase activity declined from the surface to the sub-surface soil layer regardless of the land uses. Since microorganisms are mostly confined to the surface soil layer owing to better aeration and greater nutrient availability, DHA activities were greater in the surface soil layer (0–25 cm) compared to the sub-surface (25–50 cm) soil layer where the organic matter content and nutrient availability was low and aeration was poor.

Bhowmik *et al*. (2019) reported higher DHA at surface soils while studying potential indicators of soil health degradation in different land use-based ecosystems in the Shiwaliks of Northwestern India. Significantly higher soil dehydrogenase enzyme activity in the 0–15 cm soil depth was reported from grassland and eroded soil as compared to agricultural and agroforestry land use systems. It was revealed that the lower dehydrogenase activity in the subsurface soil (15–30 cm) might probably be due to poor nutrient and aeration status and reduced rhizodeposition in the lower depths. This decline in the enzymatic activity with depth might also be due to decrease in easily decomposable organic matter with depth as compared to the 0–15 cm soil.

Tomar and Baishya (2020) have reported seasonal variation in dehydrogenase enzyme activity. Dehydrogenase showed significantly higher values in monsoon, suggesting that soil moisture has an important role in the production of dehydrogenase enzyme. It varied from 0.26 to 16.47 μg TPF g^{-1} DW h^{-1} and 0.11 to 8.95 μg TPF g^{-1} DW h^{-1} in 0–10 cm and 10–20 cm depth, respectively. A positive correlation between MBC and dehydrogenase activity was also reported during their study, indicating that as when the number of microbes increases, production of dehydrogenase enzyme also increases.

Meena and Rao (2021) have investigated the effect of different land use, *i.e.* forests *viz.* mixed forest cover (MFC), *Prosopis juliflora* (Sw.) DC-dominated forest cover (PFC), and cultivated sites *viz.* agriculture field (AF), vegetable field (VF), respectively, on soil parameter, microbial activity, and enzymes involved in soil nutrient cycle in a semiarid region of India. Higher activity of all the enzymes have been reported under mixed forest cover (MFC)/ natural forest where there is low level of anthropogenic influence. The soils were covered with high litter content and added greater SOM under MFC. According to them the intensive management practices under agricultural field and vegetable fields constantly disturb the soil and regular removal of litter layer restricted the supply of substrate for microbes, thereby reduces the enzyme activities.

B-glucosidase:

de Medeiros *et al*. (2015) demonstrated similar β-GSA among tropical dry forest and intercropping soils of Brazil with less aggressive management practices. The study also reported a reduced activity under semiarid ecosystems which was attributed to the slow decomposition of SMBC.

Saplalrinliana *et al.* (2016) studied the impact of shifting cultivation on litter accumulation and properties of *Jhum* soils of north east India and revealed increased activity of glucosidase with increase in length of the fallow phase under Mizoram and Nagaland condition; in the study to assess whether the slash-burn practice (*Jhum*) induced disturbance on the above-ground biological inputs (plant biomass and forest floor litters, FFLs) had any influence on the soil processes in terms of soil enzyme activities. They have considered *Jhum* cycles of 5, 10 and 15/20 years. The higher activity of GSA was thought to be closely linked with the greater quantity and more complexity of substrates available in the longer fallow phase.

Silva *et al.* (2019) evaluated β-GSA under tropical dry native forest, protected area, scrub, and maize cultivated area; reported reduced activity under the cultivated field; and suggested a closed linking of β-glucosidase with SOC and SOM content.

Tomar and Baishya (2020) studied seasonality and moisture regime control soil respiration, enzyme activities, and soil microbial biomass carbon in a semi-arid forest of Delhi, India. However, they did not get significant seasonal variation in β-glucosidase activity unlike seasonal variation in dehydrogenase and phenol oxidase activity.

Meena and Rao (2021) investigated the effect of different land use on soil parameter, microbial activity, and enzymes involved in soil nutrient cycle in a semiarid region of India and reported significantly higher β-GSA (μg PNG

g^{-1} h^{-1}) in mixed forest cover (623.71 ± 5.75) than *P. juliflora*-dominated forest cover (398.40 ± 9.01), agricultural field (57.58 ± 0.94), and vegetable field (32.95 ±0.49), respectively.

Acid phosphatase activity:

Verma *et al.* (2017) have reported significantly higher acid phosphatase activity in a treatment comprising of inorganic fertilizer, FYM as well as lime that maximized the crop growth and enhanced the accumulation of SOC. Besides this, the microbial activity was also highest in the combination leading possibly to P stress in the soil, thereby enhancing the phosphatase released by the microorganism to counteract the deficiency and make P available for the crops.

Bhowmik *et al.* (2019) had undertaken a study in a mixed watershed comprising of different land use systems (agricultural, grassland, agroforestry, and eroded); situated in the Shiwalik region in the foot hills of the lower Himalayas to assess potential indicators of soil health degradation. They have revealed the trend of acid PHA in 0–15 cm soil depth as agroforestry (19.77 µg PNP g^{-1} soil h^{-1}) > grassland (16.41 µg PNP g^{-1} soil h^{-1}) > agriculture (11.19 µg PNP g^{-1} soil h^{-1}) > eroded lands (7.85 µg PNP g^{-1} soil h^{-1}). In 15–30 cm soil depth also, soils from agroforestry land use had significantly higher alkaline and acid phosphatase activity as compared to the grassland and agricultural land use systems. They opined that the phosphatase enzymes activity is not only linked to the synthesis of microbial cells but also to the mineralization of organic to inorganic P. They have also reported decreased phosphatase activity with soil depth that corresponded to SOC content and distribution of microorganisms in the soil profiles.

Meena and Rao (2021) have reported high acid phosphatases (µg PNP g^{-1} h^{-1}) under mixed forest cover MFC (1051.98 ± 65.40) followed by *P. juliflora* forest cover PFC (287.18 ± 6.93), vegetable field VF (95.22 ± 4.54), and agricultural fields AF (68.02 ± 4.23), respectively. They have also reported significant variation of activity of acid phosphatases among forest land uses (MFC, PFC). However, no significant difference was determined under cultivated land uses (AF, VF).

Bacterial population:

Tangjang and Arunachalam (2008) have studied microbial population dynamics in soils under traditional agroforestry systems in Arunachal Pradesh, North East India and have reported low bacterial counts in sub-surface soils. They have also reported maximum bacterial population during rainy season than spring and post rainy seasons. According to them, during winter, low moisture content in soil slowed down microbial activity and decomposition of organic matter resulting in low microbial population.

Onyekwelu *et al.* (2011) have investigated the effects of land use systems, seasonal variations and soil depths on microbial biomass and population in Oluwa forest reserve, Nigeria. Soil samples were obtained from two soil depths (0–15 and 15–30 cm) from primary forest, degraded forest, plantation forest and agricultural land during the rainy and dry seasons as well as their transitions. Significantly higher bacteria population was reported at 0–15 cm than 15–30 cm in primary forest followed by *Gmelina* plantation and degraded forest ecosystem. Agricultural land recorded lowest population. They have reported increased bacterial population with increase in rainfall as evidenced by the significantly increasing trend of its population from March (peak of dry season) to September (peak of rainy season) indicating that the drier the soils, the lower the bacteria population.

Das and Dkhar (2012) have determined microbial populations and microbial biomass carbon in the rhizosphere soil of soybean cultivated under different organic treatments *viz.* plant compost (PC), vermicompost (VER), farmyard manure (FYM), and integrated plant compost (IPC) under Meghalaya condition. The serial dilution plate method enumerated maximum bacterial population in organically treated soybean with vermicompost and FYM that provided adequate biomass as a feed for the microbes and help in increasing microbial population in the soil.

Asadu *et al.* (2015) also have reported that bacterial count significantly affected by different land use system and conditions; the highest bacterial count was reported in surface soils of forest land use, grassland and lowest in cultivated land.

Garcha *et al.* (2016) have studied microbial diversity in soil under different land use systems in sub-mountainous zone of Punjab and reported maximum population of bacteria in orchard soils followed by mixed forest and cultivated area (maize-wheat cropping system).

Lyngdoh and Karmakar (2018) studied seasonal variations in microbial population and relationship of microbes with some soil parameters in Ri-Bhoi district of Meghalaya for surface and subsurface region of three land uses *viz.* agricultural cropland, horticultural cropland and forestland in pre-monsoon, monsoon and post-monsoon seasons. They have reported highest bacterial count in soils of forest LUS (236 cfu x 10^6) followed by horticultural and cultivated LUS. Significant variation of soil microbial population with depth was also reported, where population of bacteria was higher in the surface than sub-surface soil. They have reported increased population of bacteria in pre-monsoon season that attained a peak in monsoon and decreased afterwards towards post-monsoon season. They have related population peak attained during monsoon season to the greater availability of nutrients and other favourable conditions such as moisture and diurnal soil temperature fluctuations at mesophilic range.

Wani *et al.* (2018) conducted a study to ascertain the biological properties of soils under five land use systems, *viz.*, forestry, horticulture, agriculture, agri-horti, pasture at different locations *viz.*, Gulmarg, Pattan, Ruhama, Baramulla, Sopore of Kashmir. From their study, highest bacterial count (cfu × 10^6 g^{-1} soil) was reported in forest land use with mean value of

(178.46) followed by pasture (173.86), horticulture (vegetables) (168.46), agri-horti (158.53), horticulture (fruits) (117.86).While, the lowest (68.60) was recorded in agriculture land use. They have explained the reason of low number of soil bacteria in the cultivated land than that in the other land use systems as the presence of larger carbon source in the form of organic matter present in the forest and pasture land.

Akande and Adekayode (2019) have reported significantly higher ($p < 0.05$) number of soil bacteria in the cassava land with 6.80×10^4 cfu g^{-1} compared to other land use types and lowest bacteria population was reported in teak plantation with 6.57×10^4 cfu g^{-1}. Maximum numbers of microbes were found in surface soil (0–15 cm) as compared to other depths may be due to the presence of more organics and nutrients at the surface layer of the soil. They have also observed the decreasing trend of microbial abundance in the downward direction.

Bhowmik *et al.* (2019) have assessed the potential indicators of soil health degradation in the Shiwaliks of North Western India and have reported high bacterial counts in surface soils of different land use systems. The viable bacterial cell counts in the surface soil (0–15 cm) was significantly ($p < 0.05$) higher (18 x 10^6 cfu g^{-1} soil) in grassland soils, followed by eroded (12 x 10^6 cfu g^{-1} soil), agriculture (8 x 10^6 cfu g^{-1} soil), and lowest in agroforestry (5 x 10^6 cfu g^{-1} soil).

Kavitha *et al.* (2020) have carried out an investigation in the Nilgiri forest ecosystem Tamil Nadu, India to evaluate the microbial diversity of undisturbed forest soil in two different altitudes *viz*., Kallar and Ooty in four different seasons *viz*., summer, pre-rainy, post-rainy) and winter. Representative soil samples were collected at four different depths. Increase in the bacterial population in the forest ecosystem especially in Kallar (78.5 x 10^8 cfu g^{-1}) and Ooty (74.75 x 10^8 cfu g^{-1}) soil was reported in compared to the agro ecosystem eastern block (51.0 x 10^8 cfu g^{-1}) and polluted soil (37.0 x 10^8

cfu g^{-1}) of Nilgiri biosphere. According to them, soil sample taken during pre-rainy and post-rainy season exhibited more population in all ecosystems than sample taken during summer and winter. The increase in the population of bacteria after raining may be due to the favourable microclimatic conditions *viz*., moisture content, temperature and active litter decomposition.

2.4. Carbon fractions, carbon stock and carbon management index under different land uses

Organic carbon:

Chase and Singh (2014) studied soil nutrients and fertility in traditional land use systems of Khonoma village of Nagaland. They have reported higher SOC content in natural forest (2.85%), followed by *Jhum* fallow (2.37%) and least in soils of paddy fields (1.03%). The lowest content of SOC in soils of the paddy field was attributed to the rapid decomposition and mineralization of SOM following the clearing of fields of the harvested crops and burning. While, less exposure of forest soils to tilling, other disturbances and erosion might have recorded high OC in forest soils. Less erosion in forest soil may be due to sufficiently closed canopy and the availability of large amounts of ground cover in the form of leaf litter.

Salim *et al.* (2015) conducted a study to investigate the seasonal changes of the nutrients in the soil under different land uses *i.e*., natural forest, plantation and grassland of Jhilmil Jheel wetland, Haridwar district of Uttrakhand, India. They have reported maximum percentage of OC under natural forest (3.97%) during winter season and the minimum under grassland in the summer season (2.08%) attributing declining trend of OC during summer season to increase in temperature along with high decomposition rates (microbial respiration). They have revealed that natural forest soils had the maximum content of organic carbon in all the seasons and the minimum under grassland in all the seasons; which may be because forests have grater canopies and provided the litter in larger quantity as compared to grasslands therefore, accumulation of carbon was higher.

Chemeda *et al.* (2017) conducted a study at Warandhab area, Jimma Rare District, Wallaga Zone, Oromiya Region, Ethiopia with an objective to identify the influence of different land use types and soil depths on selected soil physical and chemical properties related to soil fertility. It was reported that soil organic matter/SOM content was significantly ($P \leq 0.01$) affected by the interaction of land use type with soil depth. The interaction effect of land use by soil depth, on the variability of SOM was significantly higher (8.37%) at surface layer of the forest land and lower (1.83%) at subsurface layer of cultivated land. The reason was attributed to intensive cultivation of the land and the total removal of crop residues for animal feed and source of energy.

Maqbool *et al.* (2017) have reported conspicuous variation of SOC content among forest land use and agriculture land use of J & K. Forest land use exhibited greater SOC content than agriculture with mean values of 23.68, 4.35, g kg^{-1} respectively. High organic carbon in forest land use was attributed to high biomass production and lower decomposition at higher reaches as compared to agriculture having lower biomass because of less vegetation.

Omer *et al.* (2018) evaluated the selected soil quality indicators on samples collected at a 0–0.15 m depth, and at various sampling dates of the year, corresponding to the fall of 2015, winter of 2015/ 2016, spring of 2016, and the summer of 2016. Samples were collected from the three crop management systems including alfalfa (*Medicago sativa*), upland cotton (*Gossypium hirsutum*), and pecan (*Carya illinoinensis*). Highest SOM was reported in the winter (11.9 g kg^{-1}) and lowest (8.4 g kg^{-1}) in the summer during their study.

Dluzewski *et al.* (2019) conducted a study to determine seasonal changes in the organic carbon content in the mineral topsoil horizon of the Dystric Brunic Arenosols. In addition, the influence of forest age on the soil organic carbon (SOC) content in the A horizon was analyzed. They have observed a clear seasonal differentiation of the SOC content. Higher SOC content in the surface horizon for 55 and 13 year old forest occurred in the autumn and winter months (11.08 g kg^{-1} and 9.61 g kg^{-1} respectively), while it was lower in spring and summer (8.85 g kg^{-1} and 8.83 g kg^{-1} respectively). Dry meteorological conditions in winter months those received small amount of precipitation and lower soil moisture have been attributed to reduce the SOC accumulation in surface horizons. The research also showed that the age of the forest stand influences the content of organic carbon significantly in the A horizon. Higher content of SOC was observed in the A horizon of the 55 years old forest stand (average 9.69 g kg^{-1}) than on the 13 years old (7.02 g kg^{-1}).

Kenye *et al.* (2019) conducted a study in Mizoram, North East India to assess soil organic carbon (SOC) concentration and stock under eight major land uses *viz.* shifting cultivation, wet rice cultivation, home gardens, forest (natural), grassland, bamboo plantation, oil palm plantation and teak plantation for three different depths (0–15, 15–30 and 30–45 cm). They have revealed that forest land use recorded the highest mean SOC concentration with 2.74% and lowest in the bamboo plantation (1.09%); both SOC concentration and SOC stock decreased with increasing soil depth.

Amgain *et al*. (2020) conducted a study to determine depth-wise soil parameters distribution in the apple growing areas of Gharpajhog Rural Municipality, Mustang, Nepal. Soil sampling was done from three depths *viz.* 0–20 cm, 20–40 cm and 40–60 cm. They have reported higher percentage of organic matter in upper surface in the apple growing areas that decreased with increasing the soil depth; stating the reason of high organic matter in surface soil as application of manure and in-situ incorporation of plant residues on surface layer.

Hoque *et al*. (2020) conducted an experiment with soils from seven land use types *viz*. non-cultivated area, banana, lentil and wheat growing plots, rice growing control plots, NPKSZn and NPK+FYM treated rice growing plots to observe the effect of soil depth on soil properties under various land use systems. They found that most of the soils under study had very low to medium organic matter content and also reported deceasing organic matter content with increasing depth under Bangladesh condition. The organic matter status of non-cultivated, banana, lentil, wheat, control rice, NPKSZn-treated rice and NPK+FYM-treated rice growing soils varied from 3.17–0.88%, 1.31–0.36%, 1.78–0.50%, 1.54–0.36%, 2.82–0.57%, 2.77–1.37% and 2.89–1.25%, respectively from top layer to sub-surface layer.

Total Organic Carbon:

Luo *et al.* (2014) conducted a study on accumulation and seasonal dynamic of the soil organic carbon in wetland of the Yellow River Estuary, China. They have reported significantly higher TOC contents in October than that in both May and August under different wetlands. The peak of TOC contents was observed in 0–10 cm. The TOC content demonstrated very few changes in the soil profiles and the values remained low 20 cm below the surface of the soil.

Meetei *et al.* (2017) has analysed surface soil samples from four predominant land-use systems *viz.*, forest, grassland, cultivated (rice) land (>10 years) and *Jhum* land (2 years) of the humid sub-tropical Senapati district of Manipur, India to assess the impact of these land-uses on various pools of SOC *viz.*, total organic carbon (TOC), oxidizable organic carbon, very labile, labile, less labile and recalcitrant carbon fractions. They have reported highest accumulation of TOC in forest (38.78 g kg^{-1}), which was statistically at par with grassland (36.63 g kg^{-1}). They have reported that TOC of *Jhum* land (33.86 g kg^{-1}) was also statistically at par with the grassland, while cultivated land showed significantly lowest value of TOC under different land use types in Hilly ecosystems of Manipur. Highest TOC content in forest soil was attributed to residue additions in forest and permanent grassland land-use systems that augmented soil aggregation and, concomitantly, soil C content. In cultivated land; due to disturbance in soil the loss of C has taken place.

Sainepo *et al*. (2018) carried out an experiment to quantify the differences in total organic carbon (TOC), particulate organic carbon (POC), mineral organic carbon (MOC) and carbon management index (CMI) among four land use types *viz.* grasslands, shrublands, agricultural lands and barelands in Olesharo Catchment, Kenya. They have reported significantly higher mean values of TOC in shrublands (22.26 g kg^{-1}) than grasslands (10.29 g kg^{-1}) and barelands (7.56 g kg^{-1}). High TOC in shrub land was attributed to the recovery of significantly higher above and below ground biomass found in the shrub land compared to agricultural land and grassland.

Sahoo *et al.* (2019) quantified active and passive carbon pools from total soil organic carbon (TOC) in seven different land use systems of Mizoram, northeast India and reported a decreasing average TOC content (%) in different land use in the order: forest > current *Jhum* > agroforestry > wet rice cultivation > *Jhum* fallow > plantation > grassland with higher accumulation of soil organic carbon in the top layers of soils of all LUS that decreased with increasing soil depth. They have attributed a near-equilibrium between C inputs and C losses in undisturbed ecosystems to higher TOC content in forest land use and its recalcitrant nature that prevented microbial decomposition.

Zhou *et al.* (2019) analysed soil samples from three agricultural lands (including two rice fields and one sugarcane field) and four non-agricultural lands (including two forest lands, one wasteland and one built-up land) in the Mun River Basin for soil carbon, nitrogen, soil pH, soil particle sizes. The results showed that total organic carbon (TOC) and nitrogen (TON) contents in topsoil (TOC: 2.78 ~ 18.83 g kg^{-1}; TON: 0.48 ~ 2.05 g kg^{-1}) were much higher than those in deep soil (TOC: 0.35 ~ 6.08 g kg^{-1}; TON: <0.99 g kg^{-1}). In topsoil, their contents of forest lands and croplands (TOC: average 15.37g kg^{-1};

TON: average 1.29 g kg^{-1}) were higher than those of other land uses (TOC: average 5.28 g kg^{-1}; TON: average 0.38 g kg^{-1}).

Katti *et al.* (2020) assessed carbon fractions in Nandipura mini-watershed area, Karnataka under different land-use systems. Eight land-use systems were selected *viz*. agricultural system (maize, ragi and groundnut), horticulture system (arecanut, coconut and pomegranate), fallow land and scrubby land. They have reported significantly higher mean value of TOC in the soil under horticultural land use comprising of arecanut land use system (13.09 g kg^{-1} at 0–20 cm, 12.04 g kg^{-1} at 20–40 cm and 10.86 g kg^{-1} at 40–60 cm) and coconut land-use system (10.91 g kg^{-1} at 0–20 cm, 10.27 g kg^{-1} at 20–40 cm and 9.28 g kg^{-1} at 40–60 cm) and the lowest mean value of TOC content was recorded under agricultural land use i.e. maize land-use system (2.11 g kg^{-1} at 0–20 cm, 1.84 g kg^{-1} at 20–40 cm and 1.31 g kg^{-1} at 40–60 cm). The TOC content in the surface layer was found to be higher and decreased with a decrease in depth. They have revealed that the variation of TOC content was due to intensive cultivation of crops which has caused 47 per cent of soil organic carbon losses in the surface layer because of the rapid decomposition of native soil organic matter.

Permanganate Oxidizable Carbon:

Mandal *et al*. (2011) estimated permanganate oxidizable active carbon as quick indicator for assessing soil quality under different land use system of rainfed Alfisols. The different land use systems evaluated were *Leucaena* (*L. leucocephala*) plantation, sorghum (*Sorghum bicolor*)-castor (*Ricinus communis*) rotation in cultivated land, *Cenchrus ciliaris* grassland and an undisturbed bare soil as benchmark. They have reported significantly higher active carbon content under *Leucaena* plantation, followed by grassland and undisturbed bare soil. Cultivated land exhibited least values of potassium permanganate oxidizable carbon and the values varied from only 2.7 to 3.4% of organic carbon. The active carbon contents were 2.7, 3.3, 3.4 and 3.1% of organic carbon content in case of plantation field, grassland, undisturbed bare soil and cultivated land, respectively. The one way analysis of variance revealed that land use systems differed significantly with regard to active C at 0.0005 level (F ratio = 19.2, $P < 0.0005$).

Omer *et al.* (2018) have evaluated the selected soil quality indicators on samples collected from three crop management systems including alfalfa (*Medicago sativa*), upland cotton (*Gossypium hirsutum*), and pecan (*Carya illinoinensis*) at a 0–0.15 m depth, and at various sampling dates of the year, corresponding to the fall of 2015, winter of 2015/ 2016, spring of 2016, and the summer of 2016. They have reported that POXC and SOM were significantly higher in the fall and winter. They have revealed that the period of lower bulk densities (fall and winter) coincides with the time when the soil organic carbon indicators (SOM and POXC) were the highest in the soil.

Badagliacca *et al.* (2020) carried out an investigation to quantify the three principal components of the soil carbon (C) stock, namely inorganic, organic and permanganate oxidizable, in 0–5 cm and 5–30 cm soil layers, of the main Mediterranean agricultural land coverages *viz.* olive grove, olive forest, citrus grove, vineyard, arable irrigated, arable rainfed and natural soil covered by Mediterranean scrub and garrigue. They have found soil POXC, identified as the labile soil C had higher values under NAT (Mediterranean scrub and garrigue) followed by olive sites and citrus plantation; while, the lowest concentration were retrieved on the arable cropping system; both under irrigated and rainfed condition. Higher values were observed on all tree crops and natural soil. They also have reported high POXC levels in uncultivated and forest soils higher than in cultivated soils suggesting that different quantities and qualities of biomass input, as well as its degradation process, can have a significant effect on soil POXC levels. They have found that Soil POXC levels highlighted a similar trend to soil TOC in all land uses, showing greater percentage incidence in the upper soil layer than in the deep one.

Katti *et al.* (2020) have reported significantly higher mean of POXC (potassium permanganate oxidizable carbon) content in arecanut land use systems (427.44 mg kg^{-1}, 421.84 mg kg^{-1} and 414.58 mg kg^{-1} at 0 to 20 cm, 20 to 40 cm and 40 to 60 cm), respectively followed by coconut land use system (418.70 mg kg^{-1} at 0–20 cm, 412.51 mg kg^{-1} at 20–40 cm and 405.37 mg kg^{-1} at 40–60 cm). Significantly lower POXC content was observed under maize land use system (348.89 mg kg^{-1}, 342.25 mg kg^{-1} and 335.13 mg kg^{-1} at 0 to 20 cm, 20 to 40 cm and 40 to 60 cm, respectively). They have also found high POXC content in the surface layer of soils compared to the sub-surface layer. The difference in POXC content among land use systems was attributed to changes in management practices that have a detrimental effect on soil carbon. A low concentration of POXC in agricultural land use systems was attributed to tillage practices.

SOC stock:

Meetei *et al*. (2017) conducted a study in humid subtropical Senapati district of Manipur, India to assess the impact of four predominant land use systems *viz.,* forest, grassland, cultivated (rice) land (>10 years) and *Jhum* land (2 years) on various pools of SOC *viz.*, total organic carbon (TOC), oxidizable organic carbon, very labile, labile, less labile and recalcitrant carbon fractions. They have reported an order of SOC stock from their experiment as: forest > grassland > *Jhum* > cultivated land. They opined that residue additions in forest and permanent grassland land use systems improved soil aggregation and thus increased soil carbon content and SOC stock.

Schiedung *et al.* (2017) studied seasonal variability of soil organic carbon fractions under arable land and reported highest water extractable SOC stocks (WESOC stocks) in the month of March (pre-monsoon), that reached the minimum during May, and then again increased in the month of October (post-monsoon).

Amanuel *et al*. (2018) investigated the variation of soil organic carbon in four land cover types: natural and mixed forest, cultivated land, eucalyptus plantation and open bush land in the Birr watershed of the upper Blue Nile (Abbay) river basin, Ethiopia. The results showed that overall mean soil organic carbon stock was higher under natural and mixed forest land use compared with other land use types and at all depths (29.62 ± 1.95 Mg C ha^{-1}), which was 36.14, 28.36, and 27.63% more than in cultivated land, open bush land, and eucalyptus plantation, respectively. This was attributed to greater inputs of vegetation and reduced decomposition of organic matter. On the other hand, the lowest soil organic carbon stock under cultivated land could be due to reduced inputs of organic matter and frequent tillage which encouraged oxidation of organic matter.

Solomon *et al*. (2018) conducted a study to explore the effects of land cover change on carbon stock dynamics in the Wujig Mahgo Waren forest, in northern Ethiopia. The carbon concentrations are highly influenced by land use and the mean biomass carbon stock was five times higher in the dense forest compared to the open forest and twenty times higher than that of the grassland. According to them, the conversion of dense forests to cultivated land resulted in a 25% reduction in soil organic carbon stock. The mean carbon stocks in the dense forests, open forests, grasslands, cultivated lands and bare lands were estimated at 181.78 ± 27.06, 104.83 ± 12.35, 108.77 ± 6.77, 76.54 ± 7.84 and 83.11 ± 8.53 Mg C ha^{-1}respectively.

Kenye *et al*. (2019) conducted a study to assess soil organic carbon (SOC) concentration and stock at different depths (0–15, 15–30 and 30–45 cm) under eight major land uses *viz*. shifting cultivation, wet rice cultivation, home gardens, forest (natural), grassland, bamboo plantation, oil palm plantation and teak plantation of Mizoram, Northeast India. They have reported the highest mean SOC stock in forest (52.74 Mg C ha^{-1}) followed by home garden and wet rice cultivation. However, they have reported less SOC stock in shifting cultivation (27.87 Mg C ha^{-1}) and lowest in grassland (27.68 Mg C ha^{-1}). They have observed that both SOC concentration and SOC stock decreased with increasing soil depth. Loss of SOC stock estimated following its conversion from forest was maximum with shifting cultivation (-5.74 Mg C ha^{-1} yr^{-1}) followed by oil palm plantation (-2.29 Mg C ha^{-1} yr^{-1}), bamboo plantation (-1.56 Mg C ha^{-1} yr^{-1}) and the least in home gardens (-0.14 Mg C ha^{-1} yr^{-1}).

Ramesh *et al*. (2019) reviewed a study conducted in North East India to estimate SOC stock in five major orchards. It was reported that fruits crops exhibited significant influence on change of SOC stock. The maximum SOC stock was found in pear (*Pyrus Communis*) (68.7 Mg ha^{-1}) followed by guava (*Psidium guajava*) (64.8 Mg ha^{-1}) orchards. While pineapple (*Ananus comosus*) (57.9 Mg ha^{-1}) exhibited lowest SOC stock along with peach (*Prunus persica*) and khasi mandarin (*Citrus reticulate*) in between the maximum and minimum range. The differences in SOC stocks among the fruit crops was attributed to variation in above and below ground biomass, plant canopy, leaf and root biomass quality and soil characteristics.

Andrade *et al.* (2020) have analyzed the effect of four land uses *viz.* dense caatinga (DC), open caatinga (OC), pasture (PA) and agriculture (AG) on TOC stocks (STK.TOC) and TN stocks (STK.TN) in a semi-arid region of Brazil. Soil samples were collected from three different depths (0–10; 10–20 and 20–30 cm). They observed that among all land uses, AG showed the lowest means of STK.TOC (6.8 Mg ha^{-1}) and STK.TN (0.28 Mg ha^{-1}). Small values of the two are related to climatic condition, management practices (fire and conventional tillage) used in rainfed farms. The replacement of native vegetation by an intensive agricultural system is responsible for the decrease in organic matter content, which leads to a reduction in soil carbon and nitrogen stock.

Katti *et al.* (2020) reported significantly higher carbon stock at the surface layer of soil of arecanut land use system (30.95 t C ha^{-1}) which was followed by coconut land use system (29.71 t C ha^{-1}) and least was reported in maize land use system (17.29 t C ha^{-1}) . They have reported lower carbon stock potential at subsurface soil layer under all land use systems when compared to surface soil depth. At 20 to 40 cm and 40 to 60 cm, arecanut land use system recorded significantly higher mean carbon stock potential of 29.71 t C ha^{-1} and 28.66 t C ha^{-1} respectively. Lowest mean carbon stock potential was recorded under maize land-use system with 16.49 t C ha^{-1} at 20 to 40 cm and 15.16 t C ha^{-1} at 40 to 60 cm. Higher carbon stocks under plantation trees indicate higher organic carbon turnover through the decomposition of leaf litter.

Carbon management index (CMI):

Kalambukattu *et al.* (2013) investigated soil carbon pools and carbon management index under different land use systems in the Central Himalayan region. They have reported that forest system had the highest value of CMI followed by organic farming, soybean-wheat system and fodder system in both summer and winter season. The regular addition of organic matter in case of forest and organic farming systems proved enhanced potential to increase the CMI by increased inputs and lower losses.

Zhao *et al.* (2014) studied stratification of carbon fractions and carbon management index in deep soil affected by the Grain-to-Green program in China. Samples were collected from three typical conversion lands, *Robinia psendoacacia* (RP), *Caragana Korshinskii Kom* (CK), and abandoned land (AB), which have been converted from slope croplands (SC) for 30 years in LHR. Along with the carbon fractions, stratification ratios (SR) and carbon management indexes (CMI) were determined on soil profiles from 0 to 200 cm. From their study they have reported significantly higher CMI values in *Robinia psendoacacia* (RP) forest compared with *Caragana Korshinskii Kom* (CK), abandoned land (AB) and slope croplands (SC) in both surface soil and subsoil revealing soil management under RP plot as more appropriate to improve the SOC status than other land use types. CMI values of RP, CK, and AB increased by 11.61–61.53% in soil layer of 100–200 cm compared with SC. Significant positive correlations between SOC stocks and CMI or SR values of both surface soil and deep soil layers indicated that they were suitable indicators for soil quality and carbon changes evaluation.

Paes *et al.* (2018) have studied carbon management index and carbon stock of a cohesive oxisol in different region Northeast of Brazil under various land use systems *viz.* conventional cassava planting (CC), pasture (PP), and 7 and 12 year agroforestry systems (AF7 and AF12, respectively); were tested against secondary forest (SF). Highest CMI have been reported in 12 year old agroforestry system compared to 7 year old agroforestry, conventional cassava planting and pasture. They have revealed that the 12 year old agroforestry system gives better quality to the soil based on high CMI value.

Sainepo *et al.* (2018) carried out a study in Olesharo Catchment, Kenya to quantify the differences in total organic carbon (TOC), particulate organic carbon (POC), mineral organic carbon (MOC) and carbon management index (CMI) among four land use types *viz.* grasslands, shrublands, agricultural lands and barelands. It was also purported to evaluate the use of CMI as an indicator for soil degradation or improvement in response to land use and land cover changes during their study. In their study, highest CMI have reported in agricultural system compared to grasslands. The use of nitrogen based fertilizer leading to increase biomass and subsequent increase in soil organic matter was attributed to high CMI value in agricultural lands. On the other hand, in grasslands, overgrazing was seen to reduce the C content which can be attributable to reduction of herbaceous fine root biomass, thereby reducing the CMI of grasslands. It was revealed that higher CMI values indicate rehabilitation of carbon while lower CMI values show that the C is being degraded.

Jiao *et al.* (2020) conducted a study is to evaluate the variation of soil texture, aggregates stability, and soil carbon affected by land uses in the

Yellow River Delta, China. They observed the significant difference of CMI among different land uses that have changed according to the patterns of the LOC concentration. The overall CMI in arable land in the top 50 cm soil profile was the lowest, and decreased with the increase of soil depth. The CMI in grassland was more than 100 in the depths of 10–20 cm and 20–30 cm, suggesting that the CMI of grassland was higher than forest land (reference soil). They have revealed that alfalfa grassland had the advantage to promote soil quality compared with arable land and forest land because of high SOC content in combination with high CMI and better soil physical properties.

2.5. Carbon mineralization pattern under different land uses

Soil Basal Respiration:

Wang *et al.* (2013) investigated soil microbial biomass carbon, dissolved organic carbon, permanganate oxidizable carbon, soil respiration and activities of six enzymes from three different single species plantations, *viz. Pinus massoniana* (PM), *Cinnamomum camphora* (CC) and *Schima superba* (SS) in sub tropical China. They have reported higher soil respiration rate under *Pinus massoniana* (PM) plantation compared to *Cinnamomum camphora* (CC) and *Schima superba* (SS). They opined that overall rate of soil respiration depends more on some factors like C availability, nutrient availability, soil temperature and soil moisture rather than the tree species.

Xiangmin *et al.* (2014) have studied land use effects on soil organic carbon, microbial biomass and microbial activity in Changbai Mountains of Northeast China. Soil carbon content, microbial biomass carbon (MBC), basal respiration and soil carbon mineralization were studied in five selected types of land use *viz.* natural old-growth broad-leaved Korean pine mixed forest (NF); spruce plantation (SP); cropland (CL); ginseng farmland (GF); and a five-year Mongolian oak young forest (YF). They have reported higher C- mineralization rate of natural mixed forest (NF) soil than ginseng farmland (GF), spruce plantation (SP) cropland (CL) and oak young forest (YF). Furthermore, the respiration rate from YF soil increased compared with that of GF soil ($p < 0.05$). The respiration rate from GF soil was higher than that from CL soil during the incubation period of 57 days. It was revealed that the low quality of SOC limits the source of energy required for soil microbial growth, which eventually decreases the C mineralization rate. In their study, they observed that the C mineralization rate significantly decreased when NF was changed into other land use types.

Fan *et al.* (2015) have studied soil respiration under different land uses in Eastern China. They have reported highest soil respiration rate in the month of July / August (rainy season) and the lowest in January (winter / dry season). It was also revealed that soil respiration rates were significantly and positively correlated with organic carbon, total nitrogen, and available phosphorous content.

Desalegn *et al.* (2019) conducted a 62-day laboratory incubation experiment using soil samples collected from five adjacent land uses and management systems (grassland, cropland, eucalyptus plantations, limed land, and fallow land) to understand carbon mineralization processes, in the central highlands of Ethiopia. They found that total carbon mineralized and the mineralization rates were consistently higher in grasslands in both 0–10 cm and 10–20 cm as compared to the other land uses and management systems. The cumulative CO_2 release followed the order: grassland > cropland > eucalyptus > fallow land > limed land. The higher CO_2 release in grassland could be attributed to the higher organic matter content as compared to other land uses. They observed a weekly pattern of C- mineralization rates where carbon dioxide-C mineralization rates during the 62-days incubation period followed a general pattern across in all land uses and management systems in which an initial increase at the beginning of the incubation followed gradual decreases as the incubation time progresses. They stated that evolution of higher amount of CO_2 at initial stage indicated a rapid depletion of an easily mineralizable fraction (labile SOC) while the slow-steady phases in which mineralization declined to a fairly constant rate indicated that the most active fraction has exhausted and the resistant and stable fraction of SOC was being mineralized.

2.6. Relationship between organic carbon fractions with physico-chemical and biological properties of soil

Mandal *et al.* (2011) has undertaken an investigation in long-term experimental plots in Alfisols soil at Hyderabad. The different land-use systems evaluated were *Leucaena* (*L. leucocephala*) plantation, sorghum (*Sorghum bicolor*)-castor (*Ricinus communis*) rotation in cultivated land, *Cenchrus ciliaris* grassland and an undisturbed bare soil for estimating permanganate oxidizable active carbon as quick indicator for assessing soil quality under different land use system**.** They have reported a close relationship between active carbon (POXC) and other soil quality parameters like OC, MBC and dehydrogenase enzyme activity. Positive correlation was obtained between active carbon (POXC)-OC (r = 0.73**), POXC-MBC (r = 0.81**) and POXC-dehydrogenase (r = 0.79**) during their study. Both active carbon and organic carbon was found to be negatively correlated to bulk density. While, OC exhibited a strong positive correlation between dehydrogenase (r = 0.66**) and microbial biomass carbon (r = 0.63*).

Somasundaram *et al.* (2013) examined the dynamics of soil physical and chemical properties under different land use systems in parts of Chambal region of Rajasthan. Soils were sampled at surface (0–15 cm) layer under different land uses *viz.* irrigated sorghum / soybean-wheat rotation for over 20 years, ten-years-old *Leucaena leucocephala* plantation, grasslands for >15 years with dominant species of *Hetropogan contortus* and *Dichanthium annulatum*, over 20-years-old undisturbed forest of *Prosospis juliflora* and shrubs and twelve years- old *Acacia senegal* plantation. Correlation matrix of 14 soil attributes representing soil physical and chemical properties resulted in a significant correlation ($P < 0.05$) in 30 out of the 91 soil attribute pairs during their study. They obtained higher correlation between SOC and available N (r=0.85**). Calcium content in soil showed significant and positive correlations with silt content (r= 0.66**) and pH (r= 0.91**). Positive correlation between Ca and pH was attributed to higher solubility and greater potential of hydrolysis of $CaCO_3$ at higher pH.

Reza *et al.* (2014) conducted a study at the Bhandari or lower range of Wokha district of Nagaland in North Eastern India to analyze the impact of human activities such as shifting agriculture (*Jhum*) and horticultural practices on microbial biomass and Fluorescein diacetate hydrolysis (FDA) and dehydrogenase (DHA) activities in soil. Pearson correlation coefficients between soil biological properties and selected soil properties indicated positive correlation between pH-OC (r= 0.670**) in their study. Similar positive correlation was observed between pH -N (r= 0.591**), pH- P (r= 0.681**), pH-MBC (r= 0.417*), pH-DHA (r= 0.553**). Significant positive correlation between OC and available nutrient *viz.* N (r= 0.921**), P (r= 0.754**) and biological parameters *viz.* MBC (r= 0.791**), MBN (r= 0.589**) and dehydrogenase activity (r= 0.697**) was also reported by them.

Singh *et al.* (2014) studied land use impact on soil quality in Eastern Himalayan region of India with the objective to identify the most appropriate soil quality indicators and to evaluate the impact of six most prevalent land use types (natural forestland, cultivated lowland, cultivated upland terrace, shifting cultivation, plantation land, and grassland) on soil quality in Dimapur, Nagaland, India. A total of 120 soil samples from surface layer (20 cm depth) were collected and analyzed for 29 physical, chemical, and biological soil attributes. Positive correlation between soil pH-OC (r= 0.54**) was reported during their study. Significant positive relation of pH with N (r= 0.51**), P (r= 0.42**), K (r= 0.72**), Ca (r= 0.69**), Mg (r= 0.76**), SMBC (r= 0.59**), SMBN (r= 0.47**), SMBP (r= 0.37**), Dehydrogenase (r= 0.37**) and soil respiration (r= 0.50**) was also obtained in their study.

They have also reported significant positive correlation between organic carbon and macro elements *viz.* OC-available N (r= 0.93**), OC-available P (r= 0.38**), OC-available K (r= 0.77**), OC-Exch Ca (r= 0.94**) and Mg (r= 0.74**); indicating that the plant nutrients have been originated from the same source *i.e.* SOC under of different LUS. They have also reported significant positive correlation between soil organic carbon and biological parameters *viz.* SMBC (r= 0.98**), SMBN (r= 0.86**), SMBP (r= 0.88**), dehydogenase (r= 0.82**) and soil respiration (r= 0.95**).

Patel *et al.* (2015) studied the seasonal impact on physico-chemical properties of soil in North and South Gujarat and have reported positive correlation between OC and macronutrients in their study during different seasons. They obtain significant positive correlation between OM-K (r = 0.647**), OM-Ca (r = 0.436**). Positive relationship was also evident between OM and pH, phosphorus and K, Ca, as well as Mg during their study.

Paul and Mukhopadhyay (2015) conducted a study in some *terai* soils under subtropical zone of Eastern India considering some soil series and some benchmark sites to evaluate distribution of available sulphur status and important soil attributes on sulphur availability. Pearson correlation tests during their investigation revealed significant and positive relationship of available S with total N (r= 0.27**) and organic carbon content (r = 0.34**), since both S and N are the integral constituents of proteins in the organic matter, these two elements use to maintain a definite N : S ratio in the organic matter.

Temsurenla and Ajungla (2017) studied status of soil physico-chemical characteristics both in rhizospheric and non-rhizospheric regions in two tea gardens of Mokokchung district in Nagaland, India. They have reported positive relationship between pH and OC (r= 0.653*). Significant positive correlation was also reported between available nutrients (N, P and K) and organic carbon in their study sites.

Verma *et al.* (2017) studied the effect of organic and inorganic amendments on soil organic carbon fractions and enzymes in an acid soil of Meghalaya and reported that organic carbon fraction and soil enzymes were highly correlated (*P=0.01*) with each other. However, correlation values were more in case of labile fractions of organic carbon with the soil enzymes. Significant positive correlation was obtained between organic carbon content and soil biological properties including MBC (r= 0.89**) and soil enzymes *viz.* dehydrogenase (r= 0.92**), β-glucosidase (r= 0.92**) and acid phosphatase (r= 0.87**). This indicates that the organic matter is the source of energy for soil organisms and their activities. The availability of substrate materials in the form of organic matter regulates the microorganism population and hence determines the extent of availability of soil enzymes.

Kenye *et al.* (2019) conducted a study to assess soil organic carbon (SOC) concentration and stock under eight major land uses: shifting cultivation, wet rice cultivation, home gardens, forest (natural), grassland, bamboo plantation, oil palm plantation and teak plantation of Mizoram, Northeast India. Soil samples at different depths (0–15, 15–30 and 30–45 cm) were analysed for soil organic carbon and carbon stock. Pearson correlation analysis of SOC concentration showed positive significant relationship with SOC stock, soil moisture content, clay and sand at $P < 0.001$ level of significance. However, it correlated negatively with bulk density (r= - 0.324**) at $P < 0.001$ and silt (r= - 0.227*) at $P < 0.05$ level of significance respectively.

Vishnu Priya *et al.* (2020) studied correlation between carbon dioxide evolution and biological quality index of long-term nutrient management adopted soils. They observed positive correlation between SOC and respiration / CO_2 evolution (r= 0.93*). Besides, they have also found positive correlation between SOC-MBC (r= 0.79*), SOC-labile carbon (r= 0.88*), SOC-dehydrogenase (r= 0.96*). MBC significantly and positively correlated with labile carbon (r= 0.74*), dehydrogenase (r= 0.87*) and soil respiration (r= 0.75*). During their study, they have reported significant positive correlation between labile carbon-dehydrogenase (r= 0.90*) and labile carbon-soil respiration (r= 0.87*) too.

Tomar and Baishya (2020) studied seasonality and moisture regime control soil respiration, enzyme activities, and soil microbial biomass carbon in a semi-arid forest of Delhi, India. Pearson correlation coefficient indicated positive correlation between MBC and soil microbiological and physical variables including dehydrogenase (r = 0.73**), phenol oxidase (r = 0.33*), soil respiration (r = 0.79**), soil moisture (r = 0.82**) and temperature (r = 0.63**).

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out in the Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema. The investigation comprised of survey, collection and analysis of soil samples (surface and sub-surface layers) from three different land use systems in three seasons of 2018 to assess the soil organic carbon fractions and physico-chemical as well as biological properties. Medziphema block of the Dimapur district was selected for the study. The details of materials and methods *viz.* geography, climate, collection and processing of soil samples, analytical methods adopted to achieve the objectives are presented in this chapter.

3.1. Description of study site

Dimapur district is bounded by Assam on its North and West, Kohima on the East and Peren district in the South. The district comprises of eight blocks *viz.* Aghunaqa, Chumukedima, Dhansiripar, Dimapur Sadar, Kuhuboto, Medziphema, Nihokhu and Niuland with an area of 927 square kilometres. Major portions of Dimapur district lies in plain sector except Medziphema block, which lies at higher altitude. Among the blocks, Medziphema block has the maximum geographical area of 345 square kilometer with 67 revenue villages (Bhalerao *et al.*, 2016). The sampling sites lies between 25.69347° N to 25.76559° N latitude and 93.82366° E to 93.88039° E longitudes. The elevation of the sampling sites ranged from 250 m in paddy field to 433 m in forest above msl. The location map of the study site is prepared by interpolating the geo-referenced soil sampling points in the google earth map of Dimapur district (Fig 3.1). The study site is endowed with a vast area under natural / undisturbed forest. Organized pineapple cultivation is a hallmark of

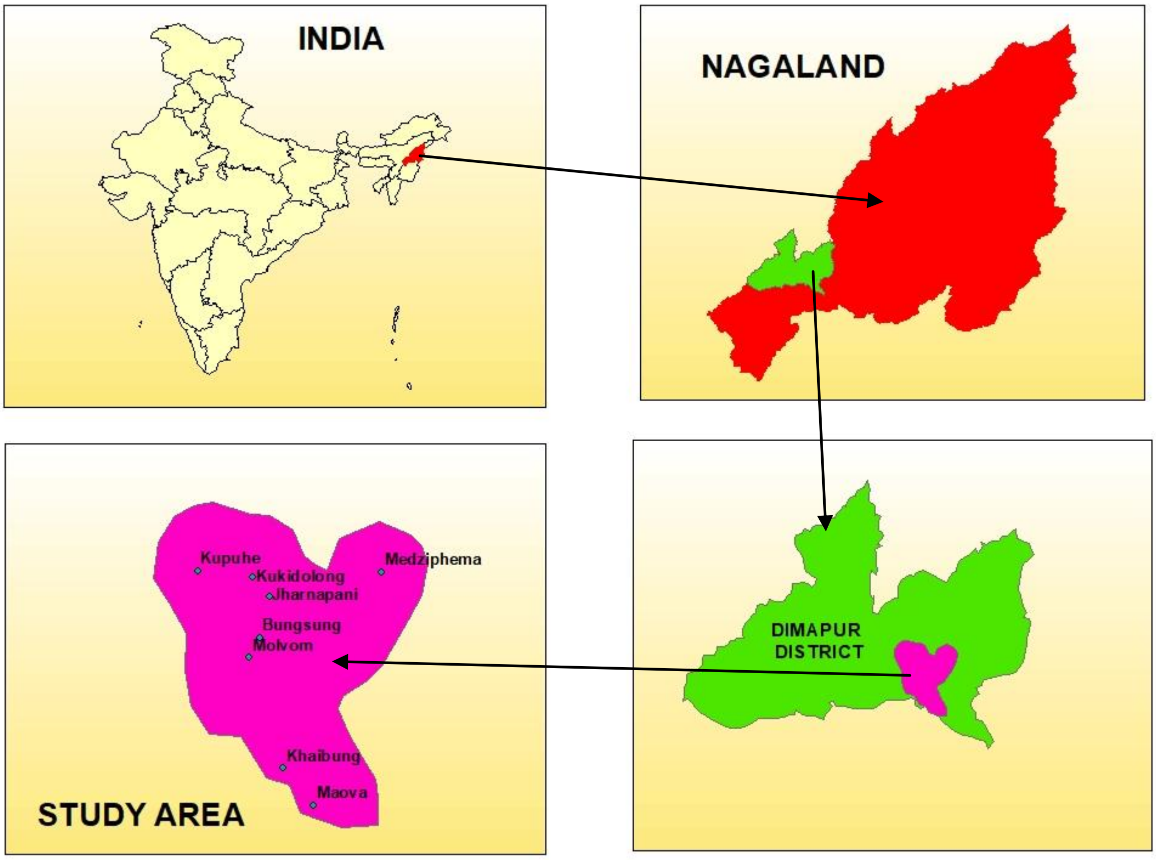


Fig 3.1: Location map of the study area

the study site, whereas wetland paddy cultivation is prevalent as a traditional land use system.

Eight different villages *viz.* Bungsung, Jharnapani, Khaibung, Kukidolong, Kupuhe, Medziphema, Maova and Molvom under Medziphema block has been selected as the study sites based on the prevalence of proposed land use systems.

3.2. Climate

Dimapur district falls under humid sub tropical agro climate zone (ACZ). In summer it is hot and humid and moderately cold in winter. The district receives rains in two spells: South-West monsoon in summer and North-East monsoon in winter. The South-West monsoon sets normally in the first week of May and extends up to October and the North-East monsoon normally sets in the month of November and extends till December. The major shares of the rains are received during June to August (Bhalerao *et al.,* 2016). The average rainfall varies from 1500 mm to 2500 mm. The monthly meteorological data including maximum and minimum temperature, maximum and minimum relative humidity and rainfall of the experimental year 2018 is presented in Table 3.1. and Fig 3.2 and 3.3.

3.3. Land use systems

Three prevalent land use system (LUS), common to the above villages have been selected for the present investigation. While searching for the history of these LUS; discussion with farmers and key informants, it was revealed that the selected LUS existed there in place for past 18–20 years. The LUS selected are as follows:

Land use I: Natural/ undisturbed forest (Forest LUS)

Land use II: Pineapple (Pineapple LUS)

Land use III: Wetland paddy (Paddy LUS)

Forest LUS represents an undisturbed forest site with mixed tree species. The common tree species found in the sampling sites were: Indian rubber (*Ficus elastica*), iron wood (*Mesua ferrea*), bastard myrobalan (*Terminalia bellerica*), beechwood (*Gmelina arborea*), Alder (*Alnus nepalensis*), Teak (*Tectona grandis*), panic grass (*Panicum spp*.), camel's foot (*Bauhinia variegate*), Indian beech (*Pongamia spp*.), needlewood (*Schima wallichii*) etc. (Singh *et al*., 2014). The forest LUS existed on hill slopes with an elevation ranging from 342 m to 433 m above msl across the villages.

Pineapple LUS in Medziphema block existed on hill slopes with organized pineapple cultivation. The elevation of sampling sites under pineapple plantation ranged from 285 m to 416 m above msl. Dominant pineapple cultivar in all the villages is 'Kew'; that are grown with a regular but small application of chemical fertilizers. The productivity of pineapple in the district is 11.59 t ha^{-1} (Jamir and Jahanara, 2019). Suckers are commonly used as planting materials, planted with double row spacing (30 cm x 60 cm x 90 cm) maintaining an approximate plant population of 44,500 plants across the slope in pits. Under Nagaland condition, pineapple is planted during the month of May to July. It generally takes 12–15 months to peak flowering.

Paddy LUS in the present study represented wetrice cultivation generally followed in valley or low land areas of the district. The elevation of paddy fields from where sampling was done ranged from 250 m to 359 m above msl. Monocropping with local paddy cultivars is practiced in low lands. Land preparation for lowland rice cultivation is done by ploughing with bullocks and power tillers (only in medium and large land holdings). Rainfall is the major source of irrigation. 25–30 days old seedlings of paddy are transplanted in July-August and harvested in the month of November-December. No evidence of application of fertilizers and pesticides was recorded while cultivating lowland paddy. The average productivity of the low land paddy in the district is 2.62 t ha^{-1} (Bhalerao *et al*., 2016).

Table 3.1. Monthly meteorological data of the Dimapur district (2018)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	Max	Min	
Jan	23.7	9.6	97	63	23.0
Feb	26.1	10.8	97	54	6.7
Mar	30.2	14.5	95	49	31.8
Apr	31.6	18.1	94	55	71.4
May	31.7	21.2	94	65	135.5
June	33.4	24.2	94	73	354.7
July	33.2	24.9	92	72	240
Aug	33.5	24.9	94	71	302.8
Sep	33.6	23.9	94	67	115.7
Oct	29.9	20.1	96	67	64.0
Nov	28.2	14.1	97	54	13.3
Dec	24.6	11.0	96	56	50.0

Source: ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Dimapur

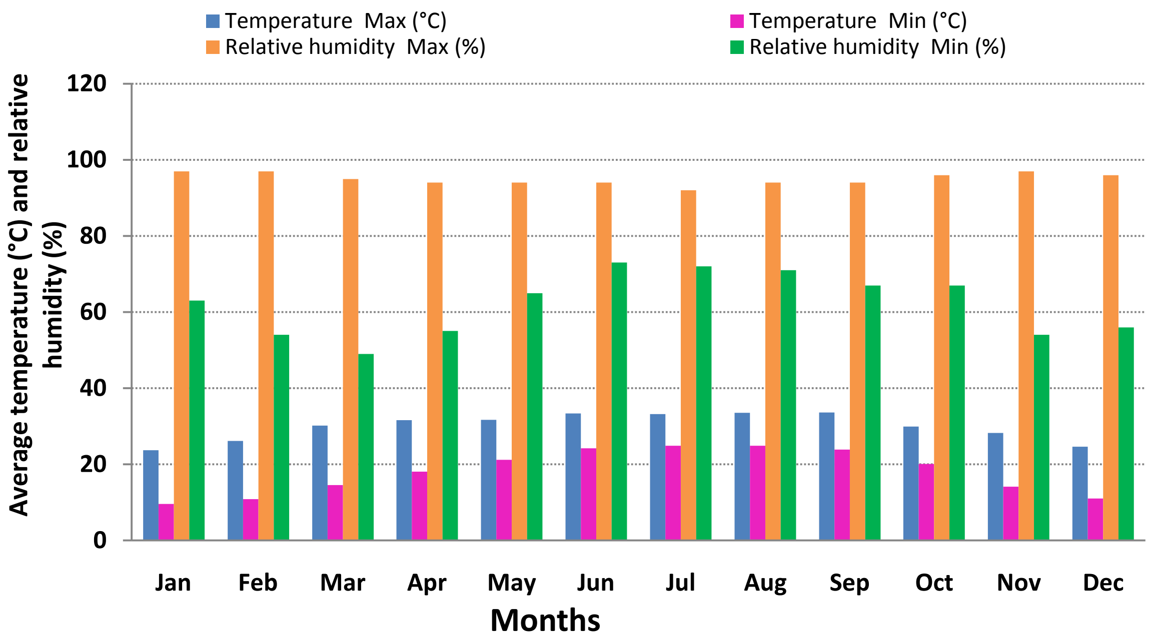


Fig 3.2 : Monthly average weather variables during sampling year (2018)

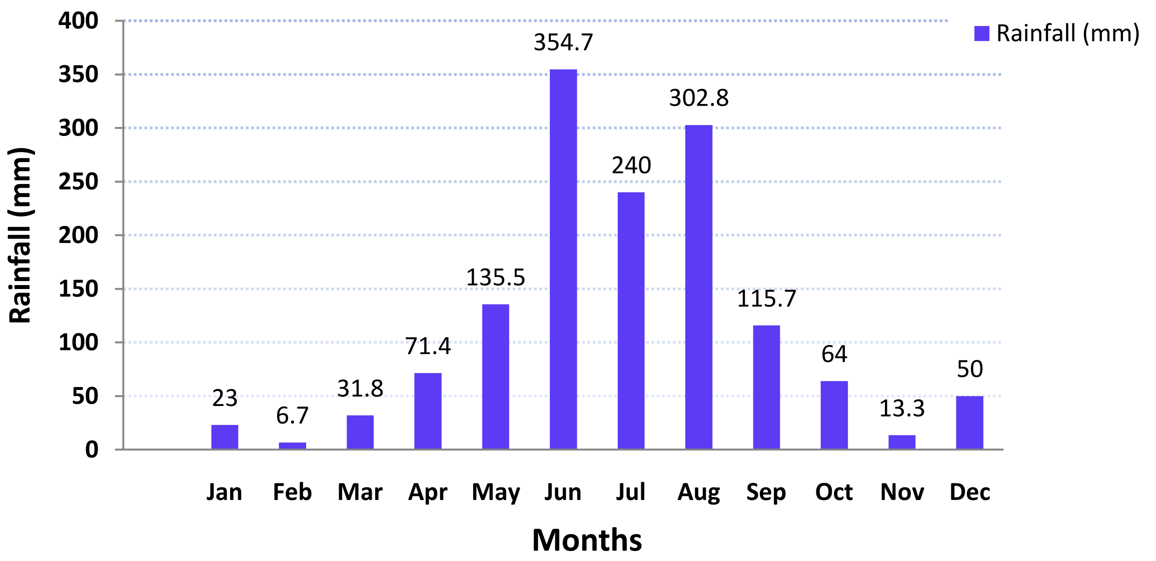


Fig 3.3: Monthly average rainfall during sampling year (2018)

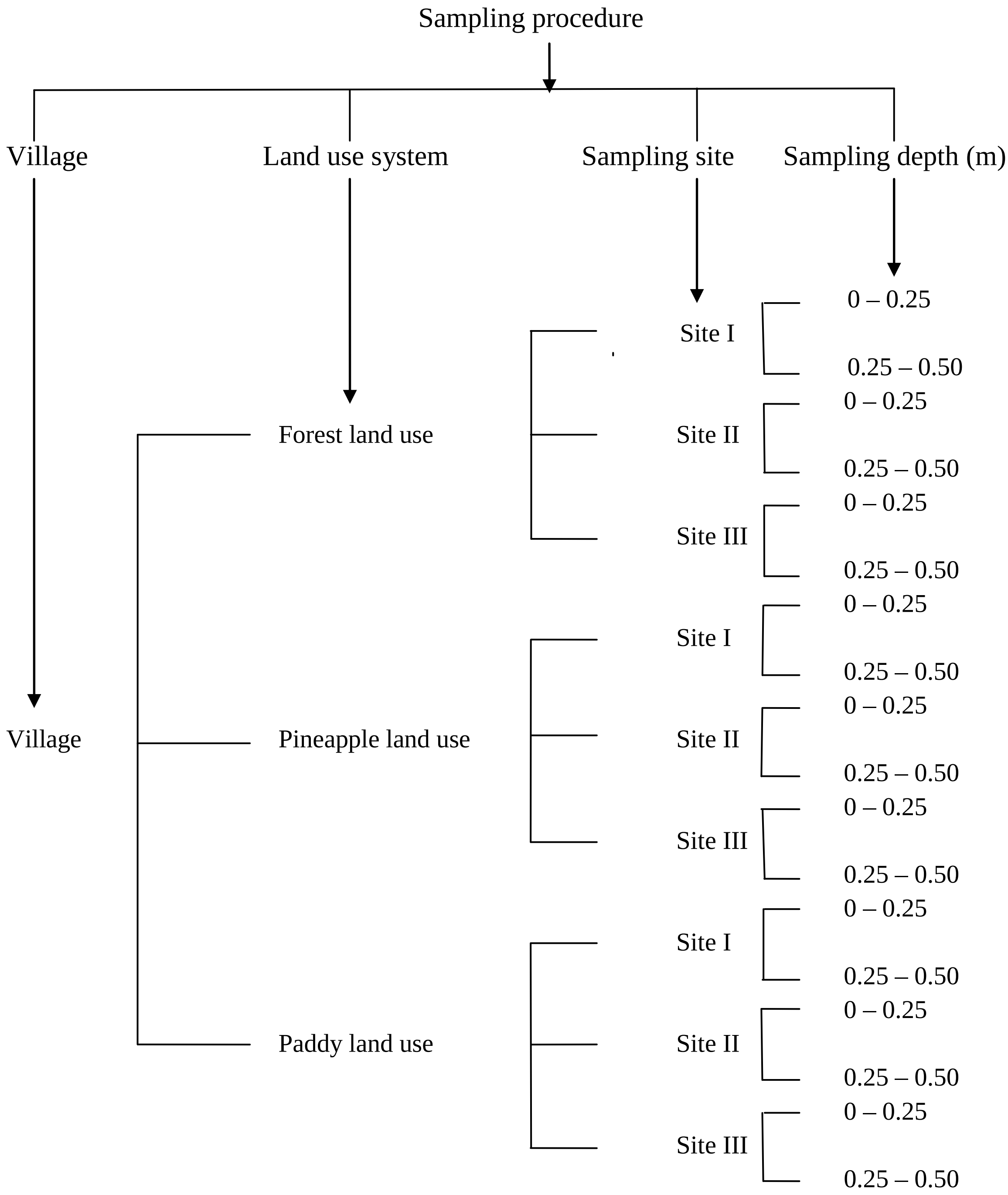
3.4. Collection soil samples

Soils of the Medziphema block falls within the 'Inceptisol' soil order with low base saturation; with an 'Udic' moisture regime and hence placed in 'Dystrudept' great group.

For the present study, geo-referenced soil samples have been collected using GPS device (Model: GARMIN etrex 30x) from eight (8) different villages; both from surface (0–0.25 m) and sub surface (0.25–0.50 m) soil layers. Under each LUS in each village under study, representative sites were selected for collection of soil samples. Based on topographic and edaphic homogeneity / heterogeneity of the selected sites (through visual observation), these sub samples were used to raise three (3) numbers of composite samples. Thus, three (3) composite soil samples were raised from each depth from each LUS of each village. So, the number of soil samples collected from three LUS in one village was eighteen (3 LUS x 3 sites x 2 depths =18). Hence, from 8 different villages, a total of 144 soil samples have been collected in one season (Fig 3.4). Sampling was done thrice in three (3) different seasons *viz.* pre-monsoon (May), monsoon (August) and post-monsoon (November) in the year 2018. Thus, a total of 432 composite soil samples have been collected for the present investigation. One part of the field moist soil samples was preserved in refrigerator for estimation of soil biological parameters. The rest of the soil samples were air-dried, ground and passed through 2 mm sieve and preserved for subsequent analysis of soil physicochemical properties.

3.5. Soil analysis

Soil physico-chemical and biological properties along with organic carbon fractions of soils under different land uses were evaluated following standard procedures. All the laboratory analysis were done in the department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University following standard analytical procedures, except TOC ; which was analysed at



Timing of sampling : May, August and November, 2018

Number of composite samples from each village : 3(land uses) x 3(sites) x 2(depth) = 18

Number of composite samples in each sampling : 8(villages) x 18 = 144

Total number of composite samples in three samplings: 3 x 144 = 432

Fig 3.4. Detail of sampling

central instrumentation lab, ICAR Research Complex for NEH Region, Barapani using TOC analyser. The different standard analytical procedures used in the present investigation are briefed below:

pH:

The soil pH was determined in 1: 2.5 soil: water suspension using glass electrode pH meter as described by Jackson (1973).

Mechanical analysis:

Air dried and processed samples were analyzed for particle-size distribution (sand, silt and clay) following International Pipette method (Piper, 1966) using 0.5 *N* NaOH as a dispersing agent. Hydrogen peroxide was used to dissolve the organic matter in the soil. After obtaining the percentage sand, silt and clay; textural classes were obtained using textural triangle.

Bulk density and Particle density:

Bulk density of the soil was obtained by dividing weight of soil by volume of soil as outlined by Chopra and Kanwar (1991). Particle density of soil was determined by pycnometer method as described by Sharma (2011). Both the densities of the soil were expressed in Mg m^{-3}.

Water holding capacity:

The water holding capacity was determined using Keen Rackzowaski boxes as described by Piper (1966). Water holding capacity was expressed in percentage (%).

Porosity:

Total porosity of the soil was calculated from the bulk density and particle density values using the formula below:

Porosity (%) = (1-bulk density/particle density) x 100

Available nitrogen:

Available nitrogen content in the soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) in ‘Kel Plus’ nitrogen distillation machine. Available nitrogen content was expressed in kg ha^{-1}.

Available phosphorus:

Available phosphorus content in soil was determined by Bray's I method as illustrated by Bray and Kurtz (1945) using 0.03*N* NH_4F + 0.025*N* HCl (pH 3.5) as extracting solution. In the filtered extract, phosphorus was estimated colorimetrically by adding ammonium molybdate and stannous chloride. The intensity (% transmittance) of characteristics blue colour in the solution gives the measure for the concentration of P in the test solution, which was read in the spectrophotometer at 660 nm wavelength. After getting % transmittance of the P in the test solution, concentration of P was read from the standard curve. Available phosphorus content was expressed as P_2O_5 kg ha^{-1}.

Available potassium:

Available potassium content in soil was determined by neutral normal ammonium acetate method (Jackson, 1973). Neutral normal NH_4OAc (pH= 7.0) was used as equilibrium solution to exchange the exchangeable K ions of the soil. In the filtered extract, K was determined using flame photometer. Available potassium content in the soil solution was converted to and expressed as available K_2O kg ha^{-1}.

Available sulphur:

Available sulphur was determined by turbidimetric method as illustrated by Chesnin and Yien (1951). Sulphate was extracted from soil sample by monocalcium phosphate solution. In the filtered extract, after adding 25% HNO_3 and acetic phosphoric acid, sulphur was determined by adding barium sulphate seed suspension, barium chloride crystals and gum acacia. The intensity of turbidity produced in the sample solution was measured by spectrophotometer at 440 nm wavelength. Available sulphur content in soil was expressed in kg ha^{-1}.

Exchangeable calcium and magnesium:

Exchangeable Ca and Mg were determined through versenate method (Richards, 1954). Soil extract is titrated with standard 0.01*N* versenate (EDTA, ethylene diamine tetra acetic acid disodium salt) using murexide indicator in presence of NaOH solution.

Similarly, erichrome black T indicator was used to determine Ca+Mg in soil extract in presence of ammonium chloride and ammonium hydroxide buffer while titrating with 0.01*N* EDTA. Thereafter, exchangeable Mg was determined by subtracting Ca content from Ca+Mg content. Exchangeable Ca and Mg were expressed in cmol (P^+) kg^{-1}.

Microbial biomass carbon:

Microbial biomass carbon (MBC) was determined by fumigation extraction method as described by Vance *et al.* (1987). Ethanol free chloroform was used to fumigate the fresh soil samples in vacuum desiccator. After 24 hrs, vacuum was released and fumigated soil samples along with their non-fumigated counterparts were extracted with 0.5*M* K_2SO_4. The filtered extract was titrated against 0.005 *N* ferrous ammonium sulphate after adding $K_2Cr_2O_7$, conc. H_2SO_4 and conc. H_3PO_4 in presence of diphenylamine indicator. Thereafter, total weight of extractable carbon in fumigated and non-fumigated soil samples were calculated out. MBC was calculated by using the following formula:

$$MBC\ (\mu g\ g^{-1}\ soil) = E_{CF}\text{-}EC_{NF} / K_{EC}$$

Where,

E_{CF} = Total weight of extractable C in fumigated soil sample

EC_{NF} = Total weight of extractable C in non-fumigated soil sample

K_{EC} = Calibration factor ~ 0.38

Dehydrogenase enzyme activity:

Dehydrogenase enzyme activity (DHA) was determined by 2-3-5-triphenyl tetrazolium chloride reduction technique as illustrated by Casida (1977). For determination of DHA, soil sample (10 g) was mixed with 0.1g $CaCO_3$ and then, the mixture was divided into three parts (each part weighed 3 g) and transferred to three screw cap flat bottom test tubes (15 ml capacity). To each test tube 0.5 ml of 1% 2, 3, 5-triphenyl tetrazolium chloride (TTC) and 1.25 ml of distilled water were added and mixed thoroughly by gentle tapping and incubated at 37 °C for 24 hour. The soil suspension was filtered through glass funnel fitted with absorbent cotton. Methanol was added to extract the soil suspension until the colour of the cotton plug became white and the final volume was made up to 50 ml. Intensity of reddish colour was measured by using spectrophotometer at 485 nm wavelength. The concentration of triphenyl formazan (TPF) in the supernatant was determined against a standard graph prepared using known concentrations of TPF. The DHA was expressed as μg TPF g^{-1} h^{-1}.

Acid phosphatase activity:

Acid phosphatase activity (PHA) was determined by *p*-nitrophenyl phosphate method (Tabatabai and Bremner, 1969). One gram soil was taken in a conical flask and 4 ml of Modified Universal Buffer (pH 6.5), 0.25 ml of toluene and 1ml of *p*-nitrophenyl phosphate were added to the soil and incubated at 37 °C for 1 hour. After incubation, 1 ml of 0.5 *M* $CaCl_2$ + 4 ml 0.5 *M* NaOH were added to the soil suspension and filtered. Intensity of yellow colour was measured in the filtrate at 400 nm wavelength using spectrophotometer. The concentration of *p*-nitrophenol in the filtrate was determined against a standard curve prepared by using *p*-nitrophenol standard solution. PHA was expressed as μg PNP g^{-1} h^{-1}.

β -glucosidase enzyme activity:

β-glucosidase enzyme activity (GSA) was determined following procedure as illustrated by Dick *et al.* (1996). For determination GSA, 1 g soil was incubated with 0.25 ml toluene, 4 ml Modified Universal Buffer (pH 6.0) solution, 1 ml *p*-nitrophenyl- β -D-glucoside (PNG) at 37 °C for 1 hour. After incubation, 1 ml of 0.5 *M* $CaCl_2$ + 4 ml 0.1 *M* THAM buffer (pH 12.0) were added to the soil suspension and filtered using Whatman No. 2 filter paper. Intensity of yellow colour was measured in the filtrate at 400 nm using spectrophotometer. The concentration of *p*-nitrophenol in the filtrate was determined against a standard curve prepared by using *p*-nitrophenol standard solution. The activity of GSA was expressed as μg PNP g^{-1} h^{-1}.

Bacterial population:

Serial dilution plate count method (Johnson and Curl, 1972) was employed to enumerate the population bacteria in the soil. The nutrient agar medium was used for isolation of bacteria. One gram soil sample was first transferred to serial dilution tube containing 9 ml of sterile water. Thereafter, from that tube, 1 ml of homogenous soil water suspension was serially diluted upto 10^5 dilution. From that dilution, 0.1 ml of soil water suspension was transferred, spread uniformly and inoculated in nutrient agar plates. The inoculated plates were incubated at 30±1°C for 24 h in BOD incubator. The colony of bacteria were counted using colony counter and expressed in cfu x 10^5 g^{-1} soil on dry weight basis.

Soil basal respiration:

Soil basal respiration (SBR) was determined in a laboratory incubation experiment taking the soils from different LUS collected in different seasons in order to study the carbon mineralization pattern. Alkali entrapment method (Anderson, 1982) was employed for determining SBR. Forty gram of fresh soil sample was taken in 500 ml conical flask for incubation study. Each sample was wetted to 50% water-filled pore space and alkali traps consisting of 10 ml of 1*N* NaOH were placed in each conical flask. After that, the conical flasks were corked tightly with rubber cork. Vacuum grease was smeared around the rubber cork to ensure proper sealing. The samples were incubated at room temperature for 8 weeks. The alkali traps were replaced at 7, 14, 21, 28, 35, 42, 49 and 56 days and titrated with acid. Unreacted alkali in the NaOH traps was back-titrated with 1 *N* HCl using phenolphthalein indicator to determine CO_2-C. The C mineralized from soils equals the amount of CO_2 evolved in 7 days interval as measured from titration. The cumulative amount of carbon mineralization was calculated out by adding up amount of CO_2-C evolved in each weekly titration upto 8 weeks (56 days). SBR was expressed in μg CO_2-C g^{-1} h^{-1}.

Organic carbon:

Organic carbon (OC) in soil was determined by wet oxidation method (Walkley and Black, 1934). Potassium dichromate ($K_2Cr_2O_7$) and conc. H_2SO_4 were used to oxidize organic matter in soil. The excess of $K_2Cr_2O_7$ not reduced by organic matter of soil is determined by back titration with standard ferrous ammonium sulphate in presence of diphenylamine indicator. OC content in soil was expressed in g kg^{-1}.

Total organic carbon:

TOC was determined by wet oxidation method as described by Snyder and Trofymow (1984). TOC was determined in 'Vario TOC analyzer', that measures total carbon (TC), total organic carbon (TOC) and total inorganic carbon (TIC) for both solid and liquid samples by differential method (TOC= TC-TIC). IR detector was used in the instrument while determining TOC of the soil samples. 10-15 mg of soil samples were injected into the combustion tube which was enriched with synthetic air (O_2). Carbon in the sample was converted into CO_2 at 950°C in presence of catalyst (CuO_2). Carrier gas carries the CO_2 to the detector tube and thus TOC was determined. The %TOC was converted and expressed in g kg^{-1}.

Permanganate oxidizable carbon:

Permanganate oxidizable carbon (POXC) was determined by the procedure as described by Blair *et al.* (1995). Five gram air dried soil was taken in a 150 ml conical flask, 20 ml 0.01*M* $KMnO_4$ solution was added to it, followed by 0.3 g $CaCl_2$ (equivalent to 0.1*M* $CaCl_2$ in 20 ml) to increase the settling of soil. The soil-$KMnO_4$-$CaCl_2$ suspension was shaken at 200 rpm for 5 min. After shaking the suspension was centrifuged at 3000 rpm for 5 min. and filtered. The bleaching of colour of $KMnO_4$ was measured by spectrophotometer at 550 nm wavelength. The standard curve was prepared with 0.0, 0.0001, 0.0002, 0.0004 and 0.00075*M* $KMnO_4$ solutions. The bleaching of the purple $KMnO_4$ colour is proportional to the amount of oxidisable C in soil. To estimate the amount of C oxidized, it was assumed according to Blair *et al.* (1995) that 1*M* MnO_4^- is consumed (reduced from Mn^{7+} to Mn^{4+}) in the oxidation of 0.75*M* (9000 mg) of C. Hence, active carbon / labile carbon were calculated using the formula below:

Active C (mg/kg) = [0.01mol/L – (a + b x absorbance)] x (9000 mg C/mol) x (0.02 L solution/0.005 kg soil)

Where, 0.01mol/L is the initial concentration of $KMnO_4$, 'a' is the intercept and 'b' is the slope of the standard curve. The numerical value 0.005 is the amount of soil in kg on oven dry basis. 0.02 L is the volume of $KMnO_4$ reacting with the sample. The POXC was converted and expressed in g kg^{-1}.

3.6. Carbon stock

Soil carbon stock for each depth was estimated by multiplying with corresponding values of bulk density and SOC content. SOC stock was calculated following the formula given by Intergovernmental Panel on Climate Change (IPCC) (2003).

SOC stock = SOC x BD x D x 10

Where,

SOC stock = C stock for the soil of interest (Mg ha^{-1}).

SOC = Concentration of soil organic carbon in a given soil mass (g kg^{-1}).

BD =Bulk density, soil mass per sample volume (Mg m^{-3}).

D = Sampling depth (m).

3.7. Carbon management index (CMI)

The computation of carbon management index (CMI) is based on labile carbon (C_L) and a non-labile carbon (C_{NL}) component. C_{NL} is being calculated as the difference between total carbon and C_L. Computation of CMI was done considering forest LUS as reference.

The CMI was computed according to the formula given by Blair *et al.* (1995) as follows:

$$CMI = CPI \times LI \times 100$$

$$CPI = \frac{\text{Total C of soil sample (g kg}^{-1}\text{)}}{\text{Total C of reference soil sample (g kg}^{-1}\text{)}}$$

$$L = \frac{\text{Carbon fraction oxidized by } KMnO_4}{\text{Carbon fraction unoxidized by } KMnO_4}$$

$$LI = \frac{\text{Lability of C in the sample}}{\text{Lability of C in reference soil}}$$

Where, CMI= carbon management index, CPI= carbon pool index, LI= lability index and L= lability of carbon

While calculating CMI, the following steps were systematically followed:

(1) $$CPI = \frac{\text{Total carbon in treatment (pineapple/paddy) (g kg}^{-1}\text{)}}{\text{Total carbon in forest (g kg}^{-1}\text{)}}$$

(2) $$\text{L in treatment} = \frac{\text{Labile C (POXC) in treatment (g kg}^{-1}\text{)}}{\text{Non-labile C (TC- POXC) in treatment (g kg}^{-1}\text{)}}$$

$$(3)\ \text{L in reference} = \frac{\text{Labile C (POXC) in reference (forest) (g kg}^{-1}\text{)}}{\text{Non-labile C (TC- POXC) in reference (forest) (g kg}^{-1}\text{)}}$$

$$(4)\ \text{LI} = \frac{\text{L in treatment (2)}}{\text{L in reference (3)}}$$

(5) CMI = CPI (1) x LI (4) x 100

3.8. Statistical analysis

Pearson's correlation analysis was carried out using SPSS software (version 23.0). All the variables of soil quality including soil physico-chemical, biological and carbon fractions measured in the study were subjected to correlation analysis. One way ANOVA and Duncan's multiple range test (DMRT) for comparison of means with LUS as factor was carried out to assess the significance of difference in soil quality attributes among LUS under study in different seasons. To determine pair-wise differences by post hoc test, the data were submitted to one way ANOVA for each season. Post hoc test was carried out at 0.05 level of significance through out.

3.9. Geospatial analysis of carbon fractions and carbon stock

The spatial coordinates which were recorded with Global Positioning System (GPS) of each of the acquired samples were converted to decimal degrees (CSV) and transferred to ArcGIS 10.8.1 software. Subsequently, the spatial coordinates was transformed to Universal Transverse Mercator (UTM) zone 46R. The spatial distribution of carbon fractions including OC, TC, POXC and carbon stock was evaluated using spatial analysis tools in ArcGIS 10.8.1 software using Inverse Distance Weighted (IDW) interpolation method.

IDW is a spatial deterministic interpolation explicitly makes the assumption that the things those are close to one another are more alike than those that are further apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the predicted location. The measured values closest to the prediction location have more influence on the predicted value than those farther away. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance. Hence, the name is Inverse Distance Weighted (IDW). The basic premise in the IDW is that, for the determination of the unknown point, the closest points have much more influence than those away from it. During the year 1965, Howard Fisher came up with an improved computer mapping program which was called as SYMAP (Synergistic Mapping) to improve interpolation where Donald Shepard further decided to investigate the interpolation in SYMAP, resulting in his famous article from 1968. The IDW interpolating function as defined by Donald Shepard is:

$$Z(x) = \Sigma^{n}_{i=1} W_i Z_i / \Sigma^{n}_{i=1} W_i$$

And $W_i = d_i^{-u}$

Where, Z (x) is the predicted value at an interpolated point; Zi is the value at a known point; n is the total number of known points used in interpolation; di is the distance between point i and the prediction point; Wi is the weight assigned to point i ; and u is the weighing power that decides how the weight decreases as the distance increases. The spatial reference (x and y coordinates) of each of the acquired sampled points were used as the known sample point location to interpolate the unknown points. Therefore the carbon parameters of known points will stand as the Z value for the determination of the unknown points.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1. Physico-chemical properties of soil under different land uses

Soil pH:

Soils from different land use systems were analyzed for various physico-chemical properties *viz.* pH, texture, bulk density, particle density, porosity and water holding capacity. The pH of soils under paddy land use was found highest (4.95) followed by forest (4.84) and pineapple (4.65) land use irrespective of seasons and depth of sampling (Table 4.1 a). The range of pH varied from 4.33–5.28; 4.20–5.20 and 4.67–5.17 in case of forest, pineapple and paddy land uses respectively. The pH of soils increased with depth in all the land uses. During monsoon season, slight reduction in pH values was recorded compared to pre-monsoon and post-monsoon season for all the three different land uses in both the depths (Table 4.1 b).

The high pH value in paddy land uses may be because of reduction of Fe and Mn oxides to Fe^{2+} and Mn^{2+} under submerged condition of lowland paddy which consumes H^{+} ions. The increase in pH at 0.25 to 0.50 m depth can be attributed to leaching of bases with percolating water to the sub-surface soil layer. The presence of bases in the sub-surface layer might have increased the pH of soils under different land uses in all the seasons. High microbial activities in the monsoon season compared to pre and post-monsoon season might have facilitated the decomposition of organic matter and release of some organic acids, thus resulted in temporary drop in pH of soils under different land use systems.

The findings of Fageria *et al.* (2011) support the result of the present investigation where it was mentioned that the pH of acidic soils increased and alkaline soils decreased because of flooding. The main changes occur in

Table 4.1 (a). pH of soils in relation to land use, sampling time and depth

Sl No.	Name of village	pH (1: 2.5)																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	5.00	4.80	4.90	5.28	4.97	5.10	4.83	4.57	4.70	5.00	4.80	4.80	5.03	4.98	5.03	5.17	5.06	5.10
2	Jharnapani	4.90	4.62	4.75	5.20	4.83	4.97	4.73	4.35	4.57	4.92	4.55	4.73	4.87	4.76	4.89	5.01	4.93	5.03
3	Khaibung	4.80	4.50	4.67	5.10	4.64	4.90	4.69	4.31	4.40	4.87	4.50	4.63	4.89	4.84	4.90	5.03	4.96	5.03
4	Kukidolong	4.77	4.37	4.53	5.07	4.63	4.80	4.67	4.23	4.37	4.85	4.43	4.63	4.83	4.68	4.79	5.00	4.92	4.96
5	Kupuhe	4.76	4.33	4.43	5.07	4.61	4.77	4.65	4.20	4.33	4.83	4.39	4.60	4.76	4.67	4.73	5.00	4.77	4.91
6	Maova	4.87	4.57	4.70	5.13	4.76	4.93	4.70	4.33	4.47	4.90	4.53	4.68	4.92	4.89	4.92	5.07	4.97	5.05
7	Medziphema	4.90	4.65	4.77	5.23	4.87	5.00	4.77	4.42	4.60	4.93	4.59	4.77	4.97	4.92	4.97	5.10	5.00	5.06
8	Molvom	4.97	4.70	4.83	5.25	4.94	5.07	4.97	4.65	4.80	5.20	4.83	4.97	5.00	4.93	5.00	5.13	5.03	5.07
Average *(ST)		**4.87**	**4.57**	**4.70**	**5.17**	**4.78**	**4.94**	**4.75**	**4.38**	**4.53**	**4.94**	**4.58**	**4.73**	**4.91**	**4.83**	**4.90**	**5.06**	**4.96**	**5.03**
Range (Depth)		4.33–5.00			4.61–5.28			4.20–4.97			4.39–5.20			4.67–5.03			4.77–5.17		
Average (Depth)		**4.71**			**4.96**			**4.55**			**4.75**			**4.88**			**5.02**		
Range **(LU)		4.33–5.28						4.20–5.20						4.67–5.17					
Average (LU)		**4.84**						**4.65**						**4.95**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.1 (b). Variation in pH under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	4.87^{a}	5.17^{a}	4.57^{a}	4.78^{a}	4.70^{a}	4.94^{a}
2	Pineapple	4.75^{b}	4.94^{b}	4.38^{b}	4.58^{b}	4.53^{b}	4.73^{b}
3	Paddy	4.91^{ac}	5.06^{c}	4.83^{c}	4.95^{c}	4.90^{c}	5.03^{ac}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

flooded or waterlogged rice soils are decreases in oxidation-reduction or redox potential and increases in iron (Fe^{2+}) and manganese (Mn^{2+}) concentrations because of the reductions of Fe^{3+} to Fe^{2+} and Mn^{4+} to Mn^{2+}. The findings of the present study is also in conformity with the Kizilkaya and Dengiz (2010) who have reported that soil pH tends to increase in the cultivated lands. They have reported significant variation in soil pH values of the natural forest, pasture and cultivated lands with less pH under natural forest and pasture soils. They also have reported slight increase in pH with increase in soil depths due to accumulation of basic cations.

Salim *et al*. (2015) also revealed the least pH values under natural forest because of high organic matter content and undisturbed nature of the natural forest soils as compared to plantation and grassland. The accumulation of plant litters and high amount of humus in forest soils is responsible for decrease in soil pH through slow decomposition. Soils become more acidic (the minimum pH was recorded in rainfall season) because of warm temperature and high rainfall as under such conditions, soils quickly weather and basic cations are leached from soil profile, leaving behind more stable materials rich in Fe and Al oxides.

The present findings deviate from the findings of Sahu *et al*. (2016) who has reported maximum pH under forest lands and minimum in rice fields. However, their findings in regard to low pH values during monsoon season compared to pre and post-monsoon season under different land uses support the present findings.

Soil texture (percent sand, silt and clay):

Mechanical analysis of soil samples collected during pre-monsoon season was done following international pipette method (Table 4.2 a). Soil textural classes were determined with the help of textural triangle. Analysis revealed that the soils of different land uses under study were mostly of ‘loam’ texture. While soils of forest lands were ‘sandy clay loam’ and ‘sandy loam’;

soils of pineapple land use were found mostly as ‘sandy clay loam’ and ‘clay loam’ in their textural class. However, dominant textural class of soils of paddy land use was ‘clay loam’ with few sampling sites exhibiting ‘sandy clay loam’ textural class. Sand content was found comparatively high in soils of forest, whereas silt and clay particles were found more under paddy land use. Increased amount of clay content at sub-surface soil was recorded for different land uses compared to surface soil layer, maximum amount of clay (33.70%) being recorded in sub-surface soils under paddy LUS followed by pineapple LUS (31.97%). However, difference in clay content of pineapple and paddy LUS was found non-significant at both the depths (Table 4.2 b). Variation in silt content at both the depth for different LUS was also found non-significant.

The ‘loam’ nature of soils under different land uses under study probably indicates the homogeneity of soil forming process and similarity of parent materials in the study sites. However, soil forming processes like erosion, illuviation, eluviations and weathering may have changed the particle size distribution affecting soil textural class under different land uses. The higher clay fraction in soil under paddy cultivation may be due to the high intensity weathering associated with shearing and pulverization of soils compared to forest and pineapple land use. Possible translocation of clay to the sub-surface soil layer may be the reason for high clay content in the sub-surface soil layers.

Similar results were reported by Moges *et al*. (2013). From a study on effect of land uses on soil quality indicators, they have reported high mean clay fraction under farm land followed by open grazing lands and the least in the protected forest land. They have also reported higher clay content in the 10–20 cm soil layers across all land use types. The result of this study was also in conformity with Jiao *et al*. (2020) who reported high sand content in forest land uses while studying variation of soil organic carbon and physical properties in relation to land uses in the Yellow River Delta, China.

Table 4.2 (a). Particle size distribution of the soils in relation to land use and depth (pre-monsoon)

Sl No.	Name of village	Particle size (%)																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
1	Bungsung	47.93	25.00	27.07	51.33	20.30	28.37	48.18	18.70	33.12	48.51	16.80	34.69	31.88	33.33	34.81	33.62	32.27	34.11
2	Jharnapani	50.76	29.58	19.67	50.58	29.74	19.68	46.01	21.33	32.67	46.18	20.17	33.67	38.03	22.64	39.33	37.98	22.72	39.32
3	Khaibung	51.67	22.16	26.17	48.73	25.36	25.91	41.01	26.40	32.60	44.67	24.33	31.00	42.50	24.07	33.45	42.72	22.35	34.94
4	Kukidolong	52.65	26.95	20.40	52.69	26.99	20.32	49.37	22.80	27.83	49.67	20.33	30.00	46.70	23.68	29.66	43.33	25.01	31.67
5	Kupuhe	50.00	18.67	31.33	50.13	17.75	32.12	40.34	33.00	26.66	37.66	29.69	32.67	35.03	32.34	32.65	32.26	33.67	34.08
6	Maova	51.35	28.82	19.82	50.67	29.83	19.50	49.39	23.32	27.29	48.69	20.33	31.00	51.21	22.15	26.67	50.67	20.51	28.83
7	Medziphema	47.34	19.24	33.43	50.78	16.52	32.70	39.01	27.32	33.67	48.03	22.67	29.35	37.38	28.50	34.13	34.68	30.99	34.33
8	Molvom	51.16	18.34	30.50	49.03	19.93	31.03	39.83	30.79	29.38	41.66	25.00	33.36	44.74	22.41	32.87	43.67	23.99	32.34
Average *(PS)		**50.36**	**23.60**	**26.05**	**50.49**	**23.30**	**26.20**	**44.14**	**25.46**	**30.40**	**45.63**	**22.42**	**31.97**	**40.93**	**26.14**	**32.95**	**39.87**	**26.44**	**33.70**
Textural class		Sandy clay loam/ Sandy loam			Sandy clay loam/ Sandy loam			Clay loam/ sandy clay loam			Clay loam/ sandy clay loam			Clay loam/ sandy clay loam			Clay loam/ sandy clay loam		

*PS : Particle size **LU: Land use

Table 4.2 (b). Variation in particle size distribution (%) under different land use systems in pre-monsoon season

Sl No.	Land use	Sand		Silt		Clay	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	50.36^{a}	50.49^{a}	23.60^{a}	23.30^{a}	26.05^{a}	26.20^{a}
2	Pineapple	44.14^{b}	45.63^{b}	25.46^{a}	22.42^{a}	30.40^{ab}	31.97^{b}
3	Paddy	40.93^{bc}	39.87^{c}	26.14^{a}	26.44^{a}	32.95^{bc}	33.70^{bc}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

Findings of present investigation is in close conformity with the findings of Dutta *et al*. (2017) where they have revealed the textural class of soils under lowland LUS as 'clay' to 'clay loam' and orchard as 'sandy clay loam' while studying the erodibility status of soils under different land uses in Chiephobozou sub-division of Kohima district, Nagaland.

The findings of Kizilkaya and Dengiz (2010) also supports the results of present investigation in which they have reported high clay content in cultivated land compared to forest and pasturelands. Similarly, Jaiyeoba (2003) revealed higher clay contents at deeper depths with the increase of cultivation year.

Bulk density:

Bulk density (BD) of forest LUS was recorded minimum (1.21Mg m^{-3}) and maximum BD in paddy LUS (1.41Mg m^{-3}) irrespective of seasons and depths (Table 4.3 a). Bulk density ranged from 1.14–1.30 Mg m^{-3}; 1.17–1.38 Mg m^{-3}; 1.31–1.53 Mg m^{-3} in forest, pineapple and paddy LUS respectively. Seasonal variation of bulk density, indicated minimum values in post-monsoon season, followed by increased values in pre-monsoon season which was further increased in monsoon season. The same trend of seasonal change in BD was observed in all three LUS. Significantly minimum values of BD was recorded in forest LUS (1.17 and 1.20 Mg m^{-3}) followed by higher BD (1.21 and 1.25 Mg m^{-3}) in pineapple and maximum in paddy LUS (1.34 and 1.37 Mg m^{-3}) during post-monsoon season at surface and sub-surface soil, respectively (Table 4.3 b). Higher values of BD were obtained in the sub-surface soils compared to surface soil layers for all LUS under study.

Bulk density has an inverse relation with organic carbon or organic matter content and directly related to soil compaction. It typically increases with soil depth since sub-surface layers are more compact and have less organic matter. The highest bulk density value in paddy LUS may be due to compaction induced by the puddling action under low land paddy fields. Low

Table 4.3 (a). Bulk density of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	BD (Mg m^{-3})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	1.17	1.19	1.14	1.19	1.23	1.18	1.24	1.27	1.19	1.27	1.32	1.23	1.36	1.40	1.31	1.38	1.48	1.35
2	Jharnapani	1.19	1.21	1.17	1.21	1.26	1.20	1.24	1.28	1.21	1.28	1.33	1.24	1.39	1.46	1.35	1.42	1.52	1.38
3	Khaibung	1.20	1.21	1.17	1.21	1.27	1.21	1.27	1.30	1.22	1.30	1.35	1.26	1.38	1.45	1.34	1.41	1.51	1.38
4	Kukidolong	1.20	1.23	1.19	1.23	1.28	1.21	1.27	1.32	1.23	1.32	1.37	1.29	1.40	1.48	1.35	1.42	1.52	1.39
5	Kupuhe	1.21	1.25	1.20	1.25	1.30	1.22	1.28	1.35	1.23	1.32	1.38	1.30	1.40	1.50	1.38	1.42	1.53	1.41
6	Maova	1.20	1.21	1.17	1.21	1.26	1.20	1.26	1.29	1.22	1.29	1.34	1.24	1.37	1.44	1.33	1.41	1.50	1.37
7	Medziphema	1.18	1.20	1.16	1.20	1.24	1.19	1.24	1.28	1.20	1.28	1.33	1.23	1.36	1.43	1.33	1.40	1.49	1.36
8	Molvom	1.17	1.20	1.15	1.20	1.24	1.19	1.23	1.26	1.17	1.26	1.31	1.22	1.36	1.42	1.32	1.39	1.49	1.35
Average*(ST)		**1.19**	**1.21**	**1.17**	**1.21**	**1.26**	**1.20**	**1.25**	**1.29**	**1.21**	**1.29**	**1.34**	**1.25**	**1.38**	**1.45**	**1.34**	**1.41**	**1.51**	**1.37**
Range (Depth)		1.14–1.25			1.18–1.30			1.17–1.35			1.22–1.38			1.31–1.50			1.35–1.53		
Average (Depth)		**1.19**			**1.22**			**1.25**			**1.29**			**1.39**			**1.43**		
Range **(LU)		1.14–1.30						1.17–1.38						1.31–1.53					
Average (LU)		**1.21**						**1.27**						**1.41**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post- monsoon

Table 4.3 (b). Variation in bulk density (Mg m^{-3}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	1.19^{a}	1.21^{a}	1.21^{a}	1.26^{a}	1.17^{a}	1.20^{a}
2	Pineapple	1.25^{b}	1.29^{b}	1.29^{b}	1.34^{b}	1.21^{b}	1.25^{b}
3	Paddy	1.38^{c}	1.41^{c}	1.45^{c}	1.51^{c}	1.34^{c}	1.37^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

organic carbon content in paddy LUS may be another reason for high bulk density. Reverse is in the case with forest and pineapple LUS. High organic carbon content in forest and pineapple LUS might have increased the porosity and reduced the soil compaction resulting in low BD under these two LUS. Increase in BD at sub-surface soil layers may also be accounted for lower organic carbon content at 0.25–0.50 m depth. Relatively high organic carbon content in the post-monsoon season might be the reason for corresponding decrease in BD values in that particular season compared to pre-monsoon and monsoon season under different land uses.

The results of the present research is in conformity with Fageria *et al*. (2011) who opined that in compacted soil, bulk density, microvoids, thermal conductivity and diffusivity increases. Kizilkaya and Dengiz (2010) also put forward similar opinion that the reduction in organic matter by conversion of natural forest into pasture and cultivated land caused high BD in cultivated soil.

Moges *et al*. (2013) also reported similar findings where they have revealed high BD in lower soil layers than top surface soil indicating the tendency of bulk density to increase with depth due to the effects of weight of the overlying soil and the decrease in soil organic matter content in sub-surface soil.

Similar research findings were reported by Jiao *et al*. (2020), where it was stated that arable lands exhibit high BD which might be the result of combined influence of the ploughing in tillage layer, roots distribution and decreased SOC and soil aggregation augmented by repeated events of sowing and harvesting.

Particle density:

Particle density (PD) of soils followed almost similar trend with that of BD as maximum particle density was recorded under paddy LUS> forest LUS > pineapple LUS with the average values of 2.64, 2.45 and 2.42 Mg m^{-3} under paddy, forest and pineapple LUS respectively. Higher values of PD were recorded at sub-surface soil layers for paddy and pineapple LUS. The lower PD values at sub-surface layers compared to surface soil for forest LUS couldn't be justified though (Table 4.4 a). Minimum PD values for different LUS were observed during post-monsoon season compared to pre-monsoon and monsoon season soil samples. During post-monsoon season, the values of PD was 2.49 and 2.41 Mg m^{-3} for forest , 2.34 and 2.42 Mg m^{-3} for pineapple and 2.58 and 2.63 Mg m^{-3} for paddy at 0–0.25 m and 0.25–0.50 m depth respectively. The variation in PD under different LUS was significant during pre-monsoon season (Table 4.4 b); however, in monsoon and post-monsoon season, significant difference in PD between pineapple and paddy LUS was not recorded.

There exists a direct relationship between soil BD and PD. That may be the reason of increase or decrease in PD with the corresponding increase or decrease in BD under different LUS. High organic carbon content under pineapple and forest LUS may be the cause of low PD under these LUS compared to paddy LUS where organic carbon content was low. High soil organic carbon content during post-monsoon season due to lesser decomposition owing to the low temperature may be ascribed for low PD of soils during that season. Low organic matter accumulation and soil organic carbon content in sub-surface soil layer can also be related to high PD at sub-surface soil. The findings are in close conformity with Jiao *et al*. (2020) who have revealed that soil bulk density (BD) is a function of soil particle size, aggregate stability and soil particle density. Decrease of SOM would cause the increase of BD and hence PD.

Porosity and water holding capacity:

Porosity of soils was found maximum under forest LUS (50.28%) followed by pineapple LUS (47.46%) and paddy LUS (46.40%) with a range of 45.92% –54.39% in forest, 44.94%–49.58% in pineapple and 42.01%– 49.56% in paddy LUS irrespective of depth and season of sampling (Table 4.5 a).

Table 4.4 (a). Particle density of soils in relation to land use, sampling time and depth

Sl No.	Name of village	PD (Mg m^{-3})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	2.42	2.33	2.43	2.33	2.37	2.33	2.34	2.33	2.29	2.38	2.49	2.36	2.45	2.59	2.45	2.50	2.55	2.47
2	Jharnapani	2.48	2.40	2.47	2.38	2.41	2.39	2.35	2.37	2.33	2.45	2.53	2.42	2.69	2.71	2.66	2.70	2.71	2.67
3	Khaibung	2.50	2.42	2.52	2.42	2.44	2.41	2.39	2.43	2.36	2.50	2.56	2.43	2.68	2.70	2.65	2.67	2.70	2.66
4	Kukidolong	2.50	2.44	2.54	2.44	2.46	2.47	2.39	2.45	2.37	2.52	2.58	2.46	2.70	2.73	2.67	2.70	2.73	2.70
5	Kupuhe	2.61	2.46	2.54	2.46	2.49	2.49	2.51	2.61	2.43	2.56	2.64	2.48	2.70	2.74	2.69	2.71	2.75	2.70
6	Maova	2.50	2.42	2.51	2.41	2.42	2.40	2.37	2.40	2.34	2.50	2.55	2.42	2.65	2.67	2.60	2.67	2.70	2.66
7	Medziphema	2.45	2.37	2.46	2.35	2.37	2.39	2.35	2.34	2.32	2.42	2.52	2.41	2.50	2.63	2.48	2.66	2.69	2.65
8	Molvom	2.42	2.36	2.45	2.33	2.37	2.38	2.31	2.32	2.27	2.35	2.49	2.35	2.48	2.61	2.47	2.55	2.66	2.53
Average *(ST)		**2.49**	**2.40**	**2.49**	**2.39**	**2.42**	**2.41**	**2.38**	**2.41**	**2.34**	**2.46**	**2.55**	**2.42**	**2.61**	**2.67**	**2.58**	**2.65**	**2.69**	**2.63**
Range (Depth)		2.33–2.61			2.33–2.49			2.27–2.61			2.35–2.64			2.45–2.74			2.47–2.75		
Average (Depth)		**2.46**			**2.40**			**2.37**			**2.47**			**2.62**			**2.65**		
Range **(LU)		2.33–2.61						2.27–2.64						2.45–2.75					
Average (LU)		**2.43**						**2.42**						**2.64**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.4 (b). Variation in particle density (Mg m^{-3}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	2.49^{a}	2.39^{a}	2.40^{a}	2.42^{a}	2.49^{a}	2.41^{a}
2	Pineapple	2.38^{b}	2.46^{b}	2.41^{ab}	2.55^{b}	2.34^{b}	2.42^{ab}
3	Paddy	2.61^{c}	2.65^{c}	2.67^{c}	2.69^{c}	2.58^{c}	2.63^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

Increase in percent pore space was recorded during post-monsoon season in all the three LUS. Significantly higher porosity was recorded in forest (52.96% and 50.16%) followed by pineapple (48.59% and 47.91%) and paddy (48.16% and 47.74%) LUS at surface and sub-surface soil respectively during post-monsoon season (Table 4.5 b). However, the variation in porosity of pineapple and paddy LUS was found non-significant during that particular season. Percent pore space decreased with depth.

Water holding capacity (WHC) also followed the similar trend where highest average value of WHC was recorded in forest (45.35%) followed by pineapple (41.28%) and least was recorded in paddy (40.0%) LUS. WHC of soils under different LUS decreased during monsoon season compared to pre- and post-monsoon season (Table 4.6 a). Significantly higher values of WHC were recorded in case of forest (47.27% and 45.24%) followed by pineapple (42.86% and 41.84%) followed by paddy (41.98% and 41.28%) in surface and sub-surface soil layers during post-monsoon season (Table 4.6 b). The variation in WHC between pineapple and paddy LUS was however non-significant during post-monsoon season in both the depths.

Increase in porosity and corresponding increase in WHC can be related to increase amount of organic carbon content and decrease in BD of soil. The findings of the present research indicated the same. Higher organic carbon content in forest LUS along with low BD may be the reason for high porosity and WHC of forest soils. Variation in seasonal accumulation of organic matter and differential organic carbon content may be the reason of difference in porosity and WHC in different sampling seasons.

The findings of Jiao *et al.* (2020) support the present findings. According to this group of scientists, soil bulk density and porosity are functions of SOM, soil particle size and aggregate stability and soil particle density. Reduction in SOM would cause the increase of BD and the decrease of

Table 4.5 (a). Porosity of soils in relation to land use, sampling time and depth

Sl No.	Name of village	Porosity (%)																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	53.70	50.95	54.39	50.06	49.71	51.80	47.74	47.50	48.89	48.34	46.67	48.16	48.51	46.18	49.56	47.54	44.74	48.70
2	Jharnapani	51.98	49.86	53.08	49.56	48.02	50.40	47.38	47.43	48.68	47.38	46.42	47.88	45.60	45.13	46.57	45.12	43.83	47.65
3	Khaibung	51.84	49.51	52.61	48.79	46.58	49.71	47.15	47.32	48.27	46.64	45.61	47.76	48.15	45.38	48.64	45.62	44.06	48.11
4	Kukidolong	51.51	47.13	52.16	48.75	46.27	49.22	46.92	47.09	48.24	46.58	45.28	47.64	45.23	44.59	46.53	45.11	43.67	46.50
5	Kupuhe	50.94	47.11	51.14	47.85	45.92	49.14	45.99	46.85	48.02	46.24	44.94	47.49	44.63	43.19	46.35	44.93	42.01	45.33
6	Maova	51.87	49.65	52.70	48.85	47.86	49.83	47.27	47.38	48.37	46.85	45.99	47.76	48.15	45.53	48.85	47.07	44.29	48.44
7	Medziphema	52.15	50.54	53.77	49.79	48.60	50.55	47.69	47.45	48.69	48.31	46.45	47.94	48.20	45.82	49.30	47.28	44.32	48.49
8	Molvom	52.92	50.75	53.87	49.99	49.47	50.67	49.20	47.66	49.58	48.40	48.15	48.63	48.30	45.91	49.49	47.41	44.32	48.68
Average *(ST)		**52.11**	**49.44**	**52.97**	**49.21**	**47.80**	**50.17**	**47.42**	**47.34**	**48.59**	**47.34**	**46.19**	**47.91**	**47.10**	**45.22**	**48.16**	**46.26**	**43.91**	**47.74**
Range (Depth)		47.11–54.39			45.92–51.80			45.99–49.58			44.94–48.63			43.19–49.56			42.01–48.70		
Average (Depth)		**51.51**			**49.06**			**47.78**			**47.15**			**46.82**			**45.97**		
Range **(LU)		45.92–54.39						44.94–49.58						42.01–49.56					
Average (LU)		**50.28**						**47.46**						**46.40**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.5 (b). Variation in porosity (%) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	52.11^{a}	49.21^{a}	49.44^{a}	47.80^{a}	52.97^{a}	50.17^{a}
2	Pineapple	47.42^{b}	47.34^{b}	47.34^{b}	46.19^{b}	48.59^{b}	47.91^{b}
3	Paddy	47.10^{bc}	46.26^{c}	45.22^{c}	43.91^{c}	48.16^{bc}	47.74^{bc}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

Table 4.6 (a). Water holding capacity of soils in relation to land use, sampling time and depth

Sl No.	Name of village	WHC (%)																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	48.69	45.29	48.76	46.48	44.54	46.94	42.27	40.82	43.30	41.56	40.96	42.38	42.21	39.56	43.39	41.10	38.00	42.33
2	Jharnapani	47.50	44.42	47.24	45.80	42.93	45.21	41.57	40.46	43.03	40.89	40.48	42.06	39.70	38.36	41.29	39.11	37.18	41.24
3	Khaibung	46.94	43.98	46.82	45.42	42.07	45.00	41.45	40.23	42.66	40.07	39.62	41.33	41.73	38.95	41.82	39.55	37.20	41.37
4	Kukidolong	46.62	42.39	46.42	45.31	41.46	44.99	41.21	40.14	42.24	39.93	39.15	41.08	39.41	37.90	41.10	39.00	36.79	40.44
5	Kupuhe	46.36	41.76	45.51	44.49	40.87	43.81	40.89	40.11	42.08	39.46	38.97	40.90	38.82	36.85	40.89	38.87	35.54	39.43
6	Maova	47.39	44.39	46.90	45.70	42.73	45.10	41.52	40.41	42.78	40.13	39.77	41.97	42.08	38.99	42.04	40.55	37.21	41.60
7	Medziphema	47.53	44.53	47.94	46.05	43.02	45.35	42.00	40.60	43.25	41.27	40.82	42.36	42.18	39.02	42.55	40.78	37.37	41.70
8	Molvom	47.62	44.82	48.56	46.42	43.20	45.51	42.81	41.24	43.51	41.79	41.16	42.67	42.20	39.33	42.80	40.89	37.64	42.13
Average *(ST)		**47.33**	**43.95**	**47.27**	**45.71**	**42.60**	**45.24**	**41.72**	**40.50**	**42.86**	**40.64**	**40.12**	**41.84**	**41.04**	**38.62**	**41.99**	**39.98**	**37.12**	**41.28**
Range (Depth)		41.76 –48.76			40.87–46.94			40.11–43.51			38.97–42.67			36.85–43.39			35.54–42.33		
Average (Depth)		**46.18**			**44.52**			**41.69**			**40.87**			**40.55**			**39.46**		
Range **(LU)		40.87–48.76						38.97–43.51						35.54–43.39					
Average (LU)		**45.35**						**41.28**						**40.00**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.6 (b). Variation in water holding capacity (%) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	47.33^{a}	45.71^{a}	43.95^{a}	42.60^{a}	47.27^{a}	45.24^{a}
2	Pineapple	41.72^{b}	40.64^{b}	40.50^{b}	40.12^{b}	42.86^{b}	41.84^{b}
3	Paddy	41.04^{bc}	39.98^{bc}	38.62^{c}	37.12^{c}	41.99^{bc}	41.28^{bc}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

porosity, consequently reducing soil infiltration, water and air storage capacities.

Anonymous (2008) revealed that the process of puddling in lowland paddy cultivation employ shearing and compactive forces that destroys natural structure and results in a condition of greatly reduced pore space. Fageria *et al.* (2011) also opined that soil compaction affects the water retention characteristics, water-intake rates, and gas exchange. In compacted soil, bulk density, microvoids, thermal conductivity and diffusivity increase and macrovoids, hydraulic conductivity, and water intake rates decrease.

Kizilkaya and Dengiz (2010) reported similar findings from a study that porosity changes when natural forestland transformed into pasture and cultivated lands. Natural forestland has high organic matter led to low bulk density and increasing total porosity. However, amount of total porosity in cultivated lands diminished due to tillage causing compaction.

4.2. Fertility status of soil under different land uses

Available nitrogen:

Nitrogen availability in soils of forest LUS was found higher (304.47 kg ha^{-1}) followed by pineapple (270.08 kg ha^{-1}) and paddy LUS (245.37 kg ha^{-1}) with range varying from 279.24–339.09 kg ha^{-1}, 237.60–298.38 kg ha^{-1} and 221.52–274.82 kg ha^{-1} in forest, pineapple and paddy LUS, respectively across the sampling seasons and depths (Table 4.7 a). Nitrogen content decreased with depth under all the LUS. Significantly higher available nitrogen content was recorded under forest LUS (325.33 kg ha^{-1}) during post-monsoon season in surface soil followed by pineapple (284.57 kg ha^{-1}) and paddy (262.27 kg ha^{-1}) LUS (Table 4.7 b). Pre-monsoon season recorded lesser amount of available nitrogen compared to post-monsoon season and least amount of available nitrogen was recorded during monsoon season (Table 4.7 b). Same trend of seasonal variation of available content was recorded for all the different LUS under investigation.

Table 4.7 (a). Available nitrogen content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Available nitrogen (kg ha^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	333.41	323.51	339.09	301.58	294.42	310.42	285.93	279.31	297.69	275.68	271.47	280.49	263.01	258.88	274.82	244.50	241.35	249.13
2	Jharnapani	318.38	299.35	325.31	296.29	287.53	305.58	283.82	277.76	290.45	268.76	262.68	277.82	246.60	233.15	254.90	229.73	225.83	234.44
3	Khaibung	307.21	294.54	320.76	288.86	282.76	301.73	273.09	269.49	277.98	254.35	250.47	257.44	256.37	245.45	266.70	239.83	234.67	245.13
4	Kukidolong	301.74	292.76	318.61	288.78	282.50	300.72	259.30	252.87	268.71	245.30	244.30	255.82	238.02	230.78	248.76	229.60	224.52	234.13
5	Kupuhe	300.76	291.99	310.68	280.75	279.24	297.38	259.07	252.63	268.22	244.20	237.60	246.63	236.63	230.07	243.39	225.84	221.52	230.40
6	Maova	309.18	295.80	322.79	290.62	285.16	303.36	283.29	274.72	278.54	255.17	251.47	261.15	257.17	254.93	267.28	240.68	237.00	245.24
7	Medziphema	320.50	301.79	327.77	300.20	288.47	307.51	285.86	277.80	296.58	272.27	263.88	280.18	261.48	255.82	271.13	242.48	238.60	247.86
8	Molvom	332.88	312.92	337.66	300.55	291.09	309.47	296.25	280.90	298.38	276.47	274.81	286.91	262.14	256.28	271.17	242.60	239.00	248.64
Average *(ST)		**315.51**	**301.58**	**325.33**	**293.45**	**286.40**	**304.52**	**278.33**	**270.69**	**284.57**	**261.53**	**257.09**	**268.31**	**252.68**	**245.67**	**262.27**	**236.91**	**232.81**	**241.87**
Range (Depth)		291.99–339.09			279.24–310.42			252.63–298.38			237.60–286.91			230.07–274.82			221.52–249.13		
Average (Depth)		**314.14**			**294.79**			**277.86**			**262.31**			**253.54**			**237.20**		
Range **(LU)		279.24–339.09						237.60–298.38						221.52–274.82					
Average (LU)		**304.47**						**270.08**						**245.37**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.7 (b). Variation in available nitrogen (kg ha^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	315.51[a]	293.45[a]	301.58[a]	286.40[a]	325.33[a]	304.52[a]
2	Pineapple	278.33[b]	261.53[b]	270.69[b]	257.09[b]	284.57[b]	268.31[b]
3	Paddy	252.68[c]	236.91[c]	245.67[c]	232.81[c]	262.27[c]	241.87[c]

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

Higher available nitrogen content under forest LUS may be due to relatively high amount of organic carbon content under forest LUS, which in turn resulted from plant and root biomass as well as residues being returned to the soil system. Most soil nitrogen is found in organic carbon and it was expected to record high available nitrogen content in organic carbon rich soils. Moreover, undisturbed nature of forest floor allows deposition of more biomass and thus more availability of nitrogen. On the other hand, lesser amount of available nitrogen content under pineapple and paddy LUS can be attributed to less accumulation of organic biomass due to cultivation practices like tillage operation and removal of residues after crop harvest coupled with inefficient replenishment through manures and fertilizers. More available nitrogen in the surface soil can be accounted for more organic matter accumulation and favourable environment for mineralization as compared to sub-surface soil layers. In the post-monsoon season, there was high accumulation of organic matter and corresponding high organic carbon content due to lesser degree of decomposition owing to less microbial activity might have resulted higher available nitrogen content compared to pre-monsoon and monsoon season.

Nitrogen is significantly higher in forest than agriculture. It is attributed to high OM and overall high turnout of nitrogen during decomposition in forests (Maqbool *et al.*, 2017). The present findings were in conformity with Chase and Singh (2014) who have reported high available nitrogen content under natural forest LUS compared to *Jhum* fallow and lowland paddy LUS while studying soil nutrients and fertility in three traditional land use systems of Khonoma village, Nagaland, India.

The findings of the study was in conformity with the findings of Moges *et al*. (2013) who have reported higher total nitrogen content in the protected forest followed by the grazing land than in other land use types including farm land while studying land use effects on soil quality indicators of Etiopia. Tellen and Yerima (2018) also reported low total nitrogen content in farmlands compared to natural forest from a study conducted in the North West region of Cameroon.

Similar findings of decreasing trend of available nitrogen with depths was reported by Khanday *et al*. (2018), while studying depth wise distribution of available nutrients of soils of horticulture growing areas of Ganderbal district of Kashmir valley. They have reported maximum amount of available nitrogen in surface horizons which decreased regularly with depth. According to them, the possible reason of this may be decreasing trend of organic carbon with depth. These results are in agreement with those of Maqbool *et al*. (2020), who have reported the higher available nitrogen in surface soils which showed a linear decreasing trend with an increase in soil depth in three different altitudes under study.

In the present study, maximum amount of available nitrogen was recorded in post-monsoon (winter / November sampling) followed by pre-monsoon (spring / May sampling) and least was recorded in monsoon (summer / August sampling) season under different LUS. The findings of Salim *et al.* (2015) supported the present findings where they have revealed the increased amount of the total nitrogen in the soils under natural forest in autumn season followed by winter, spring and the least was observed in summer season under different land uses.

Available phosphorus:

Phosphorus availability was recorded as low to medium range under different LUS. Forest LUS recorded higher available P_2O_5 (32.11 kg ha^{-1}) followed by paddy LUS (23.51 kg ha^{-1}) and pineapple LUS (22.82 kg ha^{-1}) with range varying from 21.33–39.93 kg ha^{-1}, 17.05–32.19kg ha^{-1}and 18.76–31.76 kg ha^{-1} under forest, paddy and pineapple LUS respectively (Table 4.8 a). There prevailed a decreasing trend of available phosphorus content with the increasing depth. Significant seasonal variation in available phosphorus content was recorded between forest LUS and pineapple LUS as well as forest LUS and paddy LUS; maximum being recorded in pre-monsoon season (Table 4.8 b). Phosphorus content of pineapple and paddy LUS was at par in all the three sampling seasons. Available phosphorus content was found maximum in forest LUS (35.06 kg ha^{-1}), followed by paddy (26.14 kg ha^{-1}) and pineapple (25.83 kg ha^{-1}) during pre-monsoon season. Post-monsoon season recorded lesser content of available phosphorus in soil (33.86 kg ha^{-1}, 25.63 kg ha^{-1} and 23.89 kg ha^{-1} in forest, paddy and pineapple LUS respectively). However, monsoon season recorded least amount of available phosphorus in soil under different LUS (32.17 kg ha^{-1}, 23.28 kg ha^{-1} and 22.84 kg ha^{-1} in forest, paddy and pineapple LUS respectively).

Land use change has great impact on availability of nutrients. The high available phosphorus content in the forest LUS may be attributed to favorable soil reaction and high organic matter leading to the formation of organophosphate complexes and coating of iron and aluminum particles by humus. Moreover, the organic anions released during decomposition of organic matter form chelates with Fe and Al and make the P available. The high available phosphorus content in the surface soil may be due to high organic matter content leading to formation of more organophosphate complex and subsequent availability of phosphorus. Seasonal variability in available phosphorus content can be correlated to variation in organic carbon content in different seasons. However, increased level pH of soil during pre and post-monsoon season compared to monsoon season can also be held responsible for corresponding increase in phosphorus availability in those seasons.

Hoque *et al.* (2020) reported similar findings where they have revealed more available phosphorus content under banana orchard than rice field while studying vertical distribution of soil nutrients under different land use systems in Bangladesh. They have also reported a decreasing trend of available phosphorus content with increasing depths. In conformity with the present findings, Maqbool *et al.* (2017) also have reported increased phosphorus

Table 4.8 (a). Available phosphorus content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Available P_2O_5 (kg ha^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	39.93	37.85	38.74	35.94	32.76	34.74	28.06	24.35	25.97	25.55	21.01	22.18	32.19	29.63	32.14	27.56	26.53	28.58
2	Jharnapani	35.75	33.26	35.77	33.60	28.01	32.99	25.49	22.92	24.22	22.39	20.45	20.84	23.58	20.71	24.36	19.97	17.85	20.92
3	Khaibung	34.99	30.48	34.20	31.87	27.40	28.83	24.11	21.22	22.09	20.70	19.63	20.22	26.12	21.00	24.62	23.17	17.87	21.96
4	Kukidolong	30.12	27.92	27.75	29.56	24.72	27.24	23.11	21.03	21.84	20.43	19.35	19.72	22.18	18.09	21.03	19.59	17.79	18.80
5	Kupuhe	30.05	27.53	27.38	26.84	21.33	26.39	22.78	20.65	21.61	20.04	18.76	19.32	19.21	17.91	18.21	18.24	17.05	17.95
6	Maova	35.34	31.55	34.57	32.89	27.92	28.96	25.44	21.88	22.88	20.82	20.07	20.40	26.33	22.23	25.66	24.67	20.03	23.14
7	Medziphema	36.43	33.93	36.19	33.97	31.71	33.58	25.87	23.58	24.34	23.28	20.65	20.98	27.61	27.23	27.30	25.12	20.13	24.30
8	Molvom	37.83	34.85	36.31	34.65	32.04	34.61	31.76	27.07	28.15	28.76	23.19	26.09	31.91	29.42	31.70	27.48	25.03	24.53
Average *(ST)		**35.06**	**32.17**	**33.86**	**32.42**	**28.24**	**30.92**	**25.83**	**22.84**	**23.89**	**22.75**	**20.39**	**21.22**	**26.14**	**23.28**	**25.63**	**23.23**	**20.29**	**22.52**
Range (Depth)		27.38–39.93			21.33– 35.94			20.65–31.76			18.76–28.76			17.91–32.19			17.05–28.58		
Average (Depth)		**33.70**			**30.52**			**24.18**			**21.45**			**25.02**			**22.01**		
Range **(LU)		21.33–39.93						18.76–31.76						17.05–32.19					
Average (LU)		**32.11**						**22.82**						**23.51**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.8 (b). Variation in available phosphorus (kg ha^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	35.06^{a}	32.42^{a}	32.17^{a}	28.24^{a}	33.86^{a}	30.92^{a}
2	Pineapple	25.83^{b}	22.75^{b}	22.84^{b}	20.39^{b}	23.89^{b}	21.22^{b}
3	Paddy	26.14^{bc}	23.23^{bc}	23.28^{bc}	20.29^{bc}	25.63^{bc}	22.52^{bc}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

content under forest LUS than agriculture LUS. However, they didn't get significant difference in phosphorous content between the two LUS may be due to the application of Di ammonium phosphate (DAP) fertilizer on the cultivated land which may have resulted in the increase of phosphorus in the agricultural soil too. According to them, high content of OM in case of forests which also releases organic anions on decomposition and form chelates with Fe and Al and make the P available. The findings of Salim *et al*. (2015) support the present findings where they have reported maximum available phosphorus under natural forest followed by plantation and least under grassland.

In accordance with the present findings, Bini *et al*. (2018) have reported high available phosphorus in pre-monsoon than post-monsoon and monsoon season under agricultural lands while studying the seasonal variations in soil edaphic and chemical factors of agricultural and grassland habitats of Kerala. Salim *et al.* (2015) reported maximum values of phosphorous in natural forest during winter season and the minimum under grassland during summer season. They have attributed less amount of available phosphorus in rainy season to leaching due to rain and soil erosion. Fatubarin and Olojugba (2014) reported higher available phosphorus in dry season (January) and at the beginning of rainy season (May) and remain low at the peak of the rainy season (September) while studying effect of rainfall season on the chemical properties of the forest soil of a Southern Guinea Savanna ecosystem in Nigeria.

Khanday *et al.* (2018) opined the similar fact by reporting decreasing trend of available phosphorus with increasing depth which may be due to variation in amount of organic matter and soil reaction. They have also revealed that the lower phosphorus content in sub surface soils could also be attributed to the fixation of P by clay-minerals and oxides of iron and aluminium. Maximum available phosphorus in surface layers and it exhibited a decreasing trend with an increase in soil depth, which may be due to variation in amount of organic matter and soil reaction (Maqbool *et al*., 2020).

Available potassium:

Pineapple LUS recorded maximum available potassium in the form of K_2O (210.49 kg ha^{-1}) followed by forest (148.32 kg ha^{-1}) and paddy LUS (131.71 kg ha^{-1}) across the seasons. A wide range of available potassium content was recorded in different LUS. Available potassium ranged from 172.76–244.0 kg ha^{-1} in pineapple, 113.92–183.48 kg ha^{-1} in forest and 113.10–156.76 kg ha^{-1} in paddy LUS respectively (Table 4.9 a). Average available potassium content under paddy LUS was in low range while it was in medium range under pineapple and forest LUS in different villages of the Medziphema block. Sub-surface soil layer exhibited lesser amount of potassium availability than the surface soil layers in all the three LUS. Seasonal variation in available potassium was found significant among various LUS, The pattern of seasonal variation in available potassium was pre-monsoon > post-monsoon > monsoon for all three LUS (Table 4.9 b). Maximum available potassium was recorded in pineapple (230.24 kg ha^{-1}) followed by forest (166.1 kg ha^{-1}) followed by paddy (145.13 kg ha^{-1}) LUS during pre-monsoon season. In post-monsoon season available potassium content was 220.90 kg ha^{-1}, 157.63 kg ha^{-1}, and 134.92 kg ha^{-1} in pineapple, forest and paddy LUS, while in the monsoon season, the same was 213.25 kg ha^{-1}, 146.82 kg ha^{-1} and 131.00 kg ha^{-1} for pineapple, forest and paddy LUS respectively.

Progressive pineapple farmers of the Medziphema area practice annual application of fertilizers before the onset of monsoon shower. The high available potassium content under pineapple LUS compared to the other LUS might be due to application of K through fertilizers. The comparatively higher available potassium under pineapple and forest LUS may be attributed to release of labile K from organic residues owing to favorable micro-climate under these LUS. Higher organic matter/ organic carbon content under forest and pineapple LUS

Table 4.9 (a). Available potassium content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Available K_2O (kg ha^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	183.48	164.77	175.81	163.66	149.33	155.18	241.57	227.89	234.20	218.45	201.42	207.45	156.75	143.63	149.84	145.56	128.06	139.73
2	Jharnapani	164.76	150.70	159.30	144.74	132.55	140.86	234.25	220.60	225.45	217.53	194.11	206.02	142.21	121.96	128.07	128.23	115.22	121.61
3	Khaibung	154.93	137.05	152.29	137.51	122.73	136.28	224.18	203.05	212.75	202.75	186.43	196.33	144.13	131.14	134.13	131.55	118.76	123.85
4	Kukidolong	151.73	134.32	138.63	136.38	121.23	124.21	216.60	196.80	205.61	195.12	176.93	187.18	136.23	120.88	124.80	125.24	113.42	116.68
5	Kupuhe	148.80	126.89	138.09	132.52	113.92	123.83	214.13	196.51	204.50	195.00	172.76	175.33	132.95	119.23	123.97	124.63	113.10	115.25
6	Maova	164.23	142.89	157.85	143.66	124.24	138.07	229.79	207.43	219.91	210.91	193.29	196.97	145.61	133.06	135.21	132.83	122.39	125.21
7	Medziphema	179.20	154.08	165.11	162.34	137.95	151.62	237.43	224.79	228.82	217.85	198.82	206.62	146.71	135.88	136.20	135.58	122.44	129.52
8	Molvom	181.71	163.85	173.96	163.01	145.01	154.19	244.00	228.93	235.96	221.22	202.12	207.89	156.48	142.23	147.10	143.51	125.87	135.43
Average *(ST)		**166.11**	**146.82**	**157.63**	**147.98**	**130.87**	**140.53**	**230.24**	**213.25**	**220.90**	**209.85**	**190.74**	**197.97**	**145.13**	**131.00**	**134.92**	**133.39**	**119.91**	**125.91**
Range (Depth)		126.89–183.40			113.92–163.66			196.51–244.00			172.76–221.22			119.23–156.75			113.10–145.56		
Average (Depth)		**156.85**			**139.79**			**221.46**			**199.52**			**137.02**			**126.40**		
Range **(LU)		113.92–183.48						172.76–244.00						113.10–156.75					
Average (LU)		**148.32**						**210.49**						**131.71**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.9 (b). Variation in available potassium (kg ha^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	166.11[a]	147.98[a]	146.82[a]	130.87[a]	157.63[a]	140.53[a]
2	Pineapple	230.24[b]	209.85[b]	213.25[b]	190.74[b]	220.90[b]	197.97[b]
3	Paddy	145.13[c]	133.39[c]	131.00[c]	119.91[c]	134.92[c]	125.91[c]

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

may also be the reason of accumulation of more minerals like K in those soil compared to paddy LUS. The accumulation of K in the forest LUS is likely due to the undisturbed ecosystem where natural balance is maintained and no removal of residues that removes K. No addition of any inputs for nutrient supplementation in paddy fields may have resulted in low K content since the nutrient taken up by the crops were not naturally replenished due to less organic matter in paddy LUS.

The higher amount of available K was observed in the surface horizons and showed more or less a decreasing trend with depth. This might be attributed to favourable condition that facilitates more intense weathering of K-bearing minerals, release of liable K from organic residues, and upward translocation of K from lower depths along with capillary raise of ground water. In the monsoon season, the solubility of K is higher than the dry seasons *i.e.* post and pre-monsoon season. Potassium present in soil is easily dissolved in water and eroded off. That may be the reason for decrease in available potassium content in monsoon season compared to other two seasons. Moreover, high organic carbon content in post and pre-monsoon season can also be accounted for corresponding more K availability in these two seasons.

The result of the present investigation is supported by the findings of Das *et al.* (2019) who have reported that soils of rice-fallow land use system is low in both Exch-K and NEK and requires adequate K fertilization, whereas, both Exch-K and NEK were higher in the forest soils as compared to rice-fallow soils in the three soil depths. Maqbool *et al.* (2017) reported more available K in forest soil than agricultural lands while comparing physico-chemical properties and nutrient status of soils of forest and agricultural land uses in Ganderbal, J&K. Chase and Singh (2014) have reported similar findings where they have reported maximum exchangeable K under *Jhum* fallow followed by natural forest and least was reported in paddy field. They have revealed the possibility of natural build up of K fertility because of litter fall from trees in *Jhum* fallows and natural forests. The low level of K in paddy field was due to poor recycling of nutrients from crop and grass residues due to grazing of livestock on crop residues remaining on the land after harvest as well as removal of residues under Nagaland condition. Findings of Salim *et al.* (2015) is also in line with the present findings who have reported higher available K in natural forest than plantation and grassland. They have revealed that more the organic matter more is the accumulation of minerals in the soil. However, contradictory results have been reported by Negasa (2020) who opined higher exchangeable K content in cultivated soils compared to eucalyptus plantation and grasslands in Central Highlands of Ethiopia.

Similar results were reported by Yadav *et al.* (2019), where they have reported high mean value of available potassium in pre-monsoon season than post-monsoon season, with the least available potassium in monsoon season. The higher amount of potassium in surface soils was due to greater exposure of these minerals to weathering agencies at surface than sub-soils, higher weathering of potassium bearing minerals in surface soils (Khan *et al*., 2020). Similar findings of higher available potassium content in surface soil under different LUS were reported by Khanday *et al*., (2018) and Amgain *et al*. (2020).

Available sulphur:

Variation in available sulphur content was recorded under different LUS in different seasons (Table 4.10 a). Wide range of available sulphur content was obtained in different LUS. Sulphur content ranged from 20.43 kg ha^{-1} to 46.80 kg ha^{-1}; 16.18 kg ha^{-1} to 41.01 kg ha^{-1} and 8.75 kg $ha^{-1}$to 35.69 kg ha^{-1} in pineapple, forest and paddy LUS respectively. Maximum content of available sulphur was recorded in pineapple LUS (32.26 kg ha^{-1}) followed by forest (27.09 kg ha^{-1}) and paddy LUS (22.01 kg ha^{-1}). More amounts of available sulphur content in surface soil of all the LUS was recorded which exhibited similar decreasing trend down the soil profile. Significant seasonal variation in

Table 4.10 (a). Available sulphur content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Available sulphur (kg ha^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	39.84	26.53	41.01	27.44	20.60	31.20	42.14	34.86	46.11	28.87	24.00	34.37	32.29	27.62	35.69	22.54	17.57	28.36
2	Jharnapani	31.91	25.88	35.97	21.93	18.67	28.50	38.77	33.51	42.92	26.67	21.96	32.56	20.20	16.07	22.88	15.58	13.14	19.27
3	Khaibung	29.21	24.41	34.28	21.32	17.55	27.37	36.52	30.89	39.77	23.83	21.22	31.79	24.67	21.95	32.91	17.67	15.48	24.48
4	Kukidolong	28.08	24.17	34.26	19.08	17.39	24.72	34.99	30.51	38.85	23.41	21.13	31.52	19.46	14.30	22.09	13.20	12.59	18.20
5	Kupuhe	27.76	22.93	33.45	17.86	16.18	24.55	34.51	30.36	38.51	22.78	20.43	26.02	16.84	13.55	21.11	10.41	8.75	17.15
6	Maova	31.03	24.85	35.15	21.58	17.60	28.48	36.65	32.95	40.92	23.90	21.73	32.04	25.97	23.74	34.59	20.22	16.56	26.84
7	Medziphema	33.22	25.99	36.54	24.91	18.93	28.87	40.22	33.81	43.70	26.68	22.52	32.70	29.90	23.81	35.32	20.60	17.29	27.41
8	Molvom	39.26	26.03	39.00	26.10	19.07	29.59	42.72	37.53	46.80	30.23	24.11	35.46	31.23	24.16	35.53	21.63	17.55	27.99
Average *(ST)		**32.54**	**25.10**	**36.21**	**22.53**	**18.25**	**27.91**	**38.32**	**33.05**	**42.20**	**25.80**	**22.14**	**32.06**	**25.07**	**20.65**	**30.02**	**17.73**	**14.87**	**23.71**
Range (Depth)		22.93–41.01			16.18–31.20			30.36–46.80			20.43–35.46			13.55–35.69			8.75–28.36		
Average** (Depth)		**31.28**			**22.90**			**37.86**			**26.66**			**25.25**			**18.77**		
Range (LU)		16.18–41.01						20.43–46.80						8.75–35.69					
Average (LU)		**27.09**						**32.26**						**22.01**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.10 (b). Variation in available sulphur (kg ha^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	32.54^{a}	22.53^{a}	25.10^{a}	18.25^{a}	36.21^{a}	27.91^{a}
2	Pineapple	38.32^{b}	25.80^{ab}	33.05^{b}	22.14^{b}	42.20^{b}	32.06^{b}
3	Paddy	25.07^{c}	17.73^{c}	20.65^{c}	14.87^{c}	30.02^{c}	23.71^{c}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

available sulphur content was evident among the different LUS (Table 4.10 b). During post-monsoon season, maximum available sulphur content was recorded in all three LUS which was decreased during pre-monsoon season. A further reduction in available sulphur content was recorded in monsoon season. Significantly high amount of available sulphur was recorded in pineapple LUS (42.20 kg ha^{-1}) followed by forest (36.21 kg ha^{-1}) and paddy LUS (30.02 kg ha^{-1}) during post-monsoon season. During pre-monsoon season available sulphur content was 38.32 kg ha^{-1}, 32.54 kg ha^{-1} and 25.07 kg ha^{-1} in pineapple, forest and paddy LUS respectively. However, the available S was 33.05 kg ha^{-1}, 25.10 kg ha^{-1} and 20.65 kg ha^{-1} during monsoon season in pineapple, forest and paddy LUS.

The available S content of soil is a function of mineralization of organic S, which varies from land use to land use. The higher amount of available S in pineapple LUS may be due to higher mineralization of organic S triggered by the better microbial activity. Higher biomass addition may be the reason of effective mineralization facilitated by pronounced microbial activity and comparatively high available S content in forest LUS. Furthermore, progressive farmers of Medziphema area are applying S bearing fertilizers like SSP in pineapple cultivation, which may be another reason of high available S in soils of pineapple LUS. Intensive cultivation results higher removal and depletion of soil inherent sulphur. The available S content in paddy LUS was lower may be because of continuous monocropping of rice removed greater amount of S. The possible reason for decline in available S content along the depth may be due to lower mineralization rate in the lower depth owing to slower microbial activity because of lack of carbon source and aeration status compared to surface soil. Mineralization and availability of organic S depends on the amount of organic matter / organic carbon present in soil. Seasonal variation in available S content can be linked to organic carbon content in soil. Hence, high organic carbon content in post-monsoon and pre-monsoon season can be the reason for corresponding high available S content in these seasons.

The results of the present findings are in conformity with the findings of Padhan *et al*. (2016). They have reported the highest amount of available S content in the surface layer of orchard soils and lowest in the lower depth of rice-green gram land use. They have also revealed that the orchard land use is more efficient in mineralizing the organic S to inorganic sulphate among all the land uses under their investigation. Majumdar and Patil (2016) reported less available S in paddy land use compared to forest and orchard (mango) land use. High available S in forest LUS than agriculture LUS was reported by Maqbool *et al*. (2017) while comparing physico-chemical properties and nutrient status of forest and agriculture land uses in Ganderbal, J & K.

Khan *et al*. (2020) reported similar findings with low available S content at higher depth in a study conducted at Kashmir valley. Khandey *et al*. (2018) and Maqbool *et al*. (2020) also reported decreasing content of available S with increasing soil depths.

Exchangeable calcium:

Differential Exchangeable calcium (Exch. Ca) content was recorded among the LUS under study (Table 4.11 a). Higher value of Exch. Ca was recorded in forest LUS {2.33 cmol (P^+) kg^{-1}} and minimum {1.32 cmol (P^+) kg^{-1}} was recorded in paddy LUS across the seasons and depths. The same was 1.56 cmol (P^+) kg^{-1} in pineapple LUS. Lesser content of Exch. Ca was recorded in sub-surface soil compared to surface soils. Seasonal variation indicated maximum content in the pre-monsoon followed by post-monsoon and least in monsoon season (Table 4.11 b). In the pre-monsoon season, significantly higher content of Exch. Ca was recorded in forest LUS {2.78 cmol (P^+) kg^{-1}} followed by pineapple {1.64 cmol (P^+) kg^{-1}} and paddy LUS {1.41 cmol (P^+) kg^{-1}}. During post-monsoon season the same was 2.60, 1.59 and 1.37 cmol (P^+) kg^{-1} in forest, pineapple and paddy LUS respectively. However, least content of

Table 4.11 (a). Exchangeable calcium content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Exch.Ca cmol (P^{+}) kg^{-1}																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	3.03	2.39	2.76	2.79	1.90	2.55	1.87	1.71	1.79	1.77	1.65	1.73	1.63	1.53	1.55	1.47	1.42	1.48
2	Jharnapani	2.82	1.93	2.71	2.45	1.82	2.40	1.67	1.55	1.65	1.61	1.48	1.59	1.38	1.29	1.32	1.26	1.24	1.24
3	Khaibung	2.72	1.83	2.48	2.34	1.73	2.36	1.57	1.49	1.50	1.46	1.42	1.41	1.39	1.32	1.38	1.28	1.25	1.26
4	Kukidolong	2.53	1.80	2.42	2.32	1.67	2.35	1.36	1.38	1.38	1.34	1.35	1.33	1.27	1.22	1.25	1.14	1.13	1.15
5	Kupuhe	2.48	1.72	2.40	2.18	1.61	2.17	1.35	1.33	1.30	1.22	1.22	1.24	1.25	1.20	1.22	1.13	1.03	1.10
6	Maova	2.80	1.90	2.56	2.37	1.81	2.40	1.63	1.55	1.55	1.56	1.46	1.50	1.42	1.38	1.40	1.31	1.27	1.27
7	Medziphema	2.90	2.07	2.71	2.62	1.84	2.46	1.70	1.60	1.65	1.65	1.48	1.61	1.44	1.39	1.41	1.34	1.29	1.32
8	Molvom	2.97	2.13	2.73	2.67	1.85	2.51	2.00	1.77	1.92	1.80	1.76	1.75	1.48	1.43	1.45	1.46	1.31	1.40
Average *(ST)		**2.78**	**1.97**	**2.60**	**2.47**	**1.78**	**2.40**	**1.64**	**1.55**	**1.59**	**1.55**	**1.48**	**1.52**	**1.41**	**1.35**	**1.37**	**1.30**	**1.24**	**1.28**
Range (Depth)		1.72─3.03			1.61─2.79			1.30─2.00			1.22─1.80			1.20─1.63			1.03─1.48		
Average (Depth)		**2.45**			**2.22**			**1.59**			**1.52**			**1.38**			**1.27**		
Range ** (LU)		1.61─3.03						1.22─2.00						1.03─1.63					
Average (LU)		**2.33**						**1.56**						**1.32**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.11 (b). Variation in exchangeable calcium [cmol (P^{+}) kg^{-1}] under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	2.78^{a}	2.47^{a}	1.97^{a}	1.78^{a}	2.60^{a}	2.40^{a}
2	Pineapple	1.64^{b}	1.55^{b}	1.55^{b}	1.48^{b}	1.59^{b}	1.52^{b}
3	Paddy	1.41^{c}	1.30^{c}	1.35^{c}	1.24^{c}	1.37^{c}	1.28^{c}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

Exch. Ca was recorded in monsoon season as 1.97, 1.55 and 1.35 cmol (P^{+}) kg^{-1} in forest, pineapple and paddy LUS respectively.

Exchangeable magnesium:

The trend of exchangeable magnesium (Exch. Mg) content under different LUS was found as forest > pineapple > paddy. Maximum content of Exch. Mg {1.16 cmol (P^{+}) kg^{-1}} was recorded in forest LUS and minimum {0.52 cmol (P^{+}) kg^{-1}} in paddy LUS, along with {0.72 cmol (P^{+}) kg^{-1}} in pineapple LUS (Table 4.12 a). Wide range of Exch. Mg content was observed in each of the LUS during the study in different sampling seasons (Table 4.12 b). The Exch. Mg was 1.41, 0.83 and 0.63 cmol (P^{+}) kg^{-1} in forest, pineapple and paddy LUS during pre-monsoon season respectively. During post-monsoon season this was decreased to 1.31, 0.78 and 0.59 cmol (P^{+}) kg^{-1} in forest, pineapple and paddy LUS. The same was further decreased to 1.0, 0.72 and 0.53 cmol (P^{+}) $kg^{-1}$for surface soil (0-0.25 m) in forest, pineapple and paddy LUS respectively during monsoon season. The difference in Exch. Mg content among three LUS was found significant in each of the seasons.

Litter layer in any LUS is the main source of soil organic matter and available nutrients. Thick litter layer in the forest floor may be the reason of higher content of Exch. Ca and Mg in the forest LUS. High organic matter / organic carbon content might have increased CEC and thus exchangeable bases *i.e.* Exch. Ca and Mg content. The decreasing content of Exch. Ca and Mg down the depths might be due to lesser organic matter in the sub-surface soil. During the pre and post-monsoon season, the little or no rainfall might be responsible for accumulation of the respective cations at the upper depth, as in these periods; there was little or no leaching of these cations. During monsoon season, Exch. Ca and Mg content in soil were low; this could be attributed to these elements being utilized by the regenerating plants, since these elements are important in tissues synthesis, there by indicating temporary disappearance of these elements in the soil. During pre and post-monsoon season, however,

Table 4.12 (a). Exchangeable magnesium content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Exch. Mg cmol (P+) kg^{-1}																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	1.60	1.13	1.40	1.43	0.90	1.30	1.01	0.86	0.87	0.87	0.72	0.81	0.93	0.73	0.77	0.69	0.57	0.63
2	Jharnapani	1.40	1.03	1.34	1.23	0.80	1.23	0.85	0.73	0.82	0.87	0.70	0.72	0.55	0.47	0.54	0.45	0.40	0.44
3	Khaibung	1.37	0.95	1.25	1.20	0.73	1.18	0.73	0.67	0.70	0.67	0.64	0.72	0.60	0.53	0.55	0.46	0.40	0.45
4	Kukidolong	1.37	0.90	1.23	1.17	0.70	1.17	0.72	0.63	0.69	0.57	0.63	0.65	0.54	0.44	0.50	0.41	0.35	0.41
5	Kupuhe	1.27	0.82	1.20	1.13	0.47	1.13	0.53	0.50	0.50	0.54	0.51	0.57	0.47	0.39	0.43	0.30	0.28	0.28
6	Maova	1.38	0.99	1.32	1.20	0.77	1.20	0.82	0.71	0.78	0.71	0.68	0.72	0.62	0.53	0.60	0.55	0.41	0.48
7	Medziphema	1.45	1.07	1.38	1.27	0.83	1.27	0.90	0.75	0.87	0.87	0.70	0.77	0.65	0.57	0.62	0.57	0.48	0.50
8	Molvom	1.47	1.13	1.38	1.28	0.85	1.27	1.08	0.87	0.98	0.87	0.75	0.90	0.69	0.57	0.67	0.63	0.49	0.53
Average *(ST)		**1.41**	**1.00**	**1.31**	**1.24**	**0.76**	**1.22**	**0.83**	**0.72**	**0.78**	**0.75**	**0.67**	**0.73**	**0.63**	**0.53**	**0.59**	**0.51**	**0.42**	**0.47**
Range (Depth)		0.82–1.60			0.47–1.43			0.50–1.08			0.51–0.90			0.39–0.93			0.28–0.69		
Average (Depth)		**1.24**			**1.07**			**0.77**			**0.72**			**0.58**			**0.47**		
Range ** (LU)		0.47–1.60						0.50–1.08						0.28–0.93					
Average (LU)		**1.16**						**0.74**						**0.52**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.12 (b). Variation in exchangeable magnesium [cmol (P+) kg^{-1}] under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	1.41^{a}	1.24^{a}	1.00^{a}	0.76^{a}	1.31^{a}	1.22^{a}
2	Pineapple	0.83^{b}	0.75^{b}	0.72^{b}	0.67^{ab}	0.78^{b}	0.73^{b}
3	Paddy	0.63^{c}	0.51^{c}	0.53^{c}	0.42^{c}	0.59^{c}	0.47^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

the vigorous growth of plants and trees might have been decreased which accounted for high Exch. Ca and Mg content in soil. In conformity with the present findings, Bini *et al*. (2015) have reported higher magnesium and calcium in grassland habitat than agricultural habitat. They have found a similar trend of availability of Exch. Ca and Mg under grassland and agricultural habitat, maximum being in pre-monsoon season, followed by post-monsoon and least in the monsoon season. The findings of Saha *et al*. (2012) was however contradictory to the result of present findings where they have reported comparatively less Ca and Mg content in forest LUS compared to agri-horticulture land use system under Meghalaya condition. They have revealed that agroforestry intervention increased the exchangeable Ca and Mg content and the content of these nutrients decreased with increasing soil depth. Fatubarin and Olojugba (2014) also reported similar results of increased Exch. Ca and Mg content in beginning and end of rains, while least been reported in the peak of rains (monsoon) with the distribution of exchangeable bases decreased down the depths in a study carried out in Oro forest reserve in Kwara State of Nigeria. Wani *et al.* (2017) reported higher calcium and magnesium content in surface and sub-surface soils in pear orchards of mid altitude in Jammu & Kashmir, India.

4.3. Soil biological properties under different land uses

Microbial biomass carbon:

Microbial biomass carbon (MBC) is fundamental in maintaining soil functions because it represents the main source of soil enzymes that regulates nutrient transformation process. A wide variation in MBC content among different LUS was recorded during the investigation; maximum being recorded in forest (425.59 µg g^{-1}) with range 286.68–619.21 µg g^{-1} followed by pineapple LUS (276.14 µg g^{-1}), range 172.21–442.80 µg g^{-1} and paddy LUS recorded least MBC content (259.22 µg g^{-1}) with range 100.77–495.27 µg g^{-1} across the seasons and depths (Table 4.13 a). Maximum MBC content was recorded in surface soil (0–0.25 m) in all three LUS under study. A unique trend of seasonal pattern of change in MBC was observed where MBC started increasing with the pre-monsoon shower, which attained maximum during monsoon season and then declined in post-monsoon season in case of forest and pineapple LUS. Conversely, in case of paddy LUS, a gradual decline in MBC content was recorded from pre-monsoon to monsoon to post-monsoon season. During monsoon season, significantly higher MBC content was recorded in surface soil of forest LUS (549.46 μg g^{-1}) followed by pineapple (366.19 μg g^{-1}) and paddy LUS (329.47 μg g^{-1}) (Table 4.13 b and Fig 4.1 a, 4.1 b). During pre-monsoon season MBC content was recorded as 517.05 μg g^{-1}, 403.65 μg g^{-1} and 274.44 μg g^{-1} in forest, paddy and pineapple LUS respectively. While, significantly lower MBC content among LUS was recorded as 361.56 μg g^{-1} , 252.80 μg g^{-1} and 136.93 μg g^{-1} in forest, pineapple and paddy LUS respectively during post-monsoon season in surface soils.

MBC is often limited by the soil organic carbon (SOC). The higher MBC content in forest soils may be due to high SOC and available N in this LUS. Most microorganisms are heterotrophic and their distribution and biological activity often depend on organic matter. The easily decomposable carbon source such as glucose and sucrose could make the soil microorganisms rapidly propagate and increase their numbers. Forest LUS produces abundant litter and contributes to high SOC and the deep root systems of the tree might have allowed more microbial activities than other two LUS. Low MBC in the paddy LUS may because of the different agricultural practices that lead to decrease in SOC content and corresponding decrease in MBC content. MBC was more in the upper soil layer and less in the sub-soil in all the LUS. This pattern may be because of lower carbon and nitrogen content in the lower sub-soil and more organic matter in the surface soil that promotes microbial activity. Maximum value of MBC in monsoon season (wet period) and the minimum value in post-monsoon season (dry period) may be because soil

Table 4.13 (a). Microbial biomass carbon content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	MBC (μg g^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	609.80	619.21	403.51	426.41	537.03	388.34	310.94	428.85	282.68	286.85	341.71	219.82	495.27	371.28	158.93	399.77	284.34	155.77
2	Jharnapani	543.42	573.94	381.55	398.86	413.12	341.83	286.07	393.95	239.54	248.80	332.85	216.15	343.63	316.89	124.52	275.28	203.82	113.16
3	Khaibung	486.51	493.53	359.14	342.12	396.18	322.38	256.17	319.70	233.19	225.94	290.17	191.76	390.73	319.93	125.78	327.06	213.66	115.80
4	Kukidolong	444.24	489.48	298.33	300.91	311.81	292.02	239.32	289.32	228.61	218.11	288.11	177.10	334.86	314.22	117.14	274.47	203.76	112.45
5	Kupuhe	425.60	481.19	297.34	298.43	311.51	286.68	234.96	253.72	226.20	198.69	242.10	172.21	315.57	311.11	115.89	244.83	200.04	100.77
6	Maova	487.09	551.40	367.70	391.95	412.48	331.04	256.52	390.50	233.47	239.11	331.31	194.83	431.31	325.68	148.79	333.92	241.66	146.64
7	Medziphema	545.11	584.90	385.89	418.56	439.12	342.12	297.62	410.65	281.02	267.44	335.70	216.78	453.41	334.84	150.74	338.43	244.74	148.62
8	Molvom	594.66	602.01	399.01	424.67	533.05	343.22	313.92	442.80	297.67	290.84	346.33	234.39	464.38	341.80	153.61	381.37	273.32	148.65
Average *(ST)		**517.05**	**549.46**	**361.56**	**375.24**	**419.29**	**330.95**	**274.44**	**366.19**	**252.80**	**246.97**	**313.54**	**202.88**	**403.65**	**329.47**	**136.93**	**321.89**	**233.17**	**130.23**
Range (Depth)		297.34–619.21			286.68–537.03			226.20–442.80			172.21–346.33			115.89–495.27			100.77–399.77		
Average (Depth)		**476.02**			**375.16**			**297.81**			**254.46**			**290.01**			**228.43**		
Range **(LU)		286.68–619.21						172.21–442.80						100.77–495.27					
Average (LU)		**425.59**						**276.14**						**259.22**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.13 (b). Variation in microbial biomass carbon (μg g^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	517.05^{a}	375.24^{a}	549.46^{a}	419.29^{a}	361.56^{a}	330.95^{a}
2	Pineapple	274.44^{b}	246.97^{b}	366.19^{b}	313.54^{b}	252.80^{b}	202.88^{b}
3	Paddy	403.65^{c}	321.89^{c}	329.47^{bc}	233.17^{c}	136.93^{c}	130.23^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

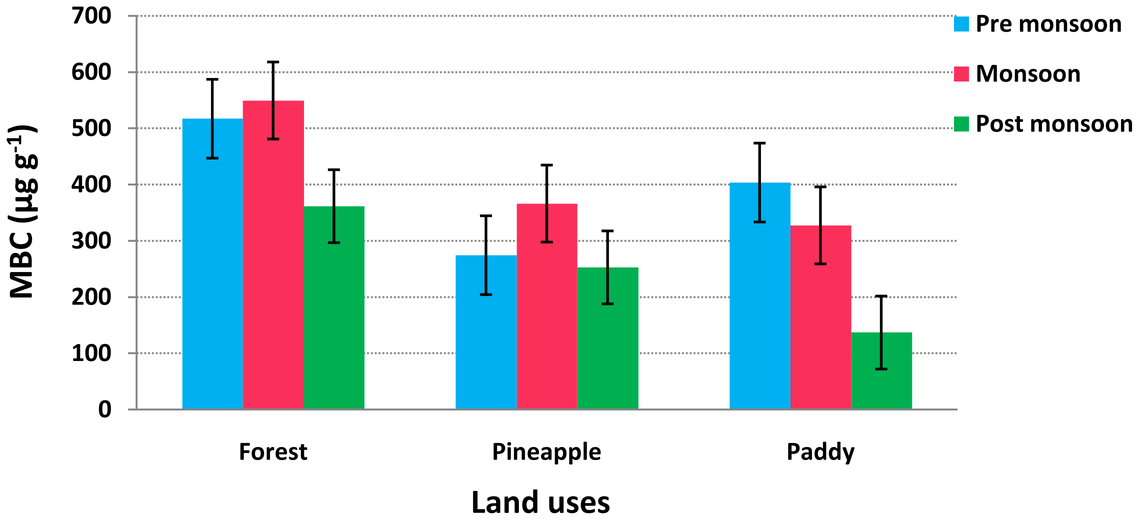


Fig 4.1 (a): Microbial biomass carbon in surface soils (0‒0.25 m) of different land use systems during various sampling seasons

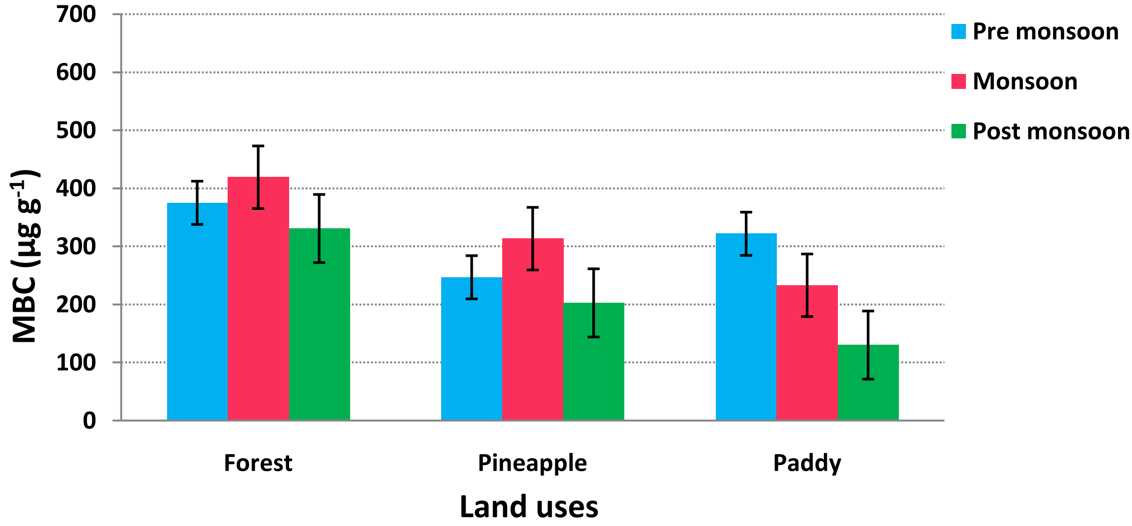


Fig 4.1 (b): Microbial biomass carbon in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

moisture changes affect the magnitude of the soil microbial biomass as many soil microorganisms are intolerant of low water content in post-monsoon season. Warm and wet weathers during the rainy season accelerated litter decomposition as microbial activities and decomposition are at peak during this season thereby increasing the immobilization of nutrients by the microbes and thus increase in MBC content. Least MBC during the post-monsoon coincides with a low temperature and less moisture in the soil leading to the death of microorganisms and hence less MBC content. High moisture in the soil of paddy cropland due to impounding water might have limited the microbial activity in the soils of paddy LUS during the monsoon season.

The findings of Lepcha and Devi (2020) are in conformity with the present findings. They have reported highest annual mean microbial biomass carbon in the forest followed by cardamom agroforestry and paddy cropland. Microbial biomass carbon exhibited a peak value in the rainy season and lowest in the winter season. They have also reported high MBC content in the surface soil than sub-surface soil in all the land use types. Similar findings were reported by Xiangmin *et al.* (2014) from a study conducted in Changbai Mountains of Northeast China. They have reported significantly higher MBC content in natural forest LUS compared to cropland and other LUS under their study. They have reported the maximum value of microbial biomass in wet period and the minimum value in dry period. In conformity with present findings, Reza *et al.* (2014) have reported significantly greater microbial biomass carbon (MBC) and nitrogen (MBN) in the soils of the undisturbed forest than the soils under various land use practices. The MBC and MBN in the surface soil layer (0–25 cm) were highest in the forest and lowest in the one year old *Jhum* fallow from a study conducted in lower range of Wokha district of Nagaland in North-Eastern India. MBC content was higher in the surface soil layer than the sub-surface layer in different agro-ecosystems of Arunachal Pradesh, North East India (Bhuyan *et al.*, 2013). Soils of NF exhibited the maximum MBC whereas the minimum was reported in bamboo forests in Mizoram, North East India (Manpoong and Tripathi, 2019). Similar findings were reported by Tomar and Baishya (2020) from a study conducted in semi arid forest soils of Delhi. They have reported highest MBC in monsoon season and lowest in the winter season. MBC also showed significant variation among the two depths and was observed higher in 0–10 cm than in 10–20 cm depth.

Dehydrogenase activity:

Dehydrogenase activity (DHA) reflects the total range of oxidative activity of soil microflora. Soil enzymes produced by the microbes have an important role in the biochemical transformation of organic matter, nutrient cycling and their release pattern. Differential content of DHA was recorded under different LUS during the present investigation. Maximum DHA was recorded in forest LUS (14.74 μg TPF g^{-1} h^{-1}) followed by pineapple (12.06 μg TPF g^{-1} h^{-1}) and paddy (10.06 μg TPF g^{-1} h^{-1}) LUS across the depths and seasons (Table 4.14 a). Highest DHA was recorded in surface soil of forest LUS (15.81μg TPF g^{-1} h^{-1}) and minimum in sub-surface soil of paddy LUS (6.92 μg TPF g^{-1} h^{-1}). However, DHA ranged from 4.53 μg TPF g^{-1} h^{-1} in sub-surface soil of paddy LUS to 20.68 μg TPF g^{-1} h^{-1} in surface soil of forest LUS. Significantly higher DHA was recorded in surface soil of forest LUS (17.42 μg TPF g^{-1} h^{-1}) followed by pineapple (14.12 μg TPF g^{-1} h^{-1}) and paddy LUS (13.76 μg TPF g^{-1} h^{-1}) during monsoon season (Table 4.14 b and Fig 4.2 a, 4.2 b). A dissimilar trend of seasonal activity of dehydrogenase enzyme was seen in case of paddy LUS where DHA in pre-monsoon > monsoon > post-monsoon (Table 4.14 b). In pre-monsoon season, DHA content was recorded as 15.64 μg TPF g^{-1} h^{-1}, 12.81 μg TPF g^{-1} h^{-1} and 14.40 μg TPF g^{-1} h^{-1} in forest, pineapple and paddy LUS respectively, while the same was 14.38 μg TPF g^{-1} h^{-1}, 11.09 μg TPF g^{-1} h^{-1} and 11.41 μg TPF g^{-1} h^{-1} in forest, pineapple and paddy LUS respectively during post-monsoon season in surface soil. Similar variation was

Table 4.14 (a). Dehydrogenase enzyme activity of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	DHA (µg TPF g^{-1} h^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	18.91	20.68	16.93	16.08	18.67	14.21	14.72	16.05	13.06	12.87	13.07	11.61	16.77	16.13	12.66	10.07	7.82	6.09
2	Jharnapani	15.65	18.12	15.29	13.39	16.16	12.52	13.66	14.80	11.31	11.71	12.43	10.86	13.72	13.30	10.95	8.20	6.44	5.44
3	Khaibung	14.22	15.20	13.55	13.01	14.23	10.19	11.71	13.68	10.25	10.80	11.31	9.26	13.88	13.50	10.99	8.21	6.48	5.78
4	Kukidolong	13.33	14.83	11.15	11.24	13.09	10.11	10.67	11.91	9.76	10.48	11.27	9.12	13.47	12.48	10.90	7.16	5.95	5.40
5	Kupuhe	13.13	13.64	11.13	10.00	12.67	9.91	10.49	11.29	9.35	10.07	11.10	9.05	13.35	12.13	9.99	7.04	5.70	4.53
6	Maova	15.17	17.84	14.71	13.11	16.04	12.48	12.34	13.84	10.26	10.96	11.44	9.89	14.22	13.78	11.78	8.63	6.82	5.97
7	Medziphema	16.78	18.50	15.84	14.39	16.27	13.07	13.78	14.93	11.58	12.29	12.61	11.32	14.23	14.07	11.96	8.65	6.92	5.99
8	Molvom	17.95	20.51	16.45	15.89	17.98	13.08	15.15	16.44	13.14	13.81	14.77	12.44	15.55	14.65	12.10	9.87	7.00	6.01
Average *(ST)		**15.64**	**17.42**	**14.38**	**13.39**	**15.64**	**11.95**	**12.81**	**14.12**	**11.09**	**11.62**	**12.25**	**10.44**	**14.40**	**13.76**	**11.41**	**8.48**	**6.64**	**5.65**
Range (Depth)		11.13─20.68			9.91─18.67			9.35─16.44			9.05─14.77			9.99─16.77			4.53─10.07		
Average (Depth)		**15.81**			**13.66**			**12.67**			**11.44**			**13.19**			**6.92**		
Range **(LU)		9.91─20.68						9.05─16.44						4.53─16.77					
Average (LU)		**14.74**						**12.06**						**10.06**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.14 (b). Variation in dehydrogenase enzyme activity (µg TPF g^{-1} h^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	15.64^{ac}	13.39^{a}	17.42^{a}	15.64^{a}	14.38^{a}	11.95^{a}
2	Pineapple	12.81^{b}	11.62^{b}	14.12^{b}	12.25^{b}	11.09^{b}	10.44^{b}
3	Paddy	14.40^{bc}	8.48^{c}	13.76^{bc}	6.64^{c}	11.41^{bc}	5.65^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

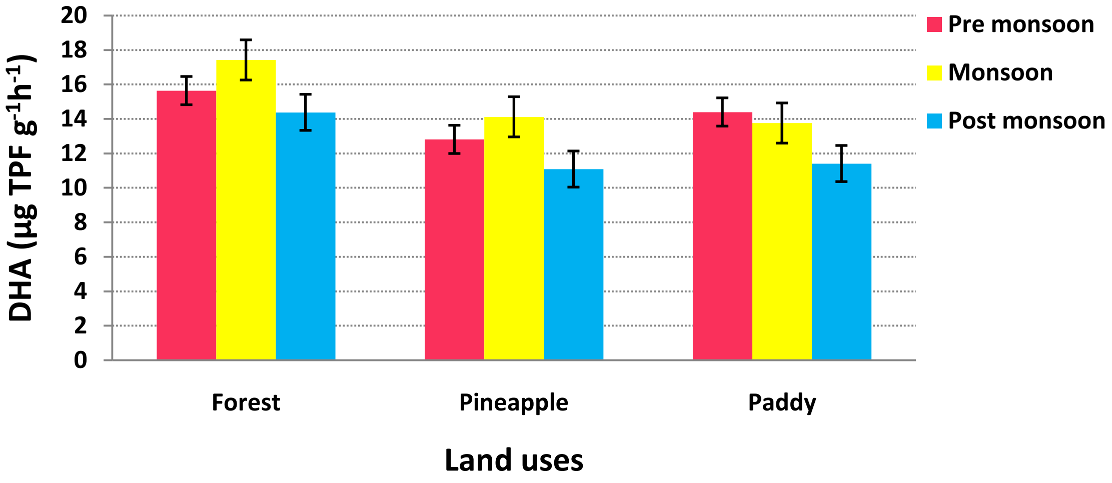


Fig 4.2 (a): Dehydrogenase activity in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

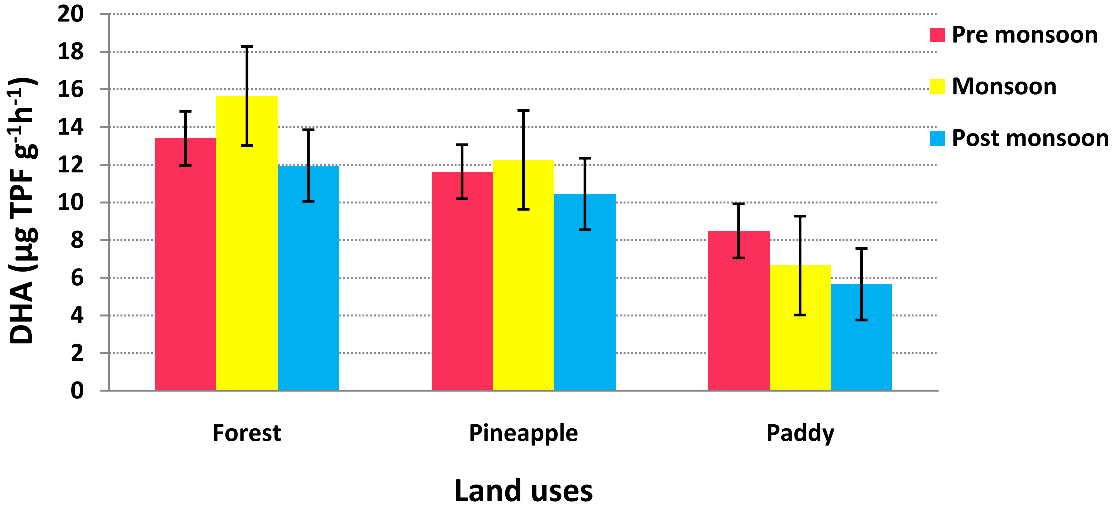


Fig 4.2 (b): Dehydrogenase activity in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

observed in sub-surface soil also. However, significant difference of DHA content between pineapple and paddy was not recorded in any of the seasons.

The activity of dehydrogenase is considered an indicator of the oxidative metabolism in soils and thus of the microbiological activity because it is linked to viable cells. Soil DHA reflects the total range of oxidative activity of soil microflora and, consequently it may be a good indicator of microbiological activity in the soil. Enzyme activity depends on the availability of substrate materials *i.e.* organic matter / organic carbon content in the soil. Higher DHA in the forest LUS may be because of abundant litter materials and below ground root biomass which contribute to the more organic matter and organic carbon content leading to more microbial activity and corresponding increase in DHA in forest LUS. Besides organic carbon, soil nutrients are the most important factor likely to regulate microbial activity and hence enzymatic reaction. Thus, better availability of nutrients (N, P, K, S, Ca and Mg) in forest LUS during present investigation can also be attributed to high DHA in forest LUS. On the other hand, the low input of detrital material and nutrients through litter fall in pineapple orchards and less input or loss of organic matter in paddy LUS due to various agricultural operations might have resulted in the decreased enzyme activity in these two LUS.

With significant seasonal variation, dehydrogenase activity was found high in monsoon season may be because of significance of soil moisture in the production of dehydrogenase enzyme. Probably the moisture content in forest and pineapple LUS was just appropriate during monsoon season for proliferation of microorganisms and production of more amount of dehydrogenase enzyme. Decrease in soil moisture content pre and post-monsoon season might have slowed down microbial activity as well as DHA. On the other hand, probably the moisture content in soil during pre-monsoon season in paddy LUS was suitable for maximum activity of microbes compared to moisture state during monsoon season when the field is kept under waterlogged condition. The major reason for increased DHA in the surface soil compared to the deeper soil depths is attributed to the greater availability of organic carbon, nutrients, moisture and adequate aeration that stimulated microbial activity in the surface soil.

The present findings are in conformity with Meena and Rao (2021), who have reported higher activity of all the enzymes under mixed forest cover (MFC) / natural forest with the low level of anthropogenic influence. The soils were covered with high litter content and added greater SOM under MFC. According to them the intensive management practices under agricultural field and vegetable fields constantly disturb the soil and regular removal of litter layer restricted the supply of substrate for microbes, thereby reduces the enzyme activities. Mukhopadhyay and Maiti (2010) also reported more DHA in undisturbed soil (natural forest) than disturbed soil (mine soil). Reza *et al*., (2014) opined varied DHA between the land uses. They have reported greatest dehydrogenase activity under forest soil followed by arecanut and pineapple orchards and *Jhum* fallows with least DHA. They also found that the dehydrogenase activity declined from the surface to the sub-surface soil layer regardless of the land uses. Since microorganisms are mostly confined to the surface soil layer owing to better aeration and greater nutrient availability, DHA activities were greater in the surface soil layer (0–25 cm) compared to the sub-surface (25–50 cm) soil layer where the organic matter content and nutrient availability was low and aeration was poor. Bhowmik *et al*. (2019) reported higher DHA at surface soils while studying potential indicators of soil health degradation indifferent land use-based ecosystems in the Shiwaliks of Northwestern India. Velmourougane *et al.* (2013) reported higher DHA in surface soil while studying dehydrogenase ezyme activity in agro-ecological sub regions of black soil regions in India. The mean dehydrogenase activity was significantly higher in 0–10 cm soil depth and decreased with soil depth in soils of mango orchard (Adak *et al*., 2014). Tomar and Baishya (2020) have reported similar findings of seasonal variation of DHA, higher being in monsoon season.

Beta-glucosidase enzyme activity:

Similar trend of beta-glucosidase activity **(**β-GSA) was recorded with MBC content and DHA. Forest LUS recorded maximum β- GSA (62.02 μg PNP g^{-1} h^{-1}). Pineapple LUS exhibited 50.15 μg PNP g^{-1} h^{-1}), while minimum GSA was recorded in paddy LUS (30.63 μg PNP g^{-1} h^{-1}) (Table 4.15 a). Wide range of GSA was recorded across the LUS with as low as 19.05 μg PNP g^{-1} h^{-1} in sub-surface soil of paddy LUS to as high as 81.24 μg PNP g^{-1} h^{-1} in surface soils of forest LUS irrespective of seasons. Gradual decline in β-GSA was recorded with increasing depth. Maximum average GSA was recorded in surface soil of forest LUS (66.36 μg PNP g^{-1} h^{-1}) and minimum in sub-surface soil of paddy LUS (26. 70 μg PNP g^{-1} h^{-1}). Significant seasonal variation in β-GSA was recorded; with maximum in monsoon season (71.78, 59.35 and 33.23 μg PNP g^{-1} h^{-1} in forest, pineapple and paddy LUS respectively) (Table 4.15 b and Fig 4.3 a, Fig 4.3 b) followed by pre-monsoon (65.72, 55.09 and 39.71 μg PNP g^{-1} h^{-1}) in forest, pineapple and paddy LUS respectively. It was recorded as 61.59, 49.45 and 30.76 μg PNP g^{-1} h^{-1} in forest, pineapple and paddy LUS respectively in post-monsoon season. In case of paddy LUS, however, a decreasing trend of β-GSA was recorded from pre-monsoon through monsoon to post-monsoon season (Table 4.15 a).

β- glucosidase is considered as one of the most important glycosidases in the soil because it helps in hydrolysis of carbohydrates having β- d-glucoside bonds, such as cellobiose and hence plays significant role in mineralization of cellulose, which is considered as the main organic carbon compound in nature. β-glucosidase catalyzes the hydrolysis of β-glucosides, thereby producing glucose from cellulose and thus the enzyme is involved in the decompositionof plant remains. The activity of β-glucosidase is likely to be controlled by organic matter in the soil and the varying inputs of the litter

Table 4.15 (a). Beta-glucosidase enzyme activity of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	β- Glucosidase (μg PNP g^{-1} h^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	78.45	81.24	70.12	68.00	70.53	64.05	60.08	64.28	54.15	51.81	57.52	45.18	44.35	37.93	34.28	38.70	28.87	25.29
2	Jharnapani	65.22	70.71	66.19	56.35	64.74	52.61	58.74	63.00	51.83	47.08	51.03	44.26	36.97	32.78	30.16	29.75	25.66	21.84
3	Khaibung	63.45	69.53	60.49	51.53	60.98	47.16	54.62	57.96	50.53	42.91	46.90	40.93	41.86	33.22	30.58	30.73	25.67	22.37
4	Kukidolong	56.28	66.24	53.91	48.17	55.36	45.02	48.84	54.32	45.60	41.12	42.38	36.03	35.57	30.55	27.61	25.80	22.66	20.06
5	Kupuhe	54.91	65.75	46.52	48.01	51.66	44.13	41.47	46.50	35.55	34.39	36.86	32.27	31.15	24.84	23.65	25.28	22.43	19.05
6	Maova	63.62	69.91	61.00	55.55	61.81	51.29	56.63	58.85	50.81	44.32	49.80	41.84	42.07	34.14	31.79	34.11	26.04	22.64
7	Medziphema	69.18	73.09	66.59	63.66	66.12	60.33	59.90	63.61	52.53	48.83	51.88	44.74	42.47	35.68	33.74	34.92	26.16	23.65
8	Molvom	74.63	77.79	67.93	66.75	69.67	60.75	60.47	66.30	54.60	56.56	58.37	49.24	43.20	36.68	34.23	38.27	26.33	24.50
Average *(ST)		**65.72**	**71.78**	**61.59**	**57.25**	**62.61**	**53.17**	**55.09**	**59.35**	**49.45**	**45.88**	**49.34**	**41.81**	**39.71**	**33.23**	**30.76**	**32.20**	**25.48**	**22.43**
Range (Depth)		46.52─81.24			44.13─70.53			35.55─66.30			32.27─58.37			23.65─44.35			19.05─38.70		
Average (Depth)		**66.36**			**57.68**			**54.63**			**45.68**			**34.56**			**26.70**		
Range **(LU)		44.13─81.24						32.27─66.30						19.05─44.35					
Average (LU)		**62.02**						**50.15**						**30.63**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.15 (b). Variation in beta glucosidase enzyme activity (μg PNP g^{-1} h^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	65.72^{a}	57.25^{a}	71.78^{a}	62.61^{a}	61.59^{a}	53.17^{a}
2	Pineapple	55.09^{b}	45.88^{b}	59.35^{b}	49.34^{b}	49.45^{b}	41.81^{b}
3	Paddy	39.71^{c}	32.20^{c}	33.23^{c}	25.48^{c}	30.76^{c}	22.43^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

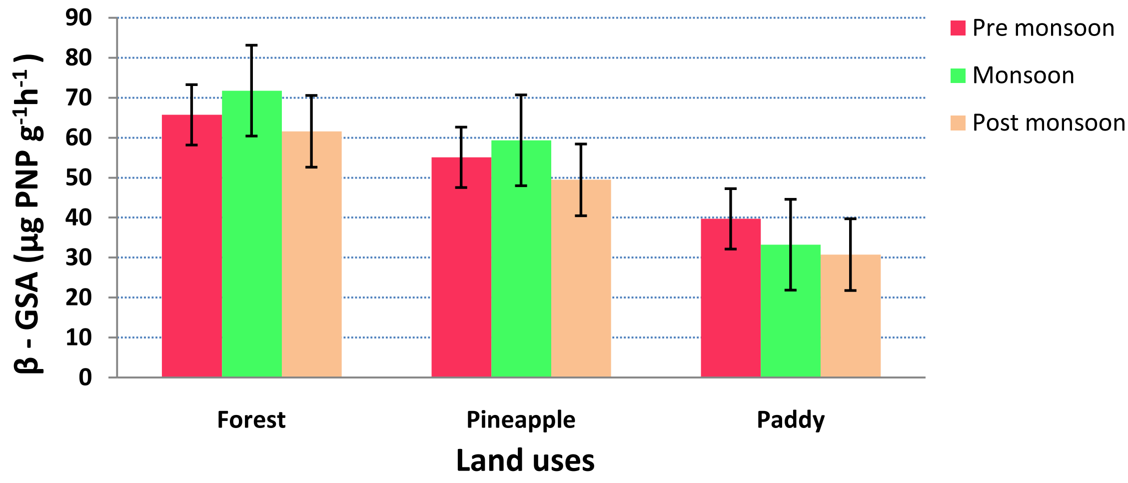


Fig 4.3 (a): β- Glucosidase activity in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

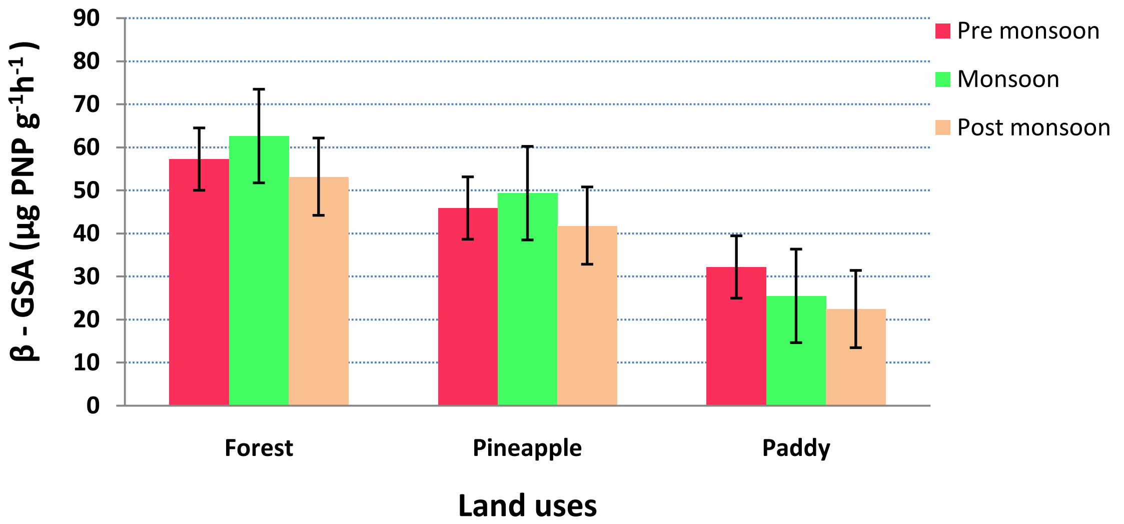


Fig 4.3 (b): β- Glucosidase activity in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

materials. The high MBC content and higher organic substrate represents high microbial activity which results in high enzymes activity with respect to β-glucosidase. Thus, high organic matter or high above and below ground substrate materials along with high MBC content in forest LUS can be attributed to corresponding increase in β-GSA compared to pineapple and paddy LUS. The intensive management practices under paddy decreases soil organic matter and regular removal of litter layer might have restricted the supply of substrate for microbes, thereby reducing β-GSA in paddy LUS. The lesser organic carbon content and the less availability of substrate materials at sub-surface soil layer may be attributed to low β-GSA at lower depth. Probably the moisture content in forest and pineapple LUS during monsoon was congenial for maximum microbial activity and thus secretion of more glucosidase enzyme. Decrease in soil moisture content in pre and post-monsoon season might have slowed down microbial activity as well as β-GSA. On the other hand, probably the moisture content in soil during pre-monsoon season in paddy LUS was suitable for maximum activity of microbes compared to monsoon season when the field experience submerged situation.

Corroborating the present findings, Meena and Rao (2021) reported significantly higher β-GSA (μg PNG g^{-1} h^{-1}) in Mixed Forest Cover (623.71 ± 5.75) than *P. juliflora*-dominated forest cover (398.40 ± 9.01), agricultural field (57.58 ± 0.94), and vegetable field (32.95 ±0.49), respectively. Silva *et al.* (2019) evaluated β-GSA under tropical dry native forest, protected area, scrub, and maize cultivated area; reported reduced activity under the cultivated field; and suggested a closed linking of β-glucosidase with SOC and SOM content. de Medeiros *et al*. (2015) demonstrated similar β-GSA among tropical dry forest and intercropping soils of Brazil with less aggressive management practices. The study also reported a reduced activity under semiarid ecosystems attributed due to the slow decomposition of MBC. Saplalrinliana *et al.* (2016) revealed the increased activity of glucosidase with the increase in length of the fallow phase in Mizoram and Nagaland condition; while conducting a study to assess whether the slash-burn practice (*Jhum*) induced disturbance on the above-ground biological inputs (plant biomass and forest floor litters, FFLs) had any influence on the soil processes in terms of soil enzyme activities. They have considered *Jhum* cycles of 5, 10 and 15 / 20 years. The higher activity of GSA is thought to be closely linked with the greater quantity and more complexity of substrates available in the longer fallow phase. Tomar and Baishya (2020) studied seasonality and moisture regime control soil respiration, enzyme activities, and soil microbial biomass carbon in a semi-arid forest of Delhi, India. However, they did not get significant seasonal variation in β-glucosidase activity unlike seasonal variation in dehydrogenase and phenol oxidase activity.

Acid phosphatase activity:

In soil ecosystems, phosphatase enzymes are supposed to play very crucial roles in P transformation. A close relationship with MBC content and PHA was recorded in the present investigation. Acid phosphatase activity (PHA) varied with the LUS (Table 4.16 a). Maximum PHA was recorded in forest LUS (100.87 μg PNP g^{-1} h^{-1}) and minimum in pineapple LUS (58.35 μg PNP g^{-1} h^{-1}). Paddy LUS exhibited more PHA (67.46 μg PNP g^{-1} h^{-1}) compared to pineapple. However, the PHA content ranged from 38.64 μg PNP g^{-1} h^{-1} in sub surface soils of pineapple LUS to as high as 185.60 μg PNP g^{-1} h^{-1} in surface soil of forest LUS.

Considering the depth, higher PHA was recorded in surface soils of all the LUS; that exhibited a decreasing trend with depth. Maximum PHA was recorded in surface soil of forest LUS (115.56 μg PNP g^{-1} h^{-1}) and minimum in sub-surface soils of pineapple LUS (53.03 μg PNP g^{-1} h^{-1}). Significant seasonal variation of PHA was observed among land uses (Table 4.16 b and Fig 4.4 a, Fig 4.4 b). In case of forest and pineapple LUS, PHA exhibited an increasing trend with onset of pre-monsoon shower in the month of May, which attained its peak in the monsoon season (August) and finally decreased in post-monsoon season *i.e.* in the month of November. On the other hand, highest PHA in case of paddy LUS was recorded in pre-monsoon season that gradually declined to post-monsoon through monsoon season. In the monsoon season, the variation of PHA was 151.43, 73.31 and71.65 μg PNP g^{-1} h^{-1} in forest, paddy and pineapple LUS respectively. Significant variation in PHA of surface soil of pineapple and paddy LUS was however not recorded in this season. Significant variation in PHA was recorded as 112.48, 87.28 and 63.60 μg PNP g^{-1} h^{-1} in forest, paddy and pineapple LUS during pre-monsoon season (Table 4.16 b) ; while during post-monsoon season, significantly different PHA was recorded as 82.79, 67.23 and 55.77 μg PNP g^{-1} h^{-1} in forest, paddy and pineapple LUS respectively.

The activity of phosphatase enzyme is involved in P-cycling and has also been reported to be governed by soil micro-climate and content of SOC and soil P. The high PHA activities in forest LUS may be due to higher organic carbon content along with the increased microbial population in forest LUS. Microbial immobilization induces P stress in soil and to compensate that temporary P- stress, phosphatase enzymes are secreted by plant roots as well as by P-solubilizing microorganisms. Acidic pH range of the LUS under study might have favoured high PHA. It is evident from present data that phosphatase activity decreased with soil depth and corresponded to SOC content and distribution of microorganisms in the soil profiles. Increased population of microorganisms during monsoon season can be attributed to higher secretion of acid phosphatase enzymes compared to pre and post-monsoon season.

Bhowmik *et al.* (2019) have reported the similar findings where they have revealed the trend of acid PHA in 0–15 cm soil depth as agroforestry > grassland > agriculture > eroded lands. In 15–30 cm soil depth also, soils from agroforestry land use had significantly higher alkaline and acid phosphatase activity as compared to the grassland and agricultural land use systems. They

Table 4.16 (a). Acid phosphatase enzyme activity of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Acid phosphatase (µg PNP g^{-1} h^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	123.30	185.60	94.10	93.56	123.68	72.87	74.32	81.15	64.95	58.95	63.47	51.21	98.56	87.21	73.95	75.48	68.55	63.05
2	Jharnapani	116.18	145.50	88.52	87.15	115.73	71.30	64.80	72.47	57.98	56.05	62.65	45.93	85.53	65.72	63.49	68.36	49.49	48.70
3	Khaibung	106.78	139.17	80.88	73.01	106.38	65.77	61.02	63.81	52.58	51.22	55.85	42.69	86.37	69.05	67.12	69.18	50.20	49.29
4	Kukidolong	103.93	137.12	68.13	66.90	103.22	53.54	52.01	62.72	43.80	49.07	55.45	39.65	74.66	64.96	62.74	64.14	46.74	45.91
5	Kupuhe	100.42	136.20	62.08	63.00	99.60	51.44	51.88	62.65	42.76	48.48	54.75	38.64	72.26	63.73	61.73	63.40	44.54	44.91
6	Maova	109.85	144.89	83.81	78.11	110.56	69.81	63.98	68.94	54.10	52.28	57.45	42.93	89.35	74.76	68.32	69.46	60.93	50.60
7	Medziphema	117.78	157.24	91.21	87.57	116.07	71.73	66.40	75.98	64.76	56.86	63.01	47.19	93.70	75.52	69.21	70.04	61.36	53.38
8	Molvom	121.62	165.68	93.62	92.08	122.67	72.41	74.41	85.47	65.26	60.67	66.49	51.70	97.78	85.54	71.19	71.43	63.93	62.42
Average *(ST)		**112.48**	**151.43**	**82.79**	**80.17**	**112.24**	**66.11**	**63.60**	**71.65**	**55.77**	**54.20**	**59.89**	**44.99**	**87.28**	**73.31**	**67.22**	**68.94**	**55.72**	**52.28**
Range (Depth)		62.08–185.60			51.44–123.68			42.76–85.47			38.64–66.49			61.73–98.56			44.54–75.48		
Average (Depth)		**115.57**			**86.17**			**63.68**			**53.03**			**75.94**			**58.98**		
Range **(LU)		51.44–185.60						38.64–85.47						44.54–98.56					
Average (LU)		**100.87**						**58.35**						**67.46**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.16 (b). Variation in acid phosphatase enzyme activity (µg PNP g^{-1} h^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	112.48^{a}	80.17^{a}	151.43^{a}	112.24^{a}	82.79^{a}	66.11^{a}
2	Pineapple	63.60^{b}	54.20^{b}	71.65^{b}	59.89^{b}	55.77^{b}	44.99^{b}
3	Paddy	87.28^{c}	68.94^{c}	73.31^{bc}	55.72^{bc}	67.22^{c}	52.28^{bc}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

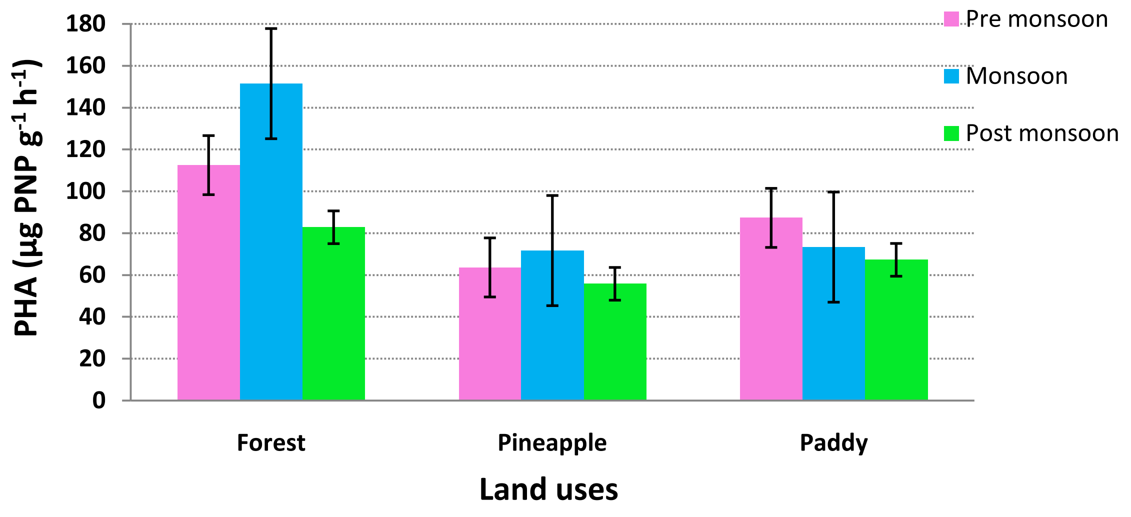


Fig 4.4 (a): Acid phosphatase activity in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

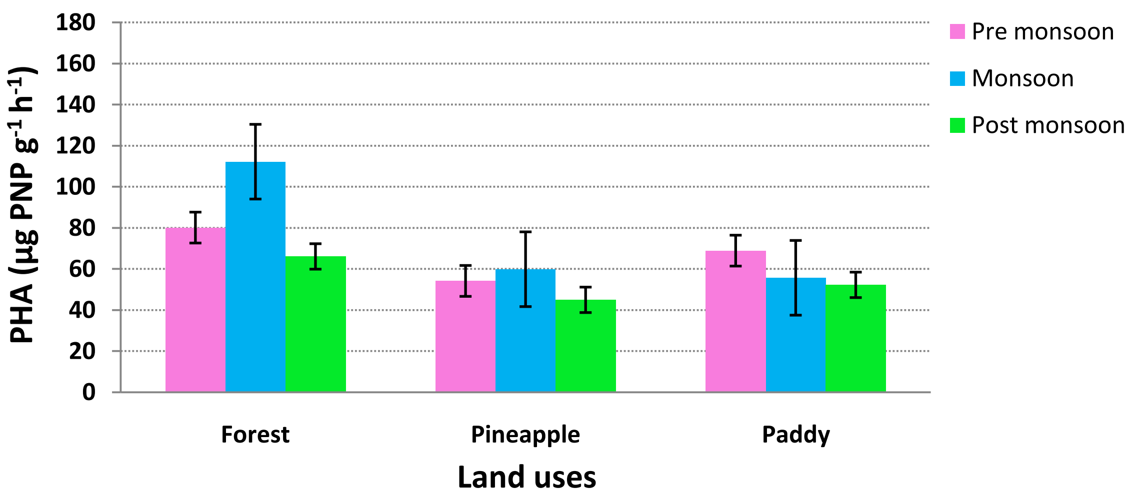


Fig 4.4 (b): Acid phosphatase activity in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

opined that the phosphatase enzymes activity is not only linked to the synthesis of microbial cells but also to the mineralization of organic P to inorganic P. They have also reported decreased phosphatase activity with soil depth that corresponded to SOC content and distribution of microorganisms in the soil profiles. In corroborating with the present findings, Meena and Rao (2021) have reported high acid phosphatases (µg PNP g^{-1} h^{-1}) under mixed forest cover (1051.98 ± 65.40) followed by *P. juliflora* forest cover (287.18 ± 6.93), vegetable field (95.22 ± 4.54), and agricultural fields (68.02 ±4.23), respectively. They have reported significant variation of activity of acid phosphatases among forest land uses (MFC, PFC). However, no significant difference was determined under cultivated land uses (AF, VF) which is in conformity with the present findings. Verma *et al.* (2017) reported similar results. Supporting the present findings, they have reported significantly higher PHA in a treatment comprising of inorganic fertilizer, FYM as well as lime that maximized the crop growth and enhanced the accumulation of SOC. Besides this, the microbial activity was also highest in the combination leading possibly to P stress in the soil, thereby enhancing the phosphatase released by the microorganism to counteract the deficiency and make P available for the crops.

Bacterial population:

A close relationship with the MBC content with bacterial population was evident during the present investigation in regard to similar trend of variation of both the parameters in seasons and depths under different LUS. Maximum number of bacteria was counted under forest LUS (58.05 cfu x 10^5 g^{-1}) followed by pineapple (41.32 cfu x 10^5 g^{-1}) and paddy LUS (27.23 cfu x 10^5 g^{-1}) across the seasons and depths (Table 4.17 a). Bacterial population ranged from 5.40 cfu x 10^5 g^{-1} in sub-surface soils of paddy LUS to 82.0 cfu x 10^5 g^{-1} in surface soil of forest LUS. Number of bacterial cells decreased with increasing depth under all the different LUS. On an average, maximum number of bacteria were recorded in surface soil of forest LUS (64.83 cfu x 10^5 g^{-1}) and minimum in sub-surface soil of paddy LUS (16.94 cfu x 10^5 g^{-1}). Significant seasonal variation of bacterial population was recorded during the period of investigation where bacterial population in monsoon season > pre-monsoon season > post-monsoon in case of both forest and pineapple LUS. On the other hand, the trend of seasonal change of bacterial population in paddy LUS was pre-monsoon > monsoon > post-monsoon (Table 4.17 b). In the monsoon season, significant variation in bacterial population was recorded; maximum being in forest (70.96 cfu x 10^5 g^{-1}) followed by pineapple (57.54 cfu x 10^5 g^{-1}) and paddy LUS (41.29 cfu x 10^5 g^{-1}) (Table 4.17 b and Fig 4.5 a, Fig 4.5 b). In pre-monsoon season the bacterial population was 64.67 cfu x 10^5 g^{-1} , 47.08 cfu x 10^5 g^{-1} and 50.04 cfu x 10^5 g^{-1} in forest, pineapple and paddy LUS respectively. Post-monsoon season recorded minimum variation in bacterial count as 58.88 cfu x 10^5 g^{-1} , 40.17 cfu x 10^5 g^{-1} and 21.21 cfu x 10^5 g^{-1} in forest, pineapple and paddy LUS respectively. In pre-monsoon season, however, the difference in bacterial population between pineapple and paddy LUS was non- significant in both the depths.

It is known that organic matter introduced to soil stimulates soil microbial populations and soil biological activity. Addition of organic matter in the form of leaf litter and below ground root biomass in forest LUS might have provided adequate biomass as a feed for the microbes that supplied large amounts of readily available C, needed for bacterial metabolism and corresponding increase in bacterial population in the soil, as evident in the present study. The high organic carbon content might have also resulted in increased nutrients in the soil, which might have acted as instant energy source for quick multiplication of bacteria under forest and pineapple LUS. The number of soil bacteria in the cultivated land; paddy LUS in particular was lower than that in the forest and pineapple LUS because in forest ecosystems most of the organic matter produced by the vegetation is returned to the soil, in contrast to agricultural land where most of the vegetation is removed for human

Table 4.17 (a). Bacterial population in soils in relation to land use, sampling time and depth

Sl No.	Name of village	Bacterial population (cfu x10^5 g^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	76.00	82.00	65.33	62.00	77.33	43.00	55.00	66.33	42.33	40.67	48.00	33.33	58.33	50.00	23.99	35.67	19.00	9.44
2	Jharnapani	66.00	72.67	60.33	55.33	67.33	41.33	45.33	57.00	40.33	32.67	40.00	28.00	45.33	35.67	20.99	27.67	11.67	6.01
3	Khaibung	58.33	64.00	56.67	43.00	58.00	35.67	44.33	54.67	38.00	31.00	37.67	24.67	48.67	41.33	21.23	30.33	12.33	7.30
4	Kukidolong	56.67	63.67	52.00	42.00	55.00	32.00	41.33	48.67	36.00	29.67	36.00	24.33	45.00	34.00	20.95	23.00	11.33	5.87
5	Kupuhe	55.33	61.67	49.33	37.00	52.00	31.33	38.33	45.33	35.00	28.33	34.67	22.00	44.00	33.00	15.99	21.00	10.67	5.40
6	Maova	61.67	66.67	58.67	50.33	59.00	40.67	45.00	55.67	39.67	31.33	37.67	25.67	51.67	42.33	21.96	33.00	13.67	7.76
7	Medziphema	68.33	75.33	64.00	57.67	69.67	41.67	52.33	64.33	42.33	37.33	46.33	31.33	53.67	46.00	22.10	33.67	14.00	8.66
8	Molvom	75.00	81.67	64.67	61.67	74.67	42.67	55.00	68.33	47.67	41.00	49.00	34.33	53.67	48.00	22.45	34.00	16.00	9.11
Average *(ST)		**64.67**	**70.96**	**58.88**	**51.13**	**64.13**	**38.54**	**47.08**	**57.54**	**40.17**	**34.00**	**41.17**	**27.96**	**50.04**	**41.29**	**21.21**	**29.79**	**13.58**	**7.44**
Range (Depth)		49.33–82.00			31.33–77.33			35.00–68.33			22.00–49.00			15.99–58.33			5.40–35.67		
Average (Depth)		**64.83**			**51.26**			**48.26**			**34.38**			**37.51**			**16.94**		
Range **(LU)		31.33–82.00						22.00–68.33						5.40–58.33					
Average (LU)		**58.05**						**41.32**						**27.23**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.17 (b). Variation in bacterial population (cfu x 10^5 g^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	64.67^{a}	51.13^{a}	70.96^{a}	64.13^{a}	58.88^{a}	38.54^{a}
2	Pineapple	47.08^{b}	34.00^{b}	57.54^{b}	41.17^{b}	40.17^{b}	27.96^{b}
3	Paddy	50.04^{bc}	29.79^{bc}	41.29^{c}	13.58^{c}	21.21^{c}	7.44^{c}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

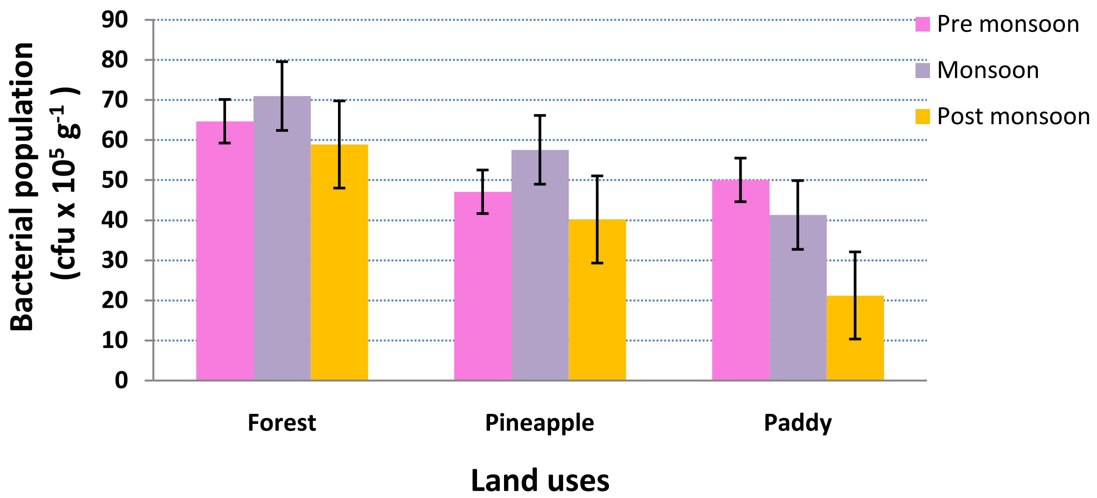


Fig 4.5 (a): Bacterial population in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

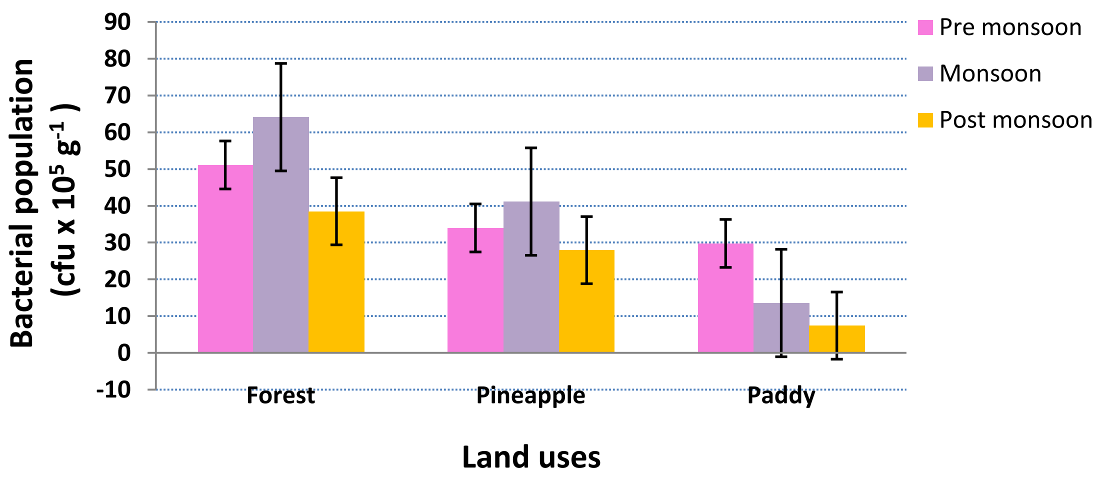


Fig 4.5 (b): Bacterial population in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

and animal consumption, leading to smaller carbon source in the form of organic matter and subsequent decrease in bacterial population. Microbial counts generally higher in the surface soil because in the surface soil high organic matter along with adequate moisture supply is acted upon by microorganisms to decompose the complex organic residues into simpler forms that facilitate rapid multiplication of microorganisms including bacteria. Moreover, less population of bacteria in sub-surface soil may be attributed to fewer amounts of minerals, low oxygen content and high carbon-dioxide concentration. Microbial activity becomes ideal at near field capacity. In contrast, flooding or water saturation over long periods leads to poor aeration and causes reduction in aerobic bacterial population. Peak in bacterial population in monsoon season may be attributed to favourable soil moisture and temperature that coincide with greater microbial population and litter decomposition rate is at its peak. Sudden outburst of bacterial population in the monsoon season probably because other organism like fungi are the inferior competitor. On the other hand, least population counts in post-monsoon or winter season in the present study may be due to low ambient temperature and physiological water stress that hindered the growth and activities of bacteria.

Corroborating with the present findings, Lyngdoh and Karmakar (2018) reported highest bacterial count in soils of forest LUS followed by horticultural and cultivated LUS from a study conducted in Ri-Bhoi district of Meghalaya, India. Significant variation of soil microbial population with depth was also reported, where population of bacteria was higher in the surface than sub-surface soil. They have reported a similar trend of seasonal variation of bacteria in which the population increased from pre-monsoon season and attained a peak in monsoon and decreased afterwards towards post-monsoon. They have related population peak attained during monsoon season to the greater availability of nutrients and other favourable conditions such as moisture and diurnal soil temperature fluctuations at mesophilic range. Kavitha *et al.* (2020)

reported increased bacterial population in the soils of forest ecosystem especially compared to the agro ecosystem and polluted soil of Nilgiri biosphere of Southern India. According to them, soil sample taken during pre-rainy and post-rainy season exhibited more population in all ecosystems than sample taken during summer and winter. The increase in the population of bacteria after raining may be due to the favourable micro-climatic conditions *viz*., moisture content, temperature, active litter decomposition. Onyekwelu *et al.* (2011) reported significantly higher bacteria population at 0–15 cm than 15–30 cm in primary forest followed by *Gmelina* plantation and degraded forest ecosystem. Agricultural land recorded lowest population. They have reported increased bacterial population with increase in rainfall as evidenced by the significantly increasing trend of its population from March (peak of dry season) to September (peak of rainy season) indicating that the drier the soils, the lower the bacteria population. In conformity with the present findings, Wani *et al.* (2018) reported highest bacterial count (cfu × 10^6 g^{-1} soil) in forest land use with mean value of (178.46) followed by pasture (173.86), horticulture (vegetables) (168.46), agri-horti (158.53), horticulture (fruits) (117.86); while, the lowest (68.60) was recorded in agriculture land use. They have explained the reason of low number of soil bacteria in the cultivated land than that in the other land use systems as the presence of larger carbon source in the form of organic matter present in the forest and pastureland. Similar results that bacterial count significantly affected by different land use system and conditions, and the highest bacterial count was reported by Asadu *et al.* (2015) in surface soils of forest land use, grassland and lowest in cultivated land. Tangjang and Arunachalam (2008) have reported low bacterial counts in sub-surface soils of traditional agroforestry systems in Arunachal Pradesh, North East India. They have also reported maximum bacterial population during rainy season than spring and post-rainy seasons. According to them, during winter, low moisture content in soil slowed down microbial activity and decomposition of organic matter resulting in low microbial population. Das and Dkhar (2012) similarly reported maximum bacterial population in organically treated soybean with vermicompost and FYM that provided adequate biomass as a feed for the microbes and help in increasing microbial population in the soil. Findings of Bhowmik *et al.* (2019) supported the present findings as they have reported high bacterial counts in surface soils of different land use systems from a study conducted in the Shiwaliks of North Western India.

4.4. Carbon fractions, carbon stock and carbon management index under different land uses

Organic carbon:

The presence of organic carbon (OC) in soil influences physico-chemical and biological properties. Soil organic carbon (SOC) has an array of effects on soil and crop parameters such as quality, fertility and productivity. Land use and management practices have a varied effect SOC, based on biomass production (above and belowground) and its addition to the soil, local climate, and soil type. Differential amount of OC content was recorded under three LUS during the period of the investigation. Across the different season and depth, forest LUS recorded maximum average content of OC (16.71 g kg^{-1}) followed by pineapple (14.23 g kg^{-1}) and paddy LUS (10.70 g kg^{-1}). The range of OC varied from 12.93–19.32 g kg^{-1}, 10.85–16.93 g kg^{-1} and 8.67–12.60 g kg^{-1} in forest, pineapple and paddy LUS respectively (Table 4.18 a). Gradual decline in OC content along the depth was recorded in all the LUS; maximum being recorded in surface soil of forest LUS (17.84 g kg^{-1}) and minimum (10.08 g kg^{-1}) was recorded in sub-surface soil of paddy LUS. Significant seasonal variation in OC content among all the LUS was recorded during three different seasons (Table 4.18 b and Fig 4.6 a, Fig 4.6 b). Maximum variation in OC was recorded during post-monsoon season (18.69, 15.61 and 12.09 g kg^{-1}) in forest, pineapple and paddy LUS respectively followed by pre-monsoon

Table 4.18 (a). Organic carbon content of soils in relation to land use, sampling time and depth

Sl No.	Name of village	Organic carbon (g kg^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	19.10	18.73	19.32	16.49	16.17	17.67	16.63	15.87	16.90	14.47	14.03	14.93	11.48	11.23	12.60	10.40	10.33	11.20
2	Jharnapani	17.77	17.07	18.87	15.23	14.75	17.20	15.17	15.10	16.27	13.93	13.40	14.73	11.20	10.53	12.00	9.57	9.37	10.77
3	Khaibung	17.20	16.83	18.57	14.83	13.98	16.28	14.03	13.97	14.50	12.40	12.53	13.18	11.22	10.77	12.03	9.63	9.57	10.80
4	Kukidolong	17.10	16.13	18.13	14.66	13.77	16.13	13.87	13.80	14.37	12.23	11.70	12.93	10.90	10.30	12.00	9.18	9.37	10.18
5	Kupuhe	16.17	15.67	17.80	14.23	12.93	15.78	12.37	11.75	14.23	11.47	10.85	12.20	10.73	10.17	11.83	8.67	9.33	9.27
6	Maova	17.27	16.85	18.60	15.23	14.50	16.47	14.88	14.47	15.01	12.70	12.80	13.30	11.30	10.77	12.03	9.97	10.15	10.83
7	Medziphema	18.10	17.70	18.95	15.27	15.70	17.30	16.38	15.69	16.68	14.00	13.92	14.77	11.30	10.80	12.07	10.20	10.23	11.13
8	Molvom	19.04	17.90	19.26	16.10	15.97	17.47	16.80	16.03	16.93	15.20	14.37	15.43	11.43	10.83	12.15	10.37	10.23	11.18
Average *(ST)		**17.72**	**17.11**	**18.69**	**15.26**	**14.72**	**16.79**	**15.02**	**14.59**	**15.61**	**13.30**	**12.95**	**13.93**	**11.20**	**10.68**	**12.09**	**9.75**	**9.82**	**10.67**
Range (Depth)		15.67 - 19.32			12.93- 17.67			11.75 - 16.93			10.85 - 15.43			10.17 - 12.60			8.67 - 11.20		
Average (Depth)		**17.84**			**15.59**			**15.07**			**13.39**			**11.32**			**10.08**		
Range **(LU)		12.93- 19.32						10.85-16.93						8.67-12.60					
Average (LU)		**16.71**						**14.23**						**10.70**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.18 (b). Variation in organic carbon content (g kg^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	17.72^{a}	15.26^{a}	17.11^{a}	14.72^{a}	18.69^{a}	16.79^{a}
2	Pineapple	15.02^{b}	13.30^{b}	14.59^{b}	12.95^{b}	15.61^{b}	13.93^{b}
3	Paddy	11.20^{c}	9.75^{c}	10.68^{c}	9.82^{c}	12.09^{c}	10.67^{c}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

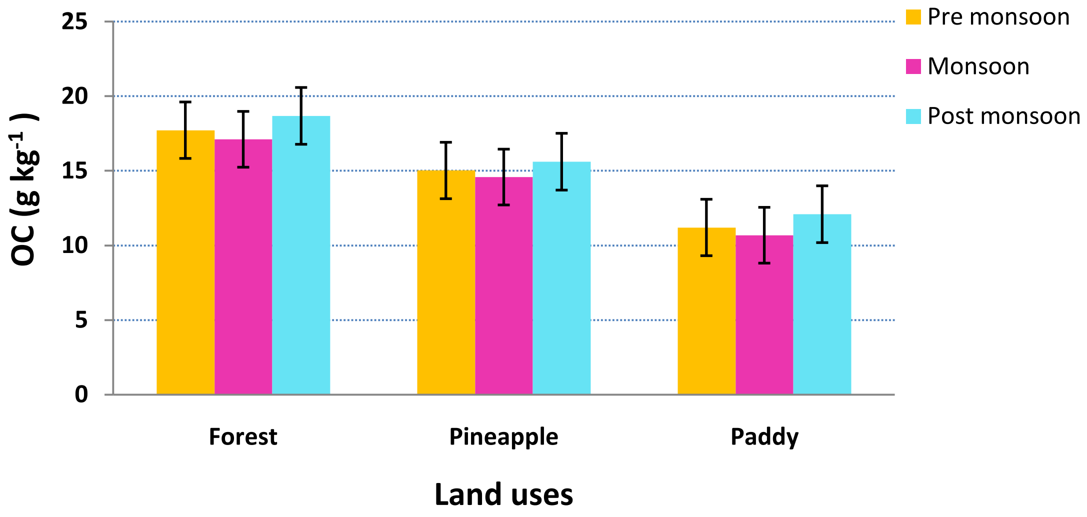


Fig 4.6 (a): Organic carbon content in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

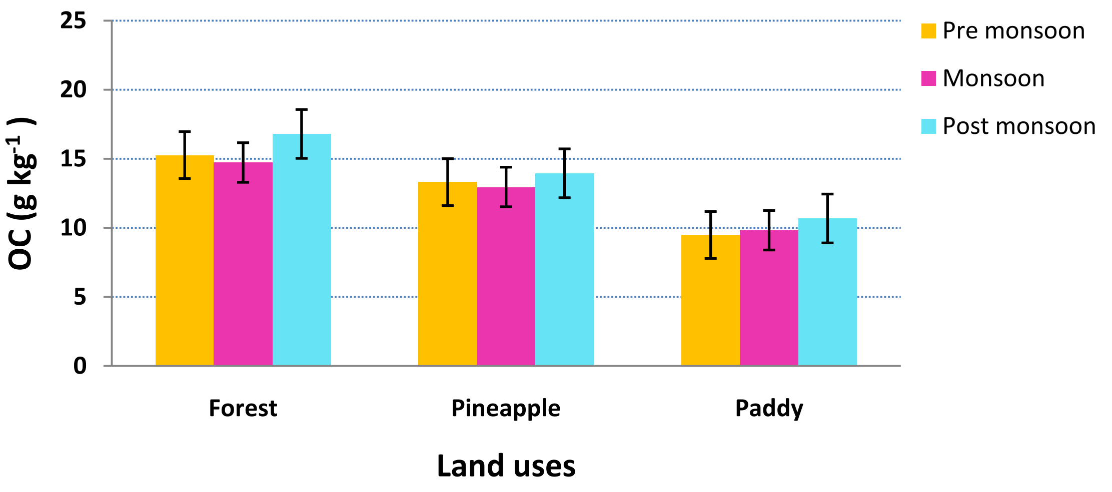


Fig 4.6 (b): Organic carbon content in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

season (17.72, 15.02 and 11.20 g kg^{-1}) in forest, pineapple and paddy LUS respectively. Least but significant variation was recorded in monsoon season (17.11, 14.59 and 10.68 g kg^{-1}) in forest, pineapple and paddy LUS respectively.

Land use and management indicates whether the soil will be a source or a sink of atmospheric carbon. Generally, land management practices with less soil disturbance increase soil organic carbon accumulation. Soil organic carbon loss also occurs when native forest ecosystems are altered to cultivated systems. The higher OC under forest LUS may be due to abundant and varied above ground and below ground plant biomass availability. In forest soils, the annual addition of organic matter from leaf litter stays in the soil due to absence of any disturbance. The enhanced soil microbial biomass carbon (SMBC) because of abundant litter (substrate) and nutrient availability also might have added to increase OC content in forest soils. Conversion of forest lands to plantation and agricultural purposes decreases soil carbon because of soil erosion and site disturbance that leads to exposure of litter material for decomposition. The less OC content in pineapple plantation and paddy LUS may be attributed to that fact. Moreover, less addition of litter material in pineapple LUS compared to forest LUS and removal of straws and stubbles after the harvest of paddy might have lead to less OC content in the later LUS. In addition to that, various agricultural operation under paddy LUS might have accelerated the decomposition of organic matter and corresponding decrease in OC content.

The deposition of high amount of organic residues in the surface soil of different LUS may be attributed to high OC content in surface soil compared to sub-surface soil layers. In addition to that, high microbial biomass carbon content in the surface soils of different LUS owing to favourable micro-climatic condition of surface soil layer might have increased OC content in surface soil; as evident from the present study. In winter or in case of post-monsoon season, because of low temperature, there is reduced or slowed rate of residue decomposition, which adds to higher carbon values. The low temperature and water stress of winter / post-monsoon reduces microbial activity in soil and mineralization or decomposition of organic matter and, thus, preserves organic matter / organic carbon compared to summer condition.

Chase and Singh (2014) reported similar findings while studying soil nutrients and fertility in traditional LUS of Nagaland. They have reported higher SOC content in natural forest, followed by *Jhum* fallow and least in soils of paddy fields. The lowest content of SOC in soils of the paddy field was attributed to the rapid decomposition and mineralization of SOM following the clearing of fields of the harvested crops and burning. While, less exposure of forest soils to tilling, other disturbances and erosion might have recorded high OC in forest soils. Likewise, in conformity with the present findings, Kenye *et al.* (2019) have revealed that forest land use recorded the highest mean SOC concentration and lowest in the bamboo plantation in Mizoram. Both SOC concentration and SOC stock decreased with increasing soil depth. Similar findings were reported by Maqbool *et al.* (2017) who reported conspicuous variation of SOC content among forest land use and agriculture land use in Ganderbal, J&K. Forest land use exhibited greater SOC content than agriculture with mean values of 23.68 and 4.35 g kg^{-1} respectively.

In corroborating with present findings, Amgain *et al*. (2020) reported higher percentage of organic matter in upper surface in the apple growing areas of Mustang district of Nepal that decreased with increasing the soil depth, stating the reason as application of manure and in-situ incorporation of plant residues on surface layer. Hoque *et al*. (2020) also reported similar findings related to deceasing organic matter content with increasing depth from a study conducted in Bangladesh.

Similar seasonal variation in SOC content was reported by Dluzewski *et al.* (2019); higher SOC content in the surface horizon for 55 and 13 year old forest occurs in the autumn and winter months, while it is lower in spring and summer. Dry meteorological conditions in winter months those received small amount of precipitation and lower soil moisture have been attributed to reduce the SOC accumulation in surface horizons. Salim *et al.* (2015) reported maximum percentage of OC under natural forest during winter season and the minimum under grassland in the summer season attributing declining trend of OC during summer season to increase in temperature along with high decomposition rates (microbial respiration). They have revealed that natural forest soils had the maximum content of organic carbon in all the seasons and the minimum under grassland in all the seasons; which may be because forests have grater canopies and provided the litter in larger quantity as compared to grasslands therefore, accumulation of carbon was higher. Omer *et al.* (2018) reported highest SOM in the winter and lowest in the summer from an experiment conducted in three crop management systems including alfalfa (*Medicago sativa*), upland cotton (*Gossypium hirsutum*), and pecan (*Carya illinoinensis*).

Total organic carbon:

Total organic carbon (TOC) is referred to as the amount of carbon bound in organic compounds in soil. These organic materials can be derived from endogenous and exogenous sources. For instance, decaying organic materials (*e.g.*, cellulose, hemicellulose, glucose, citric, amino, fulvic, humic acid, humin) and by-products of metabolic activities of microbial or living organisms (*e.g.*, suberans, murein, chitin, glomalin) can be referred to as the organic materials derived by endogenous processes. Soil amendments such as manures, composts, biosolids, fertilizers (*e.g.*, urea), organic dyes (*e.g.*, X-3B red dye), and insecticide or pesticides (*e.g.*, DDT) can be identified as exogenous organic carbon compounds (Ramesh *et al.*, 2019). The TOC content exhibited similar trend with that of OC content during the present investigation. Maximum TOC content was recorded in forest LUS (20.36 g kg^{-1}) irrespective of depths and seasons (Table 4.19 a). Pineapple LUS recorded less TOC content (17.38 g kg^{-1}) compared to forest. Least TOC content was recorded in paddy LUS (13.87 g kg^{-1}). The range of TOC varied from 11.50 g kg^{-1} in sub-surface soils of paddy LUS to a maximum of 24.14 g kg^{-1} in surface soil of forest LUS. A similar decreasing trend of TOC content with increasing depth was recorded under all LUS. Surface soil of forest LUS recorded maximum content (21.56 g kg^{-1}) of TOC while, minimum TOC content (13.16 g kg^{-1}) was recorded in sub-surface soil of paddy LUS. A significant variation in TOC content was recorded over three different seasons (Table 4.19 b and Fig 4.7 a, Fig 4.7 b). Maximum TOC content with significant variation was observed in post-monsoon season (22.67, 19.34 and 15.56 g kg^{-1}) in forest, pineapple and paddy LUS respectively followed by pre-monsoon season (21.97, 18.38 and 14.46 g kg^{-1}) in forest, pineapple and paddy LUS respectively. In monsoon season it was 20.04, 17.41 and 13.72 g kg^{-1} in forest, pineapple and paddy LUS respectively.

The high TOC content in forest LUS can be attributed to the recovery of above and below ground biomass which is significantly higher than in pineapple and paddy LUS. The litter deposition encourages turn over combined with a higher soil moisture content which is high due to the canopy provided by the trees found in forest LUS. In addition to this, minimal disturbances on soil surfaces encourage microbial activity which increases TOC in the soil. Total organic carbon was lower in paddy LUS compared to other two LUS. This may be due to the tillage practices that destroy soil aggregation and exposes organic matter to factors that encourage faster decomposition rate to carbon inputs. Moreover, the harvesting of above ground biomass for animal feed instead of leaving it as stubble may also have resulted in low TOC content. More litter inputs in the surface soil in each LUS might be the reason of higher TOC content in surface layer of soil. In August (monsoon season), the hot and rainy days, might have provided the proper conditions for organic carbon

Table 4.19 (a). Total organic carbon content of the soils in relation to land use, sampling time and depth

Sl No.	Name of village	Total organic carbon (g kg^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	23.02	22.10	24.14	21.13	19.27	21.97	20.55	19.04	21.27	17.67	17.23	18.70	15.38	14.80	16.73	13.53	13.35	15.43
2	Jharnapani	22.38	20.40	23.13	19.43	17.25	21.53	18.47	17.97	20.27	17.00	15.90	18.03	14.00	13.27	15.12	12.77	12.20	13.97
3	Khaibung	21.63	19.03	22.07	18.97	16.58	20.17	16.83	16.70	17.90	15.07	15.03	16.07	14.50	13.47	15.67	12.77	12.47	14.02
4	Kukidolong	21.50	18.57	21.27	18.90	16.40	19.47	16.40	15.93	17.37	14.33	14.10	15.97	13.53	13.13	15.03	12.67	11.90	13.85
5	Kupuhe	20.03	17.70	21.10	17.82	15.97	18.53	15.07	13.85	16.97	13.40	12.78	15.37	13.17	12.33	13.77	12.15	11.50	12.53
6	Maova	21.87	20.08	22.87	19.35	16.70	20.40	17.38	17.10	18.21	16.03	15.47	16.15	14.70	13.83	15.93	12.90	12.50	14.10
7	Medziphema	22.39	20.97	23.30	19.70	18.17	21.62	20.47	18.75	21.12	17.60	16.82	18.43	15.17	14.20	16.00	13.00	12.67	14.13
8	Molvom	22.90	21.43	23.47	20.27	18.83	21.69	21.83	19.90	21.57	19.30	17.50	19.20	15.25	14.73	16.20	13.03	13.23	15.20
Average *(ST)		**21.97**	**20.04**	**22.67**	**19.45**	**17.40**	**20.67**	**18.38**	**17.41**	**19.34**	**16.30**	**15.60**	**17.24**	**14.46**	**13.72**	**15.56**	**12.85**	**12.48**	**14.15**
Range (Depth)		17.70–24.14			15.97–21.97			13.85–21.83			12.78–19.30			12.33–16.73			11.50–15.43		
Average (Depth)		**21.56**			**19.17**			**18.37**			**16.38**			**14.58**			**13.16**		
Range **(LU)		15.97–24.14						12.78–21.83						11.50–16.73					
Average (LU)		**20.36**						**17.38**						**13.87**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.19 (b). Variation in total organic carbon content (g kg^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	21.97^{a}	19.45^{a}	20.04^{a}	17.40^{a}	22.67^{a}	20.67^{a}
2	Pineapple	18.38^{b}	16.30^{b}	17.41^{b}	15.60^{b}	19.34^{b}	17.24^{b}
3	Paddy	14.46^{c}	12.85^{c}	13.72^{c}	12.48^{c}	15.56^{c}	14.15^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

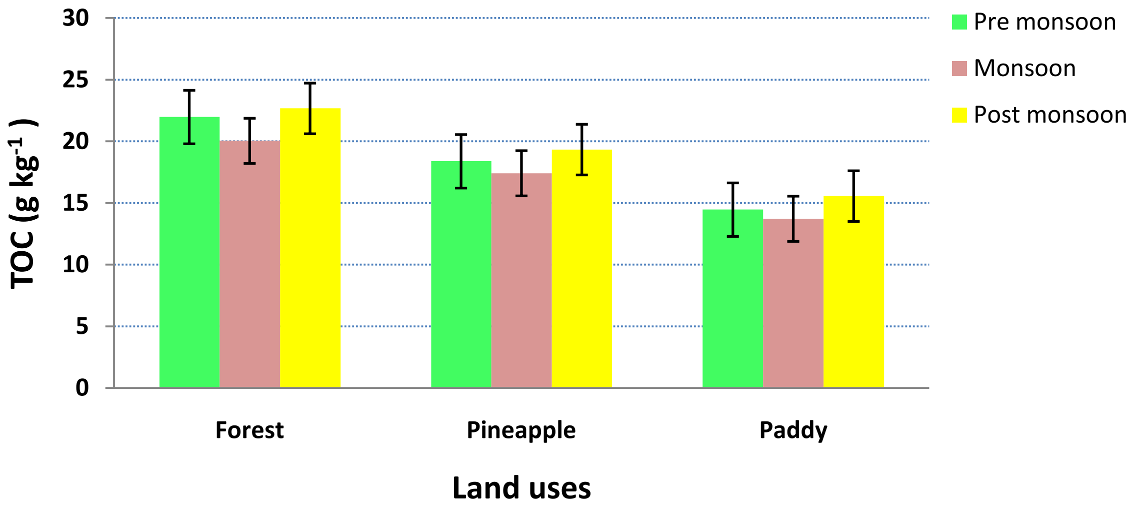


Fig 4.7 (a): Total organic carbon content in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

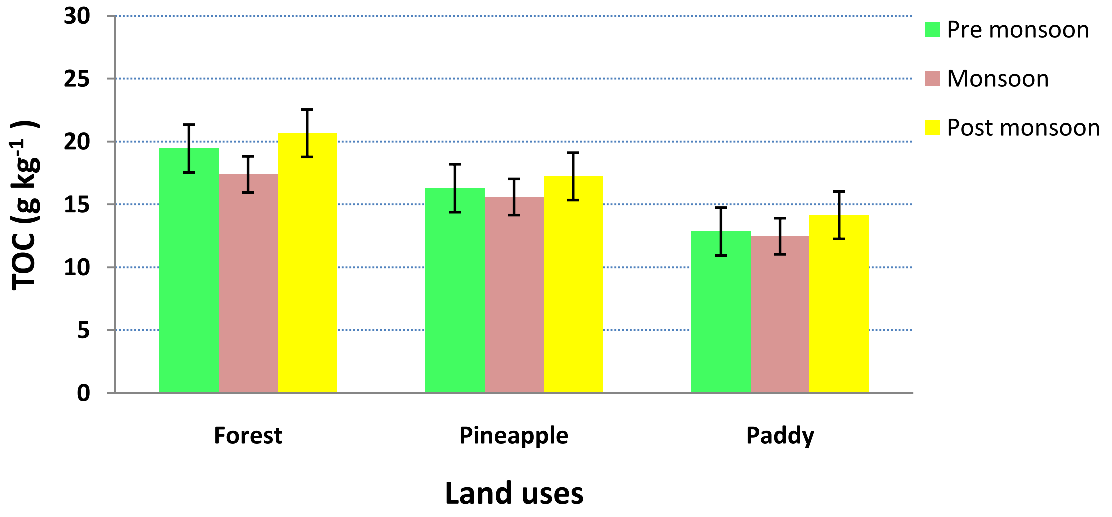


Fig 4.7 (b): Total organic carbon content in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

mineralization and decomposition with elevated microbial population, and, thus, the content of total organic carbon reduced slightly in August compared with that in November (post-monsoon) and May (pre-monsoon) when mineralization was less owing to low soil temperature and moisture condition.

In conformity with the present findings, Katti *et al.* (2020) reported significantly higher mean value of TOC in the soil under horticultural land use (arecanut and coconut land use system) and the lowest mean value of TOC content was reported under agricultural land use *i.e.* maize land use system. They have also reported higher TOC content in the surface layer that decreased with an increase in depth. Similar findings were reported by Sainepo *et al*. (2018), where they have reported significantly higher mean values of TOC in shrub lands than grasslands and barelands. In corroborating with the present findings, Meetei *et al.* (2017) reported highest accumulation of TOC in forest which was statistically at par with grassland. They have reported that TOC of *Jhum* land was also statistically at par with the grassland, while cultivated land showed significantly lowest value of TOC under different land use types in Hilly ecosystems of Manipur. Sahoo *et al.* (2019) reported similar findings of decreasing average TOC content in different land use in the order: forest > current *Jhum* > agroforestry > wetrice cultivation > *Jhum* fallow > plantation > grassland with higher accumulation of soil organic carbon in the top layers of soil of all LUS that decreased with increasing soil depth .They have attributed a near-equilibrium between C inputs and C losses in undisturbed ecosystems to higher TOC content in forest land use and its recalcitrant nature that prevented microbial decomposition.

Zhou *et al.* (2019) have reported similar findings of higher TOC content in surface layer of soil. A Similar trend of seasonal variation in TOC content was reported by Luo *et al.* (2014) from a study on accumulation and seasonal dynamic of the soil organic carbon in wetland of the Yellow River Estuary, China. They have reported higher TOC contents in October than that in both

May and August under different wetlands. They found that, on the whole, the TOC content of surface soils in October was significantly higher than that in May and August.

Permanganate oxidizable carbon:

Labile carbon, called as extractable organic carbon, is referred to as a primary energy source that can be readily degradable or consumed quickly (hours-weeks) by soil microorganisms. It is also identified as a short-lived carbon pool. For instance, simple sugars (*i.e*., glucose, fructose) and protein degradation products (*i.e*., amino acids) are labile carbon compounds. The labile fractions of soil C are often termed the active C pool, to distinguish it from the bulk of the C, which belongs to a highly recalcitrant or passive C pool that is only very slowly altered by microbial activities. A similar trend of variation of permanganate oxidizable carbon (POXC) with that of OC and TOC under different LUS was observed in the present investigation as expected. Forest LUS recorded highest POXC (0.429 g kg^{-1}) followed by pineapple (0.338 g kg^{-1}) and paddy LUS (0.215 g kg^{-1}) across the seasons and depths (Table 4.20 a). It was estimated that POXC constituted 2.1%, 1.9% and 1.5% of TOC content in under forest, pineapple and paddy LUS. Wide range of labile carbon was recorded under different LUS from as low as 0.126 g kg^{-1} in the sub-surface soil of paddy LUS to as high as 0.596 g kg^{-1} in the surface soil of forest LUS. Content of POXC was found high in the surface soils of all the LUS that exhibited a decreasing trend with increasing depth. Depth wise, maximum mean POXC (0.478 g kg^{-1}) was recorded in surface soil of forest LUS; while average minimum POXC was recorded in sub-surface soils of paddy LUS (0.184 g kg^{-1}) irrespective of seasons. Significant seasonal variation was recorded with maximum variation during post-monsoon season (0.543, 0.422 and 0.341 g kg^{-1}) in forest, pineapple and paddy LUS respectively (Table 4.20 b and Fig 4.8a, Fig 4.8 b) followed by pre-monsoon (0.468, 0.380 and 0.202 g kg^{-1}) in forest, pineapple and paddy LUS, respectively. Monsoon

Table 4.20 (a). Permanganate oxidizable carbon content of soils in relation to land use, sampling time and depth

Sl No.	Name of village	POXC (g kg^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	0.486	0.456	0.596	0.396	0.383	0.465	0.443	0.366	0.477	0.332	0.292	0.359	0.225	0.215	0.389	0.163	0.163	0.284
2	Jharnapani	0.475	0.434	0.536	0.372	0.337	0.442	0.374	0.354	0.453	0.321	0.255	0.355	0.186	0.185	0.326	0.139	0.134	0.255
3	Khaibung	0.465	0.399	0.532	0.354	0.323	0.414	0.353	0.297	0.392	0.310	0.243	0.309	0.190	0.198	0.343	0.144	0.138	0.256
4	Kukidolong	0.454	0.394	0.532	0.352	0.317	0.409	0.336	0.285	0.343	0.303	0.237	0.299	0.184	0.182	0.324	0.134	0.133	0.255
5	Kupuhe	0.443	0.375	0.526	0.336	0.304	0.405	0.291	0.284	0.316	0.215	0.230	0.265	0.184	0.176	0.307	0.133	0.126	0.246
6	Maova	0.467	0.433	0.535	0.371	0.325	0.435	0.370	0.323	0.434	0.312	0.250	0.316	0.203	0.204	0.344	0.158	0.140	0.266
7	Medziphema	0.475	0.440	0.544	0.373	0.354	0.449	0.416	0.363	0.473	0.331	0.282	0.357	0.222	0.205	0.345	0.159	0.142	0.268
8	Molvom	0.480	0.442	0.546	0.383	0.360	0.452	0.453	0.384	0.487	0.337	0.293	0.367	0.225	0.212	0.347	0.160	0.145	0.274
Average *(ST)		**0.468**	**0.421**	**0.543**	**0.367**	**0.338**	**0.434**	**0.380**	**0.332**	**0.422**	**0.307**	**0.260**	**0.328**	**0.202**	**0.197**	**0.341**	**0.149**	**0.140**	**0.263**
Range (Depth)		0.375–0.596			0.304–0.465			0.284–0.487			0.215–0.367			0.176–0.389			0.126–0.284		
Average (Depth)		**0.478**			**0.380**			**0.378**			**0.299**			**0.247**			**0.184**		
Range **(LU)		0.304–0.596						0.215–0.487						0.126–0.389					
Average (LU)		**0.429**						**0.338**						**0.215**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.20 (b). Variation in permanganate oxidizable carbon content (g kg^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	0.468^{a}	0.367^{a}	0.421^{a}	0.338^{a}	0.543^{a}	0.434^{a}
2	Pineapple	0.380^{b}	0.307^{b}	0.332^{b}	0.260^{b}	0.422^{b}	0.328^{b}
3	Paddy	0.202^{c}	0.149^{c}	0.197^{c}	0.140^{c}	0.341^{c}	0.26^{c}

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

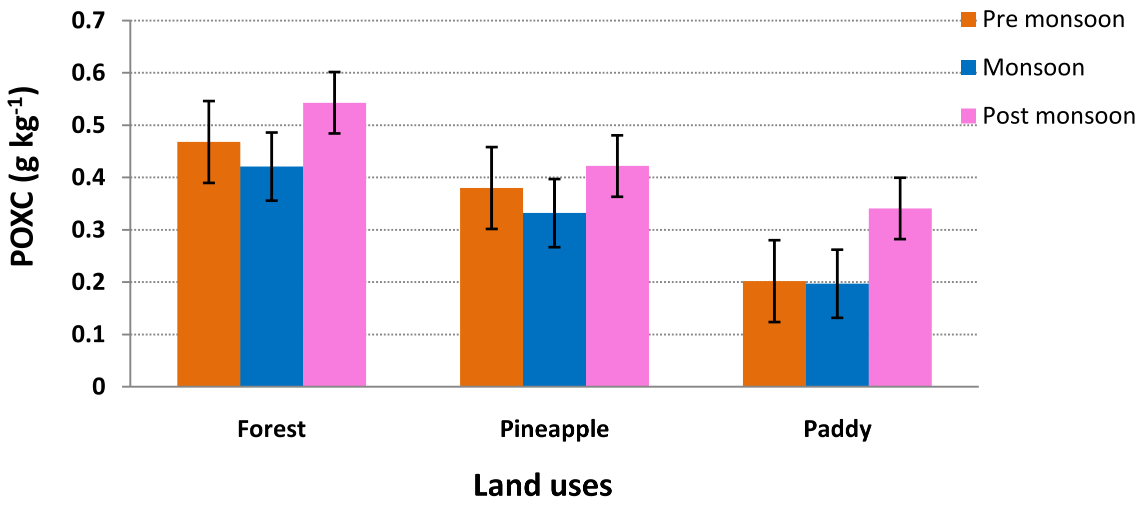


Fig 4.8 (a): Permanganate oxidizable carbon in surface soils (0-0.25 m) of different land use systems during various sampling seasons

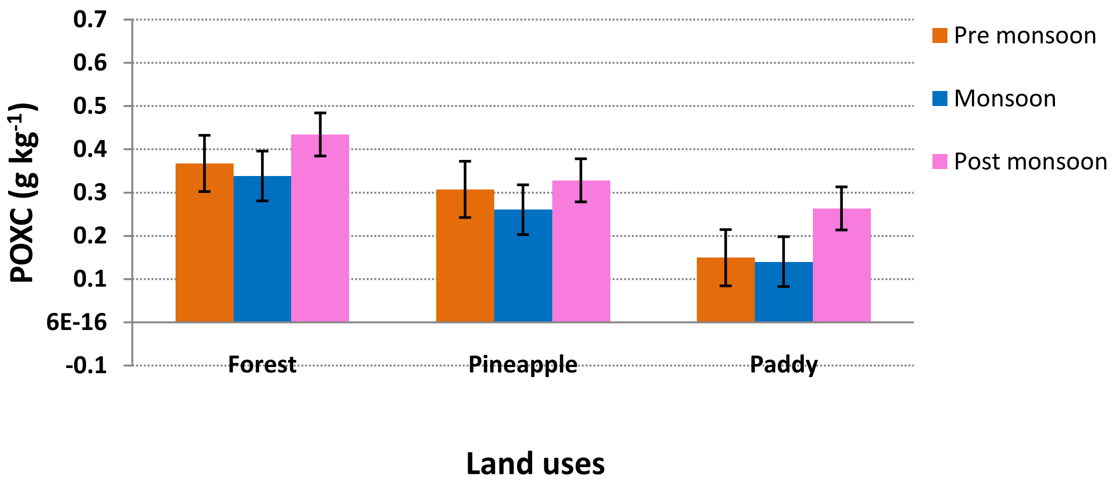


Fig 4.8 (b): Permanganate oxidizable carbon in sub -surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

season recorded least variation in POXC (0.421, 0.332 and 0.197 g kg^{-1}) in forest, pineapple and paddy LUS respectively.

Reduced tillage and high organic matter input increase concentration of labile carbon fractions in soil. Highest labile carbon (POXC) under the forest LUS compared to other LUS may be attributed to the fact that the abundance of litter materials apart from increasing labile carbon through addition of organic substrates directly, which stimulate microbial biomass; indirectly provides a suitable physical environment which can introduce external microbial populations and contribute to an increase of the labile organic carbon pools. The difference in POXC content among land use systems might be due to changes management practices that have a detrimental effect on soil carbon. The prolonged cultivation period has a negative effect on labile carbon. A low concentration of POXC in paddy land use systems can be attributed to long term cultivation of paddy with tillage practices. Accumulation of higher amount of litter materials on the surface soil compared to sub-surface soil layer may be the reason of increased different factions of organic carbon including labile / POXC fractions. Similarly, lower microbial activity and more accumulation of organic materials might have resulted subsequent increase in POXC content during post-monsoon as well as in pre-monsoon season.

In line with the present findings, Mandal *et al*. (2011) have reported significantly higher active carbon content under *Leucaena* plantation, followed by grassland and undisturbed bare soil. Cultivated land exhibited least values of potassium permanganate oxidizable carbon and the values varied from only 2.7 to 3.4% of organic carbon. Katti *et al.* (2020) opined similar result in which they have reported significantly higher mean of POXC content in arecanut land use systems followed by coconut land use system. Significantly lower POXC content was observed under maize land use system. They have also found high POXC content in the surface layer of soils compared to the sub-surface layer attributing the difference in POXC content among land use systems to changes in management practices that have a detrimental effect on soil carbon. A low concentration of POXC in agricultural land use systems can be attributed to tillage practices. Similar findings were reported by Badagliacca *et al.* (2020), where they have found soil POXC, identified as the labile soil C had higher values under NAT (Mediterranean scrub and garrigue) followed by olive sites and citrus plantation; while, the lowest concentration were retrieved on the arable cropping system; both under irrigated and rainfed condition. Higher values were observed on all tree crops and natural soil. They have found that POXC levels highlighted a similar trend to soil TOC in all land uses, showing greater percentage incidence in the upper soil layer than in the deep one.

Omer *et al.* (2018) have reported that the period of lower bulk densities (fall and winter) coincides with the time when the soil organic carbon indicators (SOM and POXC) were the highest in the soil; which was in conformity with the present findings.

Soil organic carbon stock:

The organic carbon stock in soils results from the balance between addition and deletion of organic matter in soils. Hence, the LUS has a tremendous role in the extent of carbon accumulation in soil. Besides, various climatic and soil related factors also affect the soil organic carbon stock (SOC stock). In the present investigation, highest mean SOC stock was recorded in the forest LUS (50.35 Mg ha^{-1}) followed by pineapple (45.16 Mg ha^{-1}) and paddy LUS (37.56 Mg ha^{-1}) across the season and depths (Table 4.21 a). The SOC stock was found ranging from 30.83 Mg ha^{-1} in paddy LUS to 55.88 Mg ha^{-1} in forest LUS. Surface soil layer (0–0.25m) recorded more SOC stocks irrespective of LUS compared to sub-surface (0.25–0.50m). Maximum average SOC stock was recorded in surface soils of forest LUS (53.06 Mg ha^{-1}) while minimum was recorded in sub-surface soils of paddy LUS (35.94 Mg ha^{-1}). Significant seasonal variation in SOC stock was recorded during the period of investigation; maximum variation being recorded during post-monsoon season in both surface (54.68, 47.14 and 40.43 Mg ha^{-1} in forest, pineapple and paddy LUS respectively) and sub-surface soils (Table 4.21 b and Fig 4.9 a, Fig 4.9 b). Erratic but significant variation of SOC stock was recorded in pre-monsoon and monsoon season. Though SOC stock during pre-monsoon season in forest LUS exceeded that of monsoon season, the same was recorded more in monsoon season under pineapple and paddy LUS compared to pre-monsoon season. The variation in SOC stock was 52.64, 46.96 and 38.54 Mg ha^{-1} in surface soil of forest, pineapple and paddy LUS respectively during pre-monsoon season. While in monsoon season, the variation was 51.87, 47.12 and 38.59 Mg ha^{-1} respectively in surface soil layer of forest, pineapple and paddy LUS.

According to Kasel and Bennett (2007), land management with less soil disturbance increased soil carbon accumulation and build up of SOC stock. Loss of soil organic carbon occurs when native forest ecosystems are altered to cultivated systems. The higher SOC stock in the forest LUS as obtained during the present investigation may be because of the huge annual addition of organic matter that stays in the soil for longer period. The lower bulk density as a result of fewer disturbances, higher litter fall, and organic matter accumulation might have led to better soil organic carbon sequestration and build up of higher SOC stock under forest LUS compared to other two LUS. Continuous residue additions in forest land use systems can augment soil aggregation and, concomitantly, soil carbon content. The system of lowland paddy cultivation with puddling alters the soil structure, fragmenting and redistributing the macroaggregates as microaggregates. Thus, the organic matter that was protected from the action of microorganisms might have mineralized quickly, reduced the soil carbon content which can be attributed to less SOC stock under paddy LUS. Though bulk density of soils under different LUS increased with depth, it couldn't influence the stock of SOC much. SOC stock at greater

Table 4.21 (a). Soil organic carbon stock in relation to land use, sampling time and depth

Sl No.	Name of village	SOC Stock (Mg ha^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	55.84	55.88	55.50	49.19	49.71	52.11	51.40	50.27	50.05	45.79	46.43	45.92	39.03	39.31	41.27	35.93	38.16	37.94
2	Jharnapani	52.71	51.49	55.19	46.20	46.59	51.45	47.00	48.19	49.21	44.59	44.55	45.42	38.43	38.36	40.19	33.80	35.71	36.99
3	Khaibung	51.59	51.06	54.15	45.06	44.52	48.85	44.44	45.68	44.24	40.42	42.19	41.42	38.70	38.53	40.31	34.20	36.20	37.03
4	Kukidolong	51.30	49.62	53.55	44.75	44.15	48.80	44.14	45.52	44.20	40.39	39.99	41.34	38.14	38.22	40.02	32.60	35.61	35.30
5	Kupuhe	48.77	48.97	53.19	44.49	42.14	48.13	39.47	39.77	43.65	37.95	37.42	39.65	37.56	38.02	40.01	30.83	35.58	32.75
6	Maova	51.93	51.11	55.11	45.57	45.66	49.95	46.88	46.66	45.79	40.96	42.89	41.60	38.71	38.56	40.40	35.06	38.11	37.25
7	Medziphema	53.24	52.97	55.22	46.31	48.51	51.46	50.67	50.20	49.66	44.67	46.15	45.79	38.78	38.76	40.40	35.78	38.12	37.74
8	Molvom	55.71	53.87	55.49	48.44	49.36	51.81	51.66	50.65	50.28	48.02	47.05	47.21	39.00	38.93	40.84	35.80	38.14	37.90
Average *(ST)		**52.64**	**51.87**	**54.68**	**46.25**	**46.33**	**50.32**	**46.96**	**47.12**	**47.14**	**42.85**	**43.33**	**43.54**	**38.54**	**38.59**	**40.43**	**34.25**	**36.95**	**36.61**
Range (Depth)		48.77–55.88			42.14–52.11			39.47–51.66			37.42– 48.02			37.56–41.27			30.83– 38.16		
Average (Depth)		**53.06**			**47.63**			**47.07**			**43.24**			**39.19**			**35.94**		
Range **(LU)		42.14–55.88						37.42–51.66						30.83–41.27					
Average (LU)		**50.35**						**45.16**						**37.56**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.21 (b). Variation in soil organic carbon stock (Mg ha^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	52.64^{a}	46.25^{a}	51.87^{a}	46.33^{a}	54.68^{a}	50.32^{a}
2	Pineapple	46.96^{b}	42.85^{b}	47.12^{b}	43.33^{b}	47.14^{b}	43.54^{b}
3	Paddy	38.54^{c}	34.25^{c}	38.59^{c}	36.95^{c}	40.43^{c}	36.61^{c}

Values followed by different letters under different land uses are significantly different ($P<0.05$) by the Duncan's multiple range test

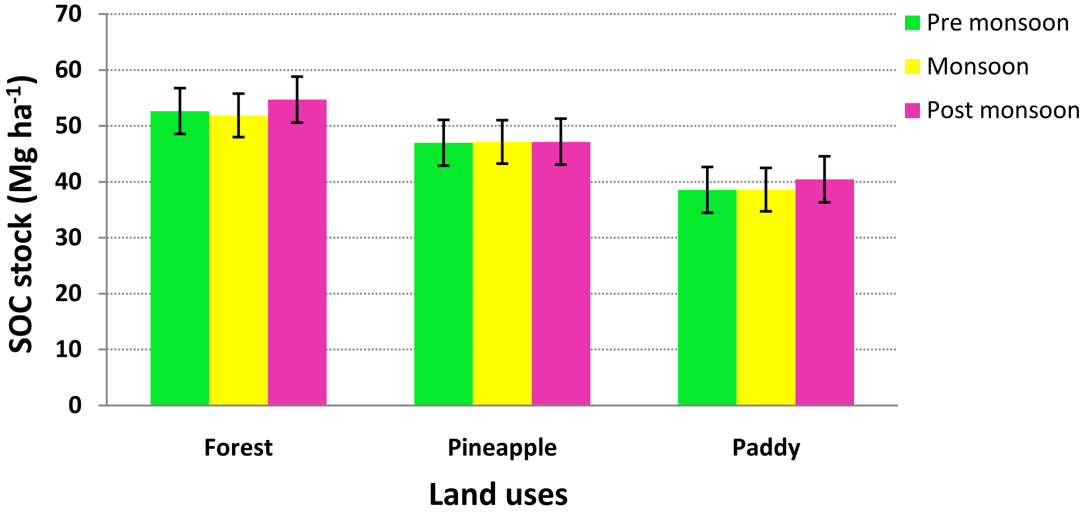


Fig 4.9 (a): SOC stock in surface soils (0- 0.25 m) of different land use systems during various sampling seasons

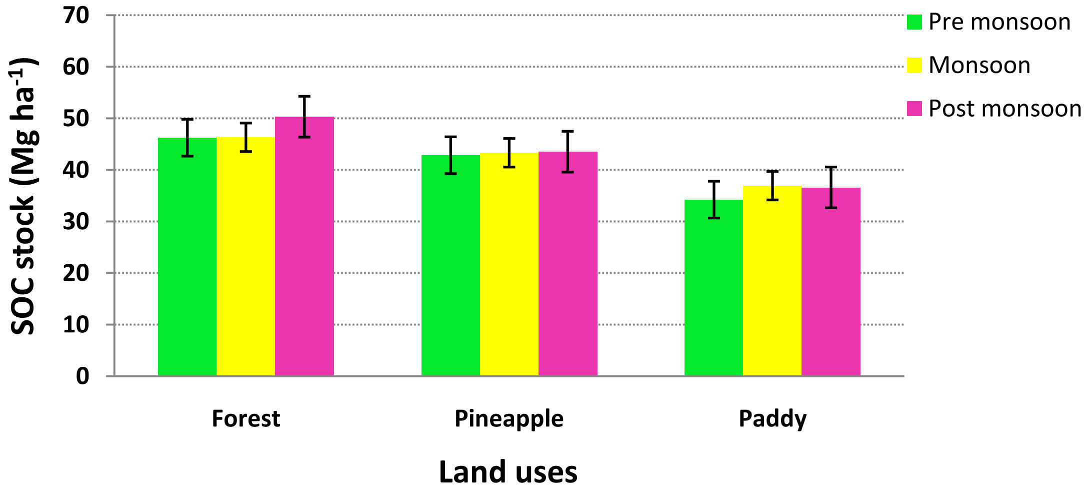


Fig 4.9 (b): SOC stock in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

depth was less compared to surface soil may be because of lesser organic carbon content at greater depth, that have more influence on SOC stock. Lesser rate of decomposition of organic residues in post-monsoon season owing to reduced microbial activity might have favoured the buildup of SOC stock to a greater extent compared to monsoon season.

In line with the findings of present investigation, Kenye *et al*. (2019) reported the highest mean SOC stock (in 0–45 cm) in forest followed by home garden and wetrice cultivation. However, they have reported less SOC stock in shifting cultivation and lowest in grassland. Meetei *et al*. (2017) reported a similar order of SOC stock from their experiment as: forest > grassland > *Jhum* > cultivated land. They opined that residue additions in forest and permanent grassland land use systems improved soil aggregation and thus increased soil carbon content and SOC stock. Andrade *et al.* (2020) also reported lowest stock of TOC in agricultural lands. It was revealed that the replacement of native vegetation by an intensive agricultural system was responsible for the decrease in organic matter content, which leads to a reduction in soil carbon and nitrogen stock. The carbon concentrations are highly influenced by land use and the mean biomass carbon stock was five times higher in the dense forest compared to the open forest and twenty times higher than that of the grassland (Solomon *et al*., 2018). According to them, the conversion of dense forests to cultivated land resulted in a 25% reduction in soil organic carbon stock. In a study conducted in North East India to estimate SOC stock in five major orchards, it was reported that fruits crops exhibited significant influence on change of SOC stock. The maximum SOC stock was found in pear (*Pyrus Communis*) followed by guava (*Psidium guajava*) orchards. While pineapple (*Ananus comosus*) exhibited lowest SOC stock along with peach (*Prunus persica*) and khasi mandarin (*Citrus reticulate*) in between the maximum and minimum range. The differences in SOC stocks among the fruit crops was attributed to variation in above and below ground biomass, plant canopy, leaf and root biomass quality and soil characteristics (Ramesh *et al*., 2019).

In conformity with the results of present investigation, Katti *et al.* (2020) reported significantly higher carbon stock at the surface layer of soil of arecanut land use system which was followed by coconut land use system and least was reported in maize land use system. They have reported lower carbon stock potential at sub-surface soil layer under all land use systems when compared to surface soil depth. The present findings are supported by the findings of Schiedung *et al.* (2017), who have reported highest water extractable SOC stocks (WESOC stocks) in the month of March (pre-monsoon), that reached the minimum during May, and then again increased in the month of October (post-monsoon).

Carbon management index:

Carbon management index (CMI) compares the changes that occur in total and labile / active carbon as a result of land management practices under different LUS. The CMI is considered as the designated indicator of carbon dynamics of the system. Higher CMI indicates that the LUS is giving better quality to soil because carbon compounds particularly the more labile fractions provide energy for soil organisms and stimulate their activity, which contributes to nutrient release from plant and animal residues and the synthesis of humic substances that affect both soil physical and chemical characteristics. During the present investigation, forest LUS, which was considered as reference for calculation of CMI was assigned a CMI value of 100 and CMI of pineapple and paddy was calculated based on CMI of forest LUS. Although total C varied significantly among the different land use systems, CMI showed a dissimilar trend in the present study. Blair *et al*., (1995) have revealed that the value itself is not important but the differences reflect how different land uses are affecting the systems. Pineapple LUS recorded highest average CMI value (78.94) and paddy LUS the lowest average (49.02) (Table 4.22). However, a wide range of CMI was calculated for both pineapple (57.54–95.47) and paddy LUS (34.74–66.14) in various study sites. A marginal increase in average CMI value in surface soil layers was recorded for both pineapple and paddy LUS. However, the trend was not same for all the study sites. A dissimilar trend of CMI were calculated in pineapple and paddy LUS during different seasons. The trend for pineapple LUS was pre-monsoon > monsoon > post-monsoon whereas, in case of paddy LUS it was recorded as post-monsoon > monsoon > pre-monsoon (Table 4.22 and Fig 4.10 a, Fig 4.10 b).

The regular addition of organic matter and wide canopy coverage in case of pineapple might have enhanced potential to increase the CMI by increased inputs and lower losses. High carbon pool index (CPI) value along with higher lability index (LI) can be attributed to higher CMI in the pineapple LUS compared to paddy LUS. In conformity with the present findings, Paes *et al.* (2018) have reported highest CMI in 12 year old agroforestry system compared to 7 year old agroforestry, conventional cassava planting and pasture. They have revealed that the 12 year old agroforestry system gives better quality to the soil based on high CMI value. Contrary to present findings, Sainepo *et al.* (2018) have reported highest CMI in agricultural system compared to grass lands. The use of nitrogen based fertilizer leading to increase biomass and subsequent increase in soil organic matter was attributed to high CMI value in agricultural lands. Zhao *et al.* (2014) reported significantly higher CMI values in *Robinia psendoacacia* (RP) forest compared with *Caragana Korshinskii Kom* (CK), Abandoned land (AB) and slope croplands (SC) in both surface soil and sub-soil revealing soil management under RP plot as more appropriate to improve the SOC status than other land use types. Corroborating with the present findings, Jiao *et al.* (2020) reported lowest overall CMI in arable land among three land use types. They have revealed that alfalfa grassland had the advantage to promote soil quality compared with arable land and forest land

Table 4.22. Carbon management index under pineapple and paddy land use

Sl No.	Name of village	CMI											
		Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	93.49	87.23	88.20	92.96	79.44	87.33	49.16	49.57	65.27	45.90	47.34	66.14
2	Jharnapani	79.67	79.51	79.94	86.78	77.24	77.01	39.09	44.70	60.74	38.33	38.80	57.47
3	Khaibung	75.76	75.12	73.00	83.52	76.12	71.26	42.39	46.92	62.74	39.66	41.46	58.76
4	Kukidolong	74.34	74.46	64.18	81.55	70.49	68.42	38.52	44.30	60.66	37.35	37.00	56.37
5	Kupuhe	62.29	65.36	59.73	57.54	70.47	58.39	37.88	41.64	58.21	34.74	36.15	56.05
6	Maova	76.79	75.74	79.79	86.42	76.42	76.06	43.28	47.56	62.95	41.22	41.70	62.22
7	Medziphema	91.47	79.93	82.85	87.71	77.73	78.94	45.94	48.60	64.32	42.07	42.17	63.18
8	Molvom	94.39	92.17	91.37	95.47	86.27	88.64	47.19	49.00	65.19	42.96	45.64	64.25
Average *(ST)		**81.03**	**78.69**	**77.38**	**83.99**	**76.77**	**75.76**	**42.93**	**46.54**	**62.51**	**40.28**	**41.28**	**60.56**
Range (Depth)		59.73–94.39			57.54–95.47			37.88–65.27			34.74–66.14		
Average (Depth)		**79.03**			**78.84**			**50.66**			**47.37**		
Range **(LU)		57.54–95.47						34.74–66.14					
Average (LU)		**78.94**						**49.02**					

*ST : Sampling time **LU: Land use I: Pre-monsoon II: Monsoon III: Post-monsoon

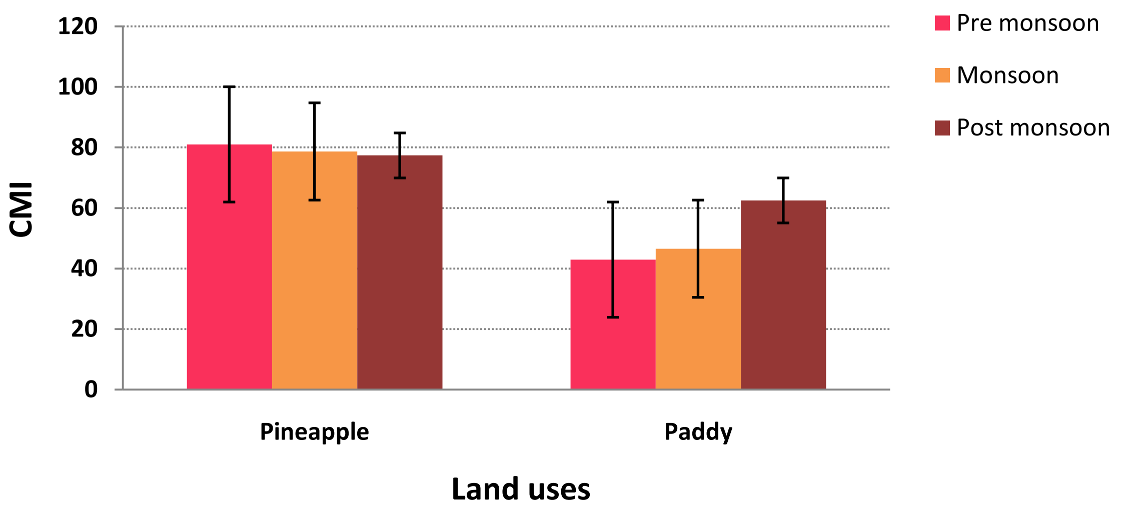


Fig 4.10 (a): Carbon management index of surface soils (0- 0.25 m) under different land use systems during various sampling seasons

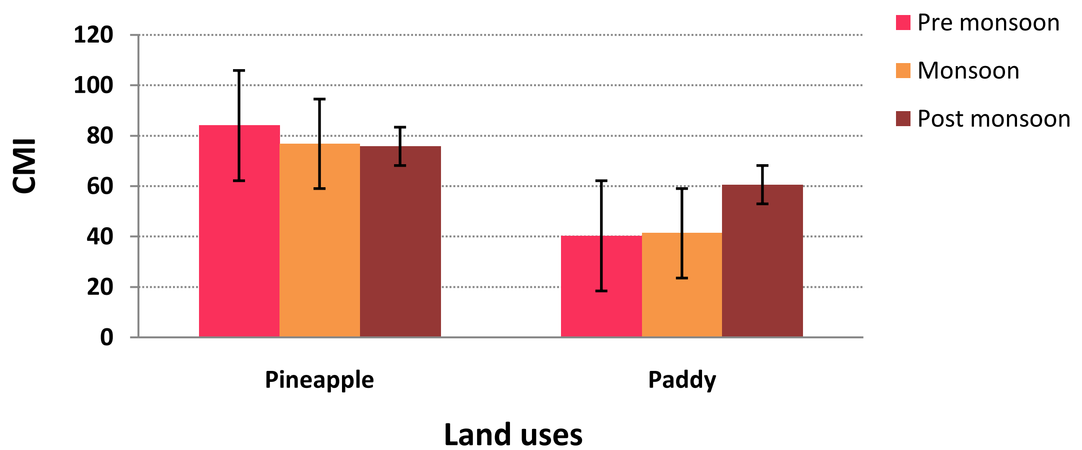


Fig 4.10 (b): Carbon management index of sub-surface soils (0.25-0.50 m) under different land use systems during various sampling seasons

because of high SOC content in combination with high CMI and better soil physical properties.

Kalambukattu *et al.* (2013) reported similar seasonal trend of CMI. They have reported that forest system had the highest value of CMI followed by organic farming, soybean- wheat system and fodder system in both summer and winter season. The regular addition of organic matter in case of forest and organic farming systems proved enhanced potential to increase the CMI by increased inputs and lower losses.

4.5. Spatial distribution of carbon fractions under different LUS in different seasons

Spatial distribution of organic carbon:

The organic carbon content under different LUS for both the soil layers were interpolated in location maps obtained through ArcGIS 10.8.1 software with the help of spatial coordinates to assess the spatial variability and spread across the study area in different seasons.

The results obtained from interpolation are classified based on acceptance of critical limits denoted by different colours. From the maps, maximum content of OC was observed during the post-monsoon season in the study site irrespective of the LUS (Fig 4.11 a, Fig 4.11 b) followed by pre-monsoon (Fig 4.12 a, Fig 4.12 b). Lower content of OC in the study site was evidenced during monsoon season (Fig 4.13 a, Fig 4.13 b). In the post-monsoon season, the forest LUS exhibited maximum content of OC that ranged from 17.10 to 19.88 g kg^{-1} with maximum spread in the critical limit ranged from 18.78 to 18.96 g kg^{-1} followed by pineapple LUS (13.90 to 17.30 g kg^{-1}) with maximum spread in the critical limit ranging from 15.25 to 15.91 g kg^{-1} in the surface soil. Among the different villages, Molvom, Bungsung and Medziphema seen to have higher OC content under pineapple LUS in the critical limit ranging from 16.59 to 17.30 g kg^{-1} (Fig 4.11 a). Paddy LUS can be

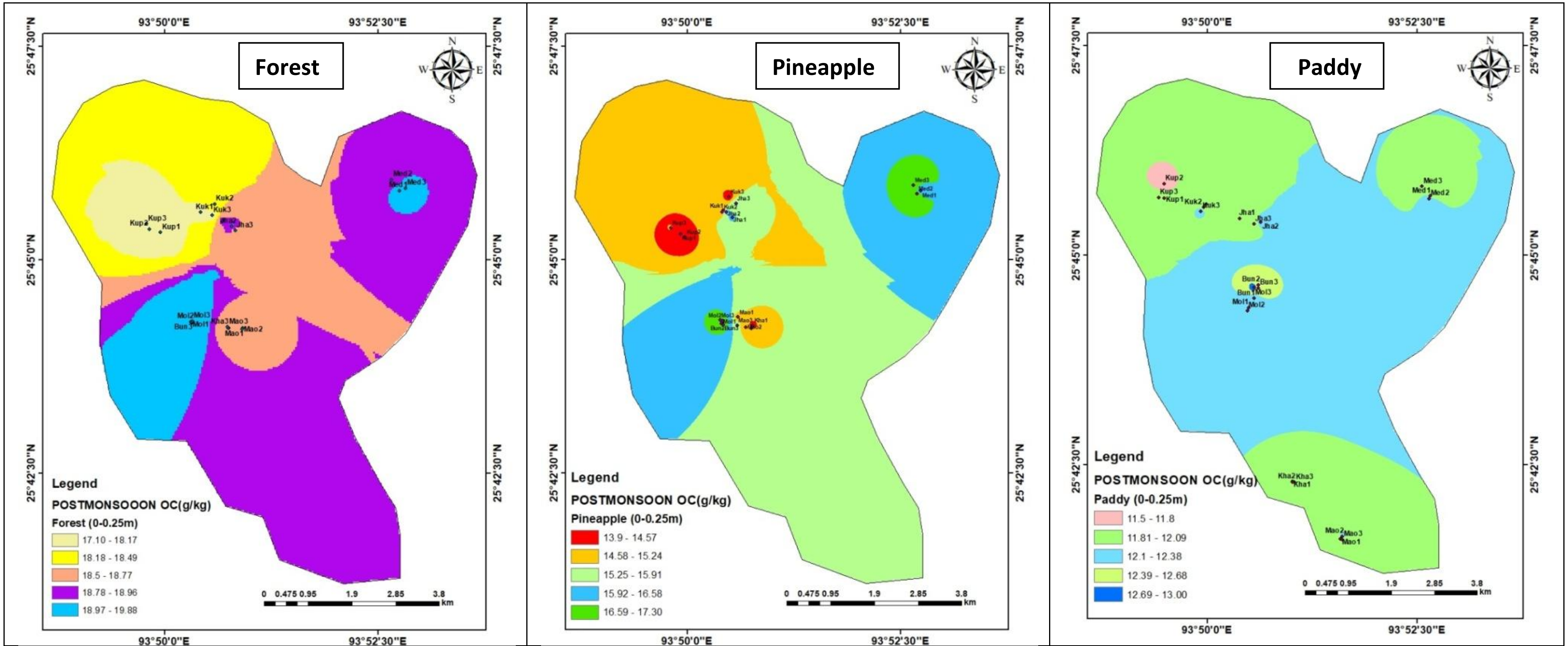


Fig 4.11 (a): Spatial distribution of OC content in surface soils (0–0.25 m) of different LUS during post-monsoon season

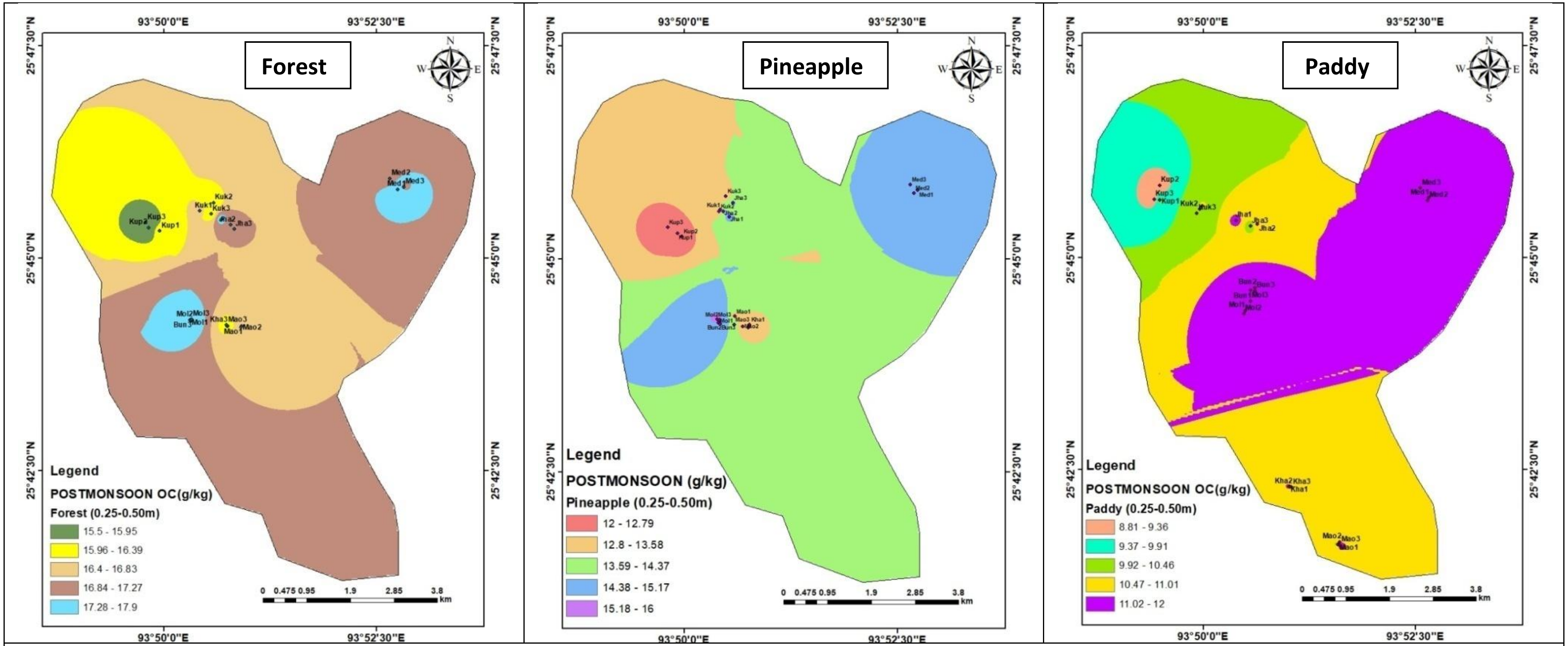


Fig 4.11 (b): Spatial distribution of OC content in sub-surface soils (0.25–0.50 m) of different LUS during post-monsoon season

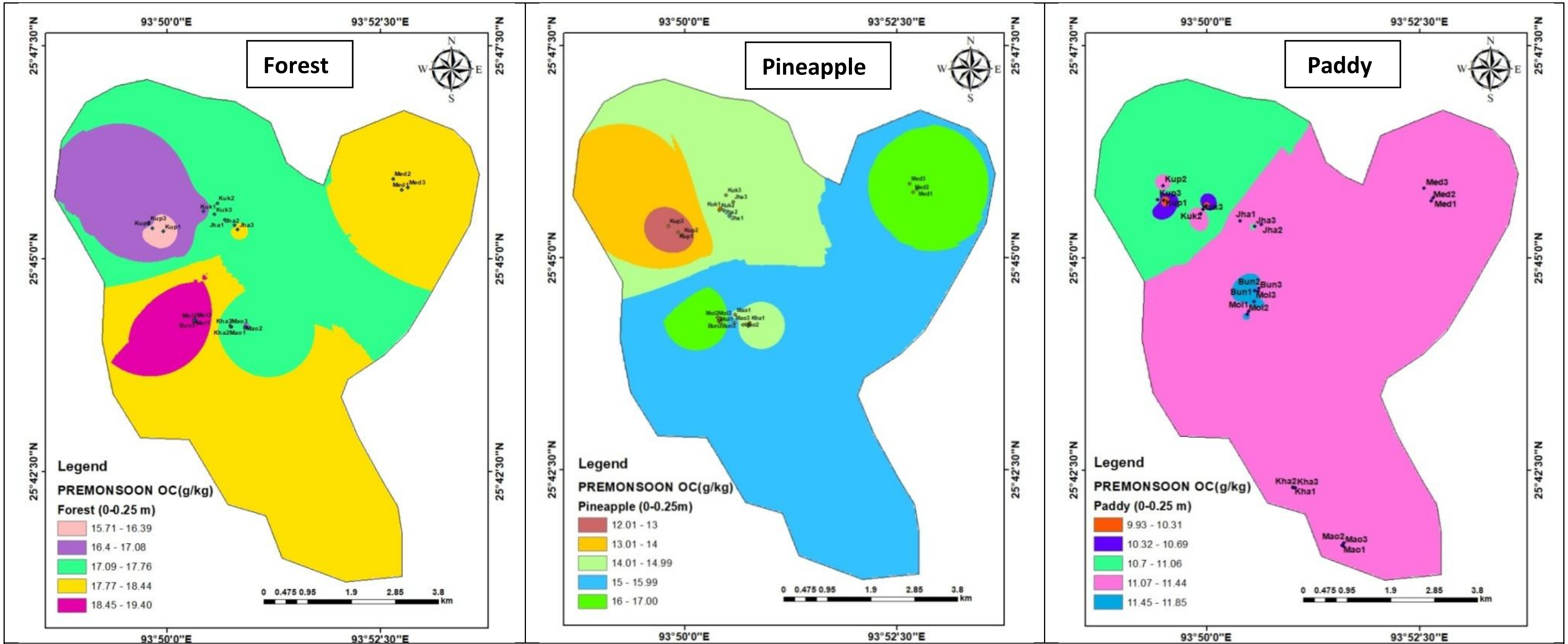


Fig 4.12 (a): Spatial distribution of OC content in surface soils (0–0.25 m) of different LUS during pre-monsoon season

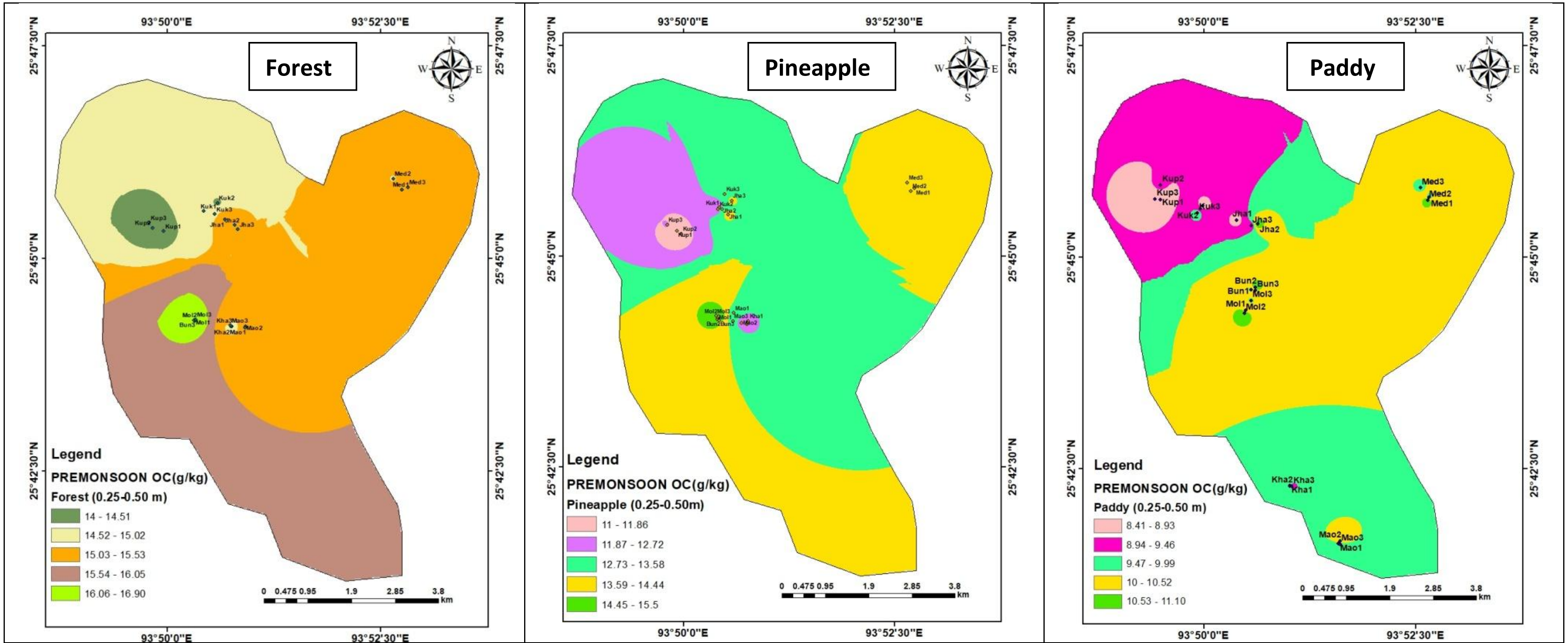


Fig 4.12 (b): Spatial distribution of OC content in sub-surface soils (0.25–0.50 m) of different LUS during pre-monsoon season

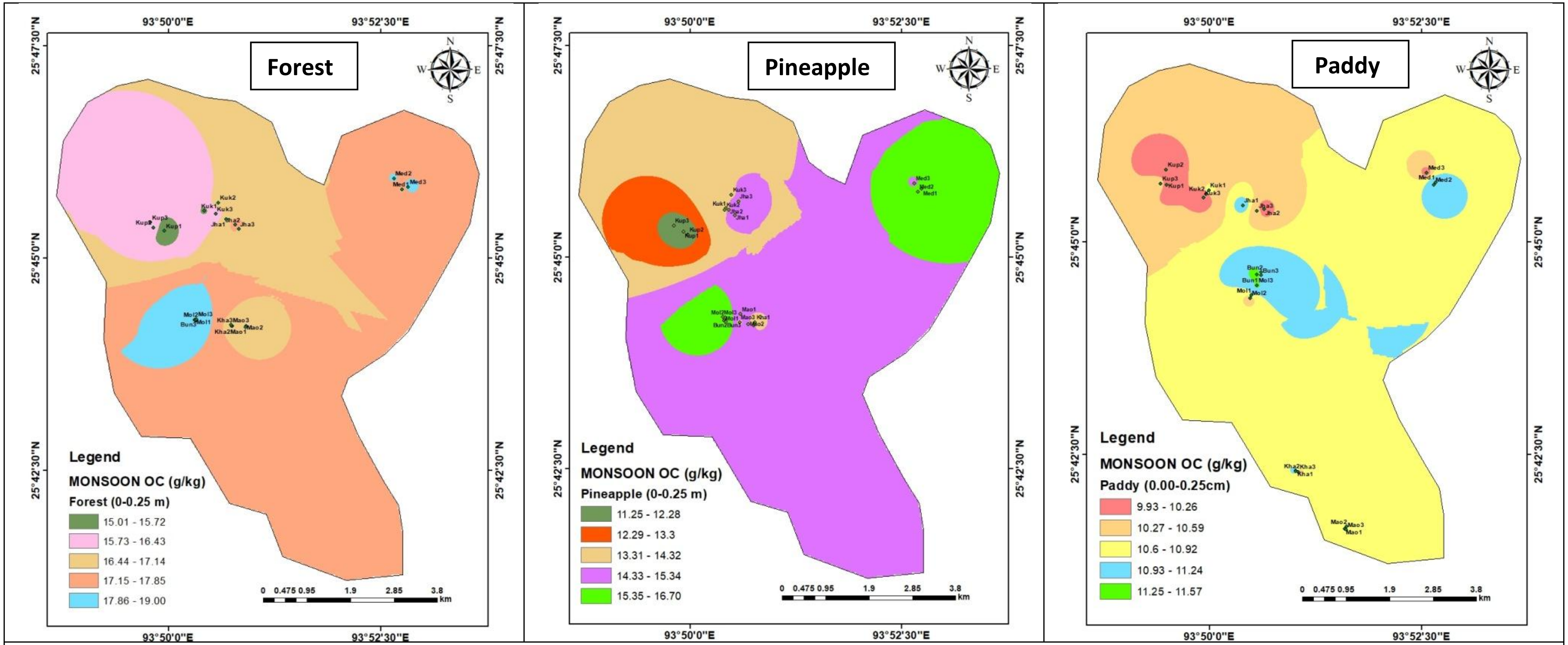


Fig 4.13 (a): Spatial distribution of OC content in surface soils (0–0.25 m) of different LUS during monsoon season

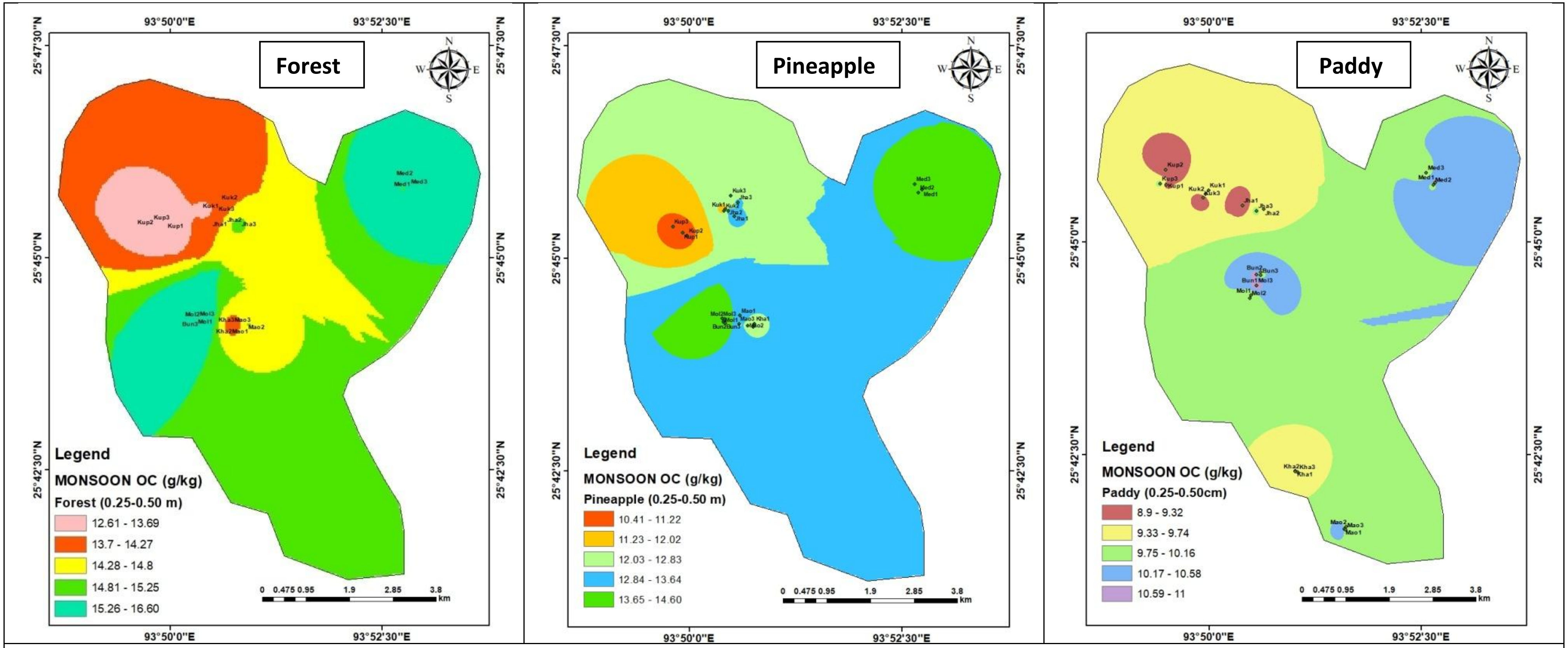


Fig 4.13 (b): Spatial distribution of OC content in sub-surface soils (0.25–0.50 m) of different LUS during monsoon season

observed with minimum content (11.50–13.0 g kg^{-1}) of OC as evidenced from spatial variability map in surface soil during post- monsoon season.

The spatial distribution of OC changes with season, as observed from the spatial variability maps. From the map it was observed that during pre-monsoon season, forest LUS exhibited maximum content of OC that ranged from 15.71 to 19.40 g kg^{-1} followed by pineapple LUS from 12.01 to 17.0 g kg^{-1}. Paddy LUS can be observed with minimum content of OC ranging from 9.93 to 11.85 g kg^{-1} in the surface soil layer as evidenced from spatial variability map (Fig 4.12 a). Maximum spread of OC in study area under the forest LUS was observed in the critical limit ranged from 17.77 to 18.44 g kg^{-1}. While in pineapple LUS, the maximum spread was observed in the critical limit ranged from 15.0 to 15.99 g kg^{-1} and in paddy LUS, maximum spread was observed in the critical limit ranged from 11.07–11.44 g kg^{-1} (Fig 4.12 a).

Lower content of OC with distinct spatial variability was observed in monsoon season in both the depths. The critical limit of OC in forest LUS varied from 15.0 to 19.0 g kg^{-1} with maximum spread in the range 17.15 to 17.85 g kg^{-1} (Fig 4.13 a). Similarly pineapple LUS was seen to contain OC ranging from 11.25 to 16.7 g kg^{-1} with maximum spread in the critical limit range 14.33 to 15.34 g kg^{-1}. In the study area, paddy LUS was seen to have lowest OC content among three LUS. Paddy LUS was seen to have OC content in the range of 9.93 to 11.57g kg^{-1} with maximum spread in the range of 10.6 to 10.92 g kg^{-1} in surface soils (Fig 4.13 a).

Spatial distribution of total organic carbon:

Similar trend of spatial variability in case of total organic carbon (TOC) was also observed in the study area. Maximum content of TOC was observed during the post-monsoon season in the study area irrespective of the LUS (Fig 4.14 a, Fig 4.14 b) followed by pre-monsoon (Fig 4.15 a, Fig 4.15 b). Lower TOC content was evidenced during monsoon season (Fig 4.16 a, Fig 4.16 b). In the post-monsoon season, the forest LUS exhibited maximum content of TOC in the critical limit range of 20.71 to 25.30 g kg^{-1} with maximum predicted spread in the critical limit range of 22.75 to 23.14 g kg^{-1} followed by pineapple LUS (16.37 to 22.2 g kg^{-1}) with maximum spread in the critical limit ranging from 18.58 to 19.67g kg^{-1} in the surface soil. Among the different villages, Molvom, Bungsung and Medziphema seen to have higher TOC content, while sites under Kukidolong and Kupuhe village appeared in the lower range of TOC content under pineapple LUS (Fig 4.14 a). Paddy LUS indicated minimum content (13.41 to 14.36 g kg^{-1}) of TOC as evidenced from spatial variability map in the post-monsoon season.

The spatial variation of TOC was evidenced with season, as observed from the spatial variability maps. From the map it can be observed that during pre-monsoon season, forest LUS exhibited maximum content of TOC that ranged from 19.90 to 23.60 g kg^{-1}. Maximum spread of TOC in study area under the forest LUS was observed in the critical limit ranged from 21.88 to 22.52 g kg^{-1} (Fig 4.15 a). Pineapple LUS was observed to contain TOC in the limit ranging from 14.70 to 22.30 g kg^{-1}. Paddy LUS was observed with minimum content (13.0 to 15.60 g kg^{-1}) of TOC in the surface soil layer as evidenced from spatial variability map (Fig 4.15 a).

Distinct spatial variability was observed in case of TOC content during monsoon season also in both the depths. The critical limit of TOC in forest LUS ranged from 17.31 to 22.40 g kg^{-1} with maximum spread in the range 20.12 to 21.05 g kg^{-1} (Fig 4.16 a). Similarly pineapple LUS was seen to contain TOC ranging from 13.35 to 20.90 g kg^{-1} with maximum spread in the critical limit range 17.52–18.90 g kg^{-1}. In the study area, paddy LUS was seen to have lowest TOC content among all LUS. Paddy LUS was seen to have TOC content in the range of 11.61 to 15.89 g kg^{-1} with maximum spread in the range of 13.33 to 14.17 g kg^{-1} in surface soils (Fig 4.16 a).

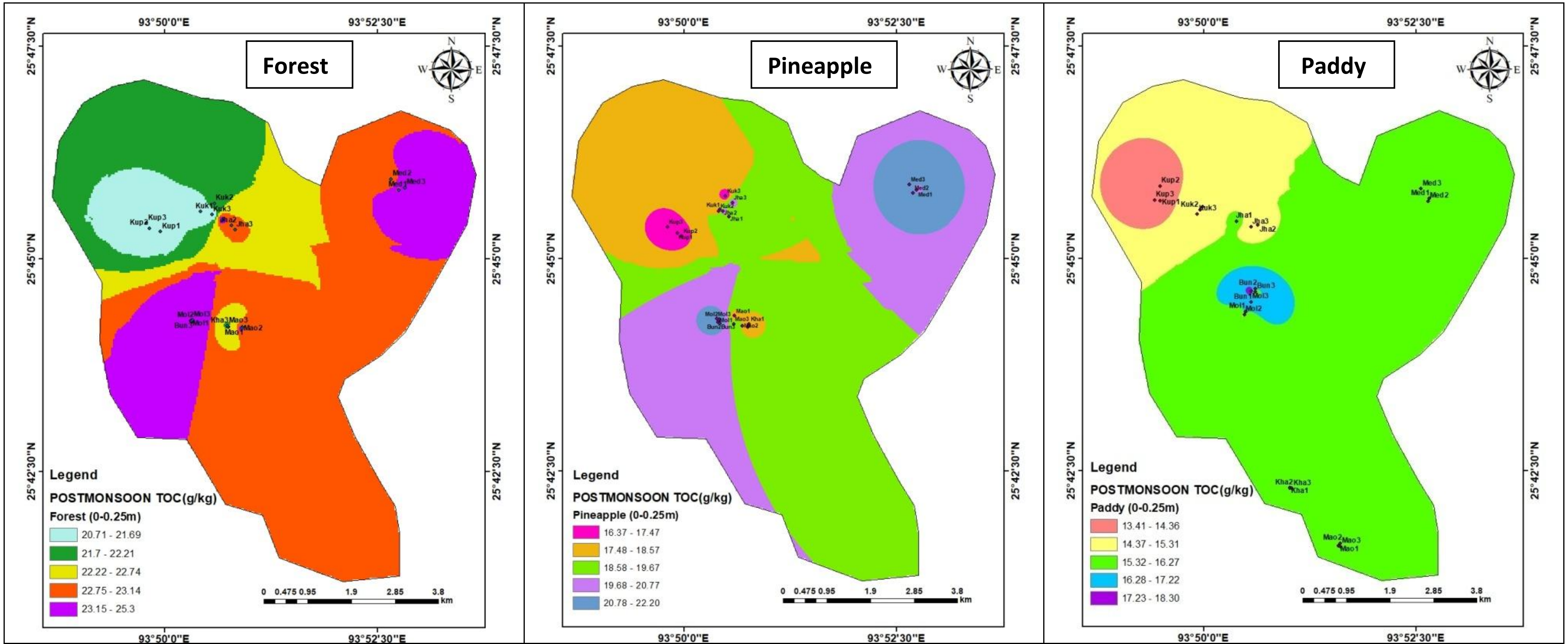


Fig 4.14 (a): Spatial distribution of TOC content in surface soils (0–0.25 m) of different LUS during post-monsoon season

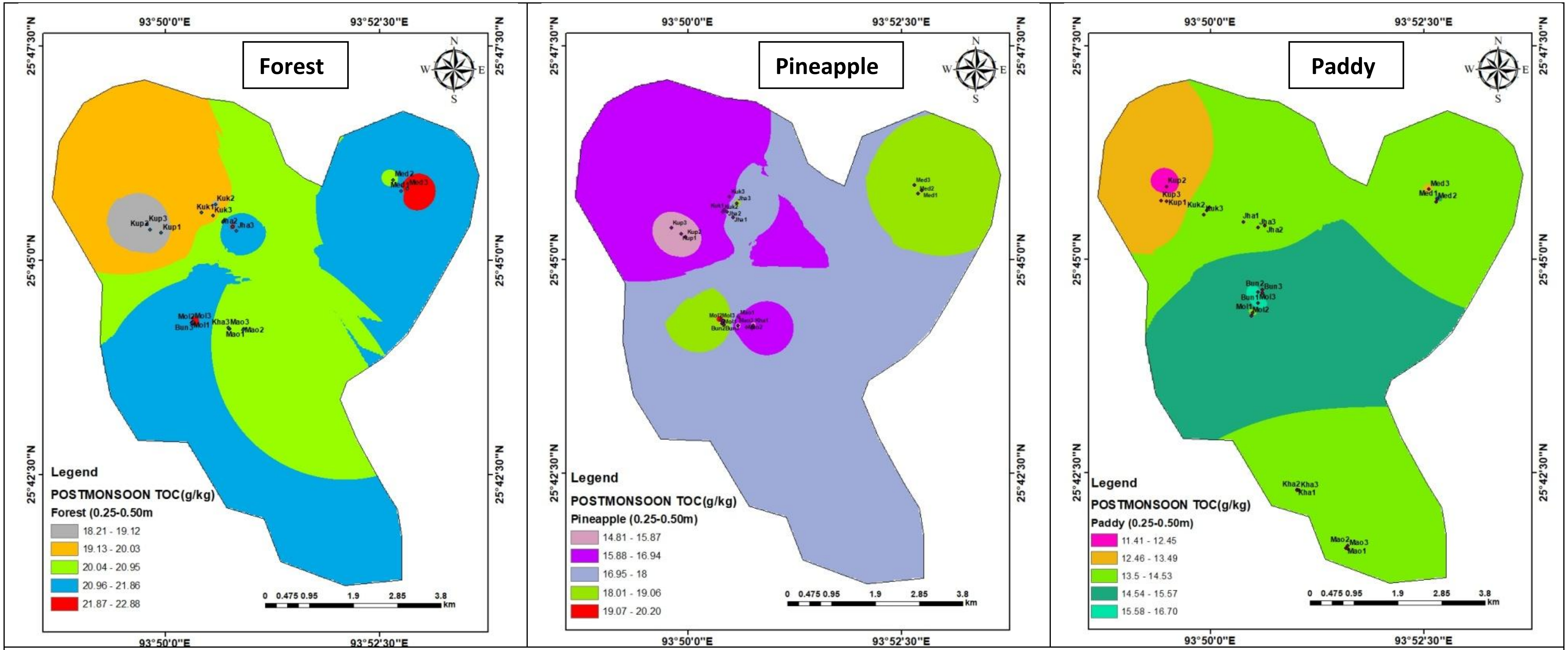


Fig 4.14 (b): Spatial distribution of TOC content in sub-surface soils (0.25–0.50 m) of different LUS during post-monsoon season

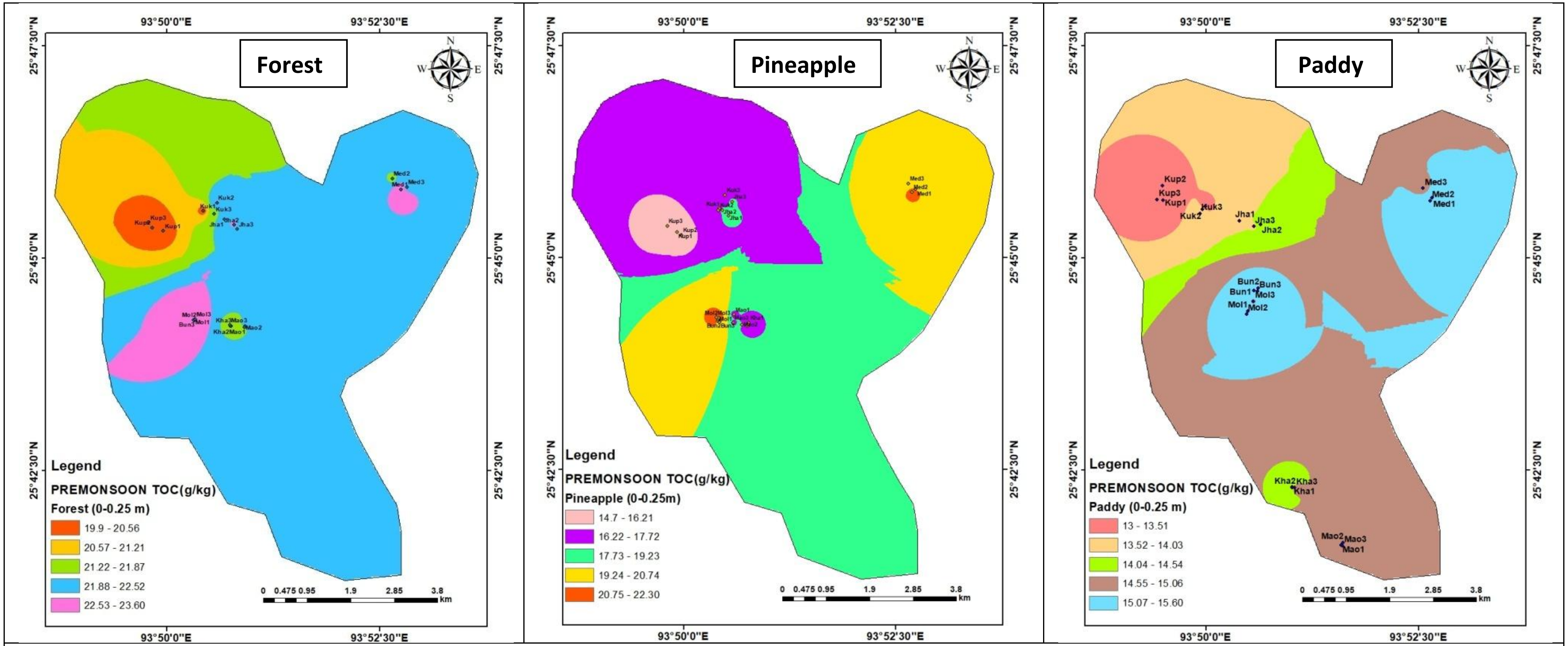


Fig 4.15 (a): Spatial distribution of TOC content in surface soils (0–0.25 m) of different LUS during pre-monsoon season

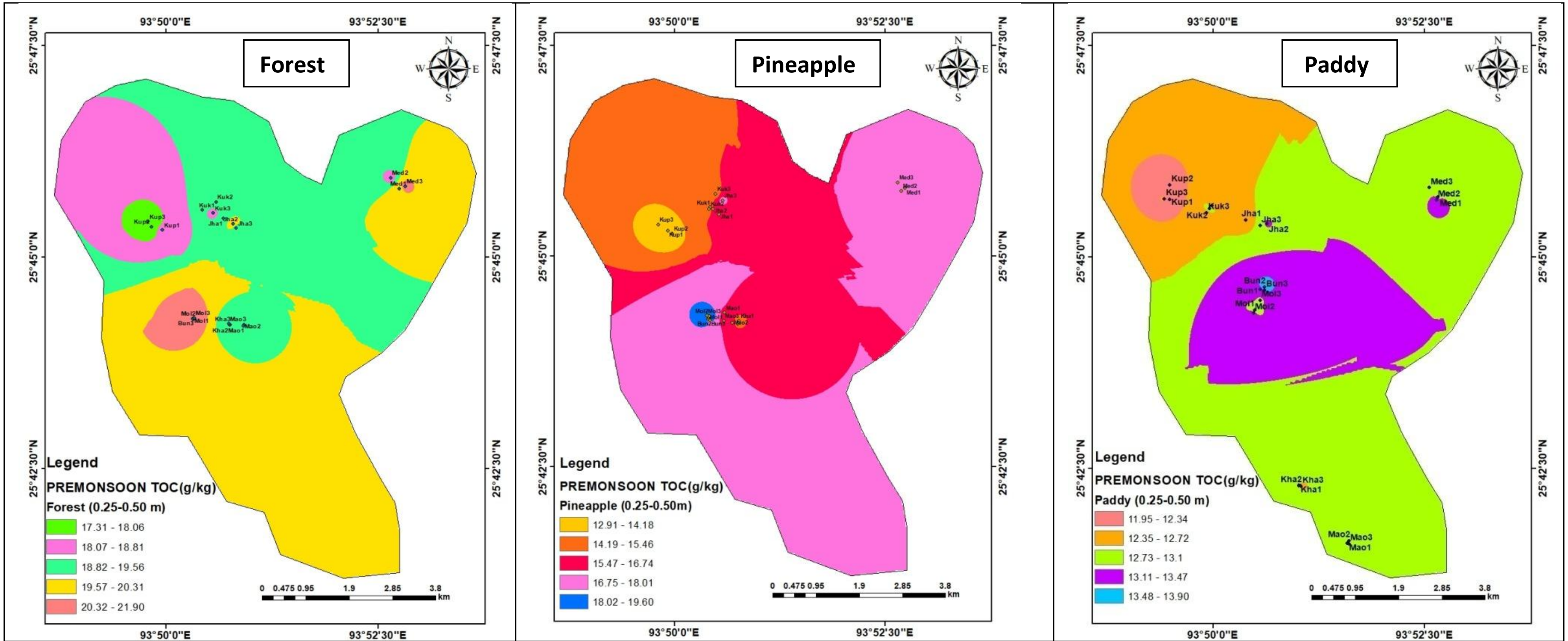


Fig 4.15 (b): Spatial distribution of TOC content in sub-surface soils (0.25–0.50 m) of different LUS during pre-monsoon season

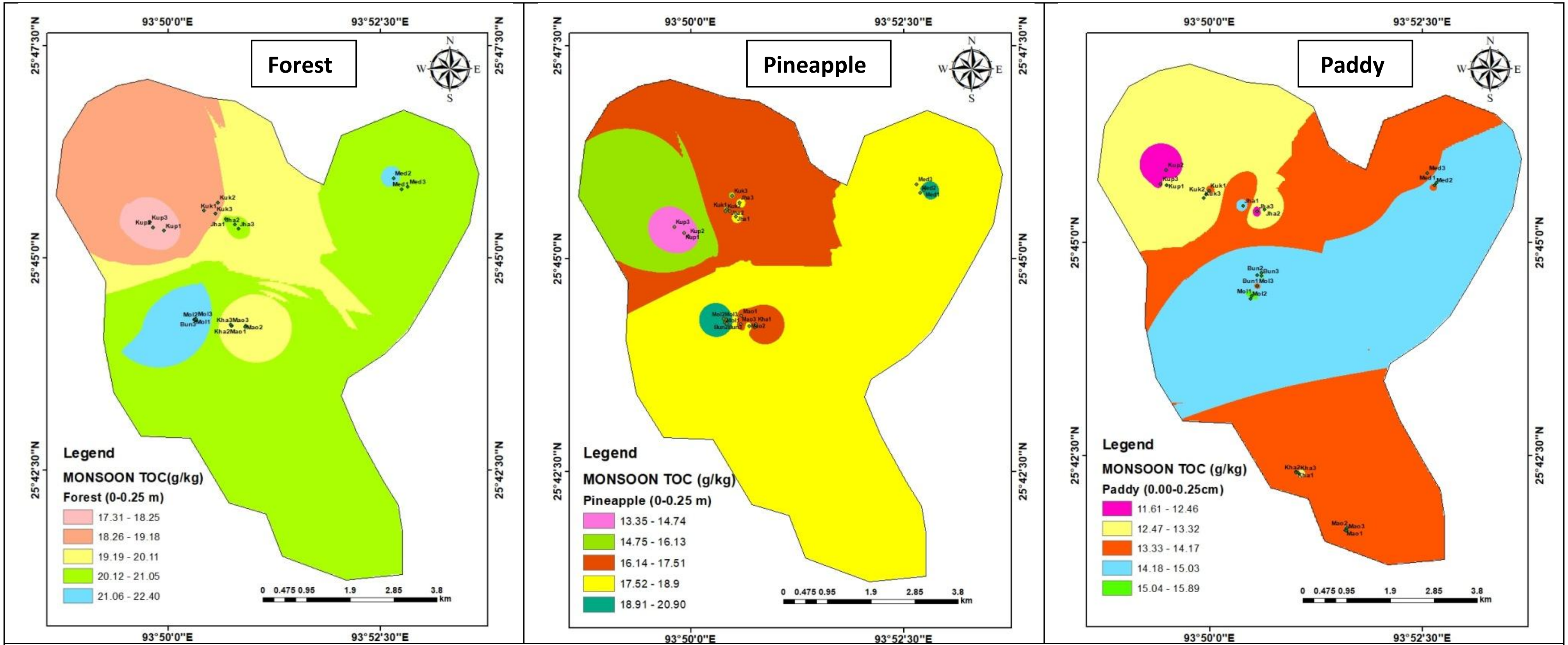


Fig 4.16 (a): Spatial distribution of TOC content in surface soils (0–0.25 m) of different LUS during monsoon season

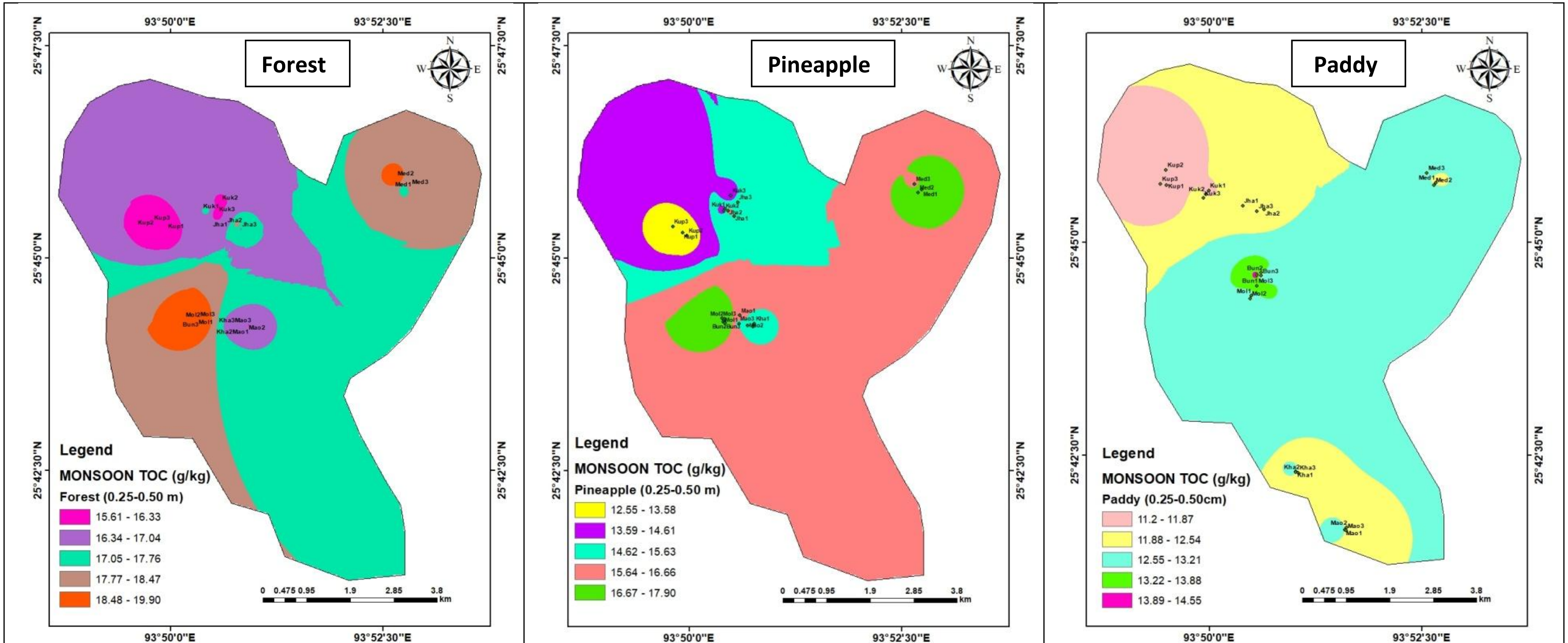


Fig 4.16 (b): Spatial distribution of TOC content in sub-surface soils (0.25–0.50 m) of different LUS during monsoon season

Spatial distribution of permanganate oxidizable carbon:

Distinct spatial variability in case of permanganate oxidizable carbon (POXC) was observed in the study area. Maximum content of POXC was observed during the post-monsoon season in the study area irrespective of the LUS (Fig 4.17 a, Fig 4.17 b) followed by pre-monsoon (Fig 4.18 a, Fig 4.18 b). Lower content of POXC in the study area was evidenced during monsoon season (Fig 4.19 a, Fig 4.19 b). In the post-monsoon season, the forest LUS exhibited maximum content of POXC in the critical limit range 524.52 to 580.75 mg kg^{-1}. Lower range of POXC content (524.52 to 537.53 mg kg^{-1}) was observed in the sampling sites of Kupuhe, Kukidolong, Jharnapani, Khaibung and Maova village (Fig 4.17 a) in surface soils. Pineapple LUS was seen to contain POXC in the critical range 312.67 to 489.56 mg kg^{-1}. Pineapple cultivation sites of Medziphema, Bungsung and Molvom village was seen to contain higher range of POXC content (Fig 4.17 a) in the surface soil. Paddy LUS was observed with minimum content of POXC ranged from 304.16 to 391.73 mg kg^{-1} with maximum spread in the critical limit range 339.0 to 356.41 mg kg^{-1} as evidenced from spatial variability map in surface soil layer in the post-monsoon season.

During pre-monsoon season, forest LUS exhibited maximum content of POXC that ranged from 440.98 to 487.40 mg kg^{-1}. Pineapple LUS was observed to contain POXC in the limit ranging from 287.08 to 455.60 mg kg^{-1}. Spatial variability map have shown the maximum spread of POXC in the critical limit range 386.63 to 419.78 mg kg^{-1} in the study site under pineapple LUS. Paddy LUS can be observed with POXC content ranged from 180.11 to 228.0 mg kg^{-1} (Fig 4.18 a). Minimum content of POXC was evidenced in the sampling sites of paddy LUS in Kupuhe, Kukidolong and Jharnapani village in the surface soil layer as evidenced from spatial variability map during pre-monsoon season.

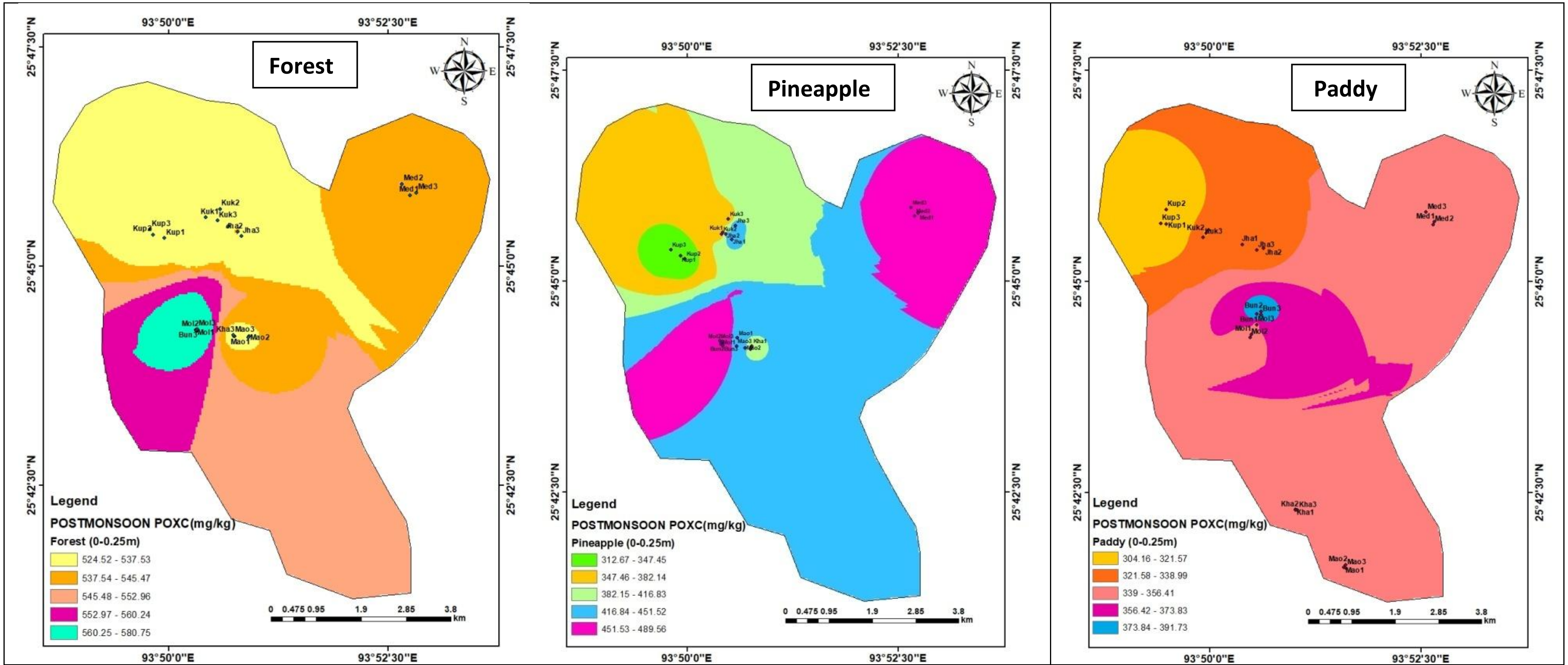


Fig 4.17 (a): Spatial distribution of POXC content in surface soils (0–0.25 m) of different LUS during post-monsoon season

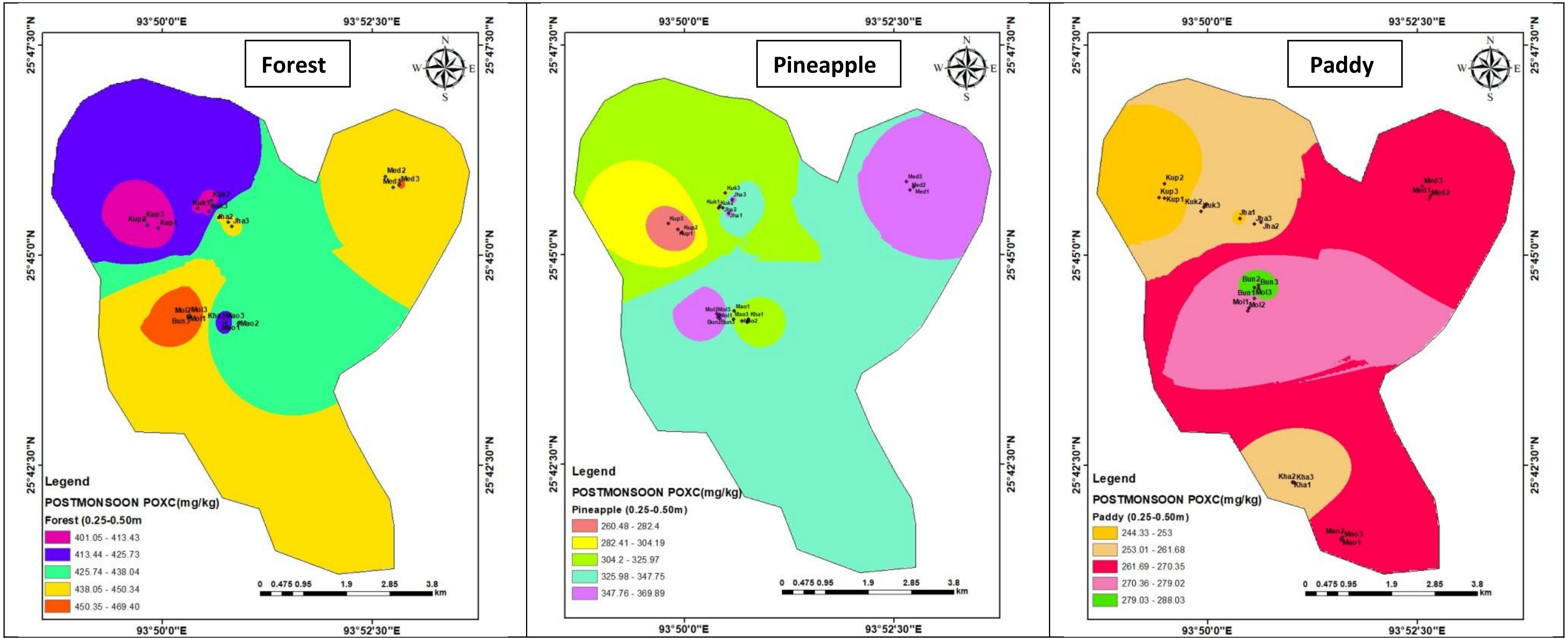


Fig 4.17 (b): Spatial distribution of POXC content in sub-surface soils (0.25–0.50 m) of different LUS during post-monsoon season

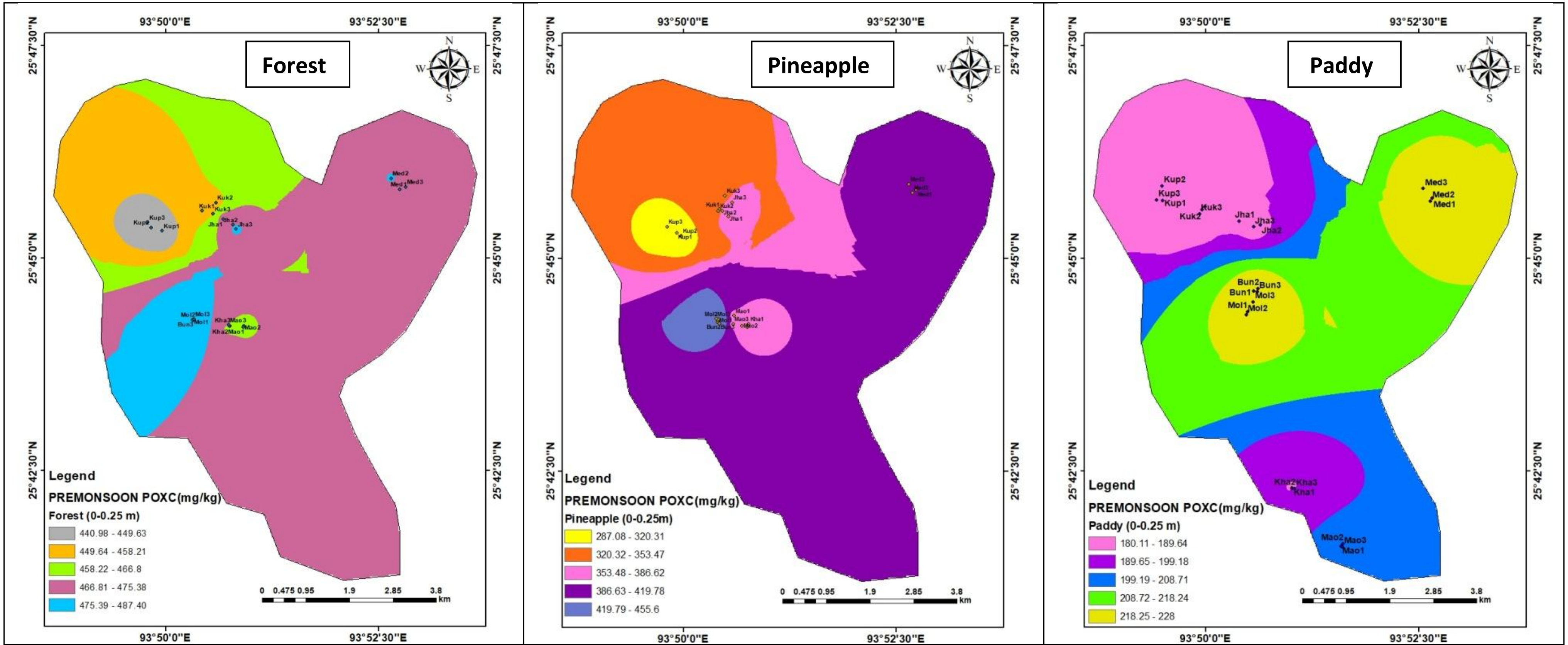


Fig 4.18 (a): Spatial distribution of POXC content in surface soils (0–0.25 m) of different LUS during pre-monsoon season

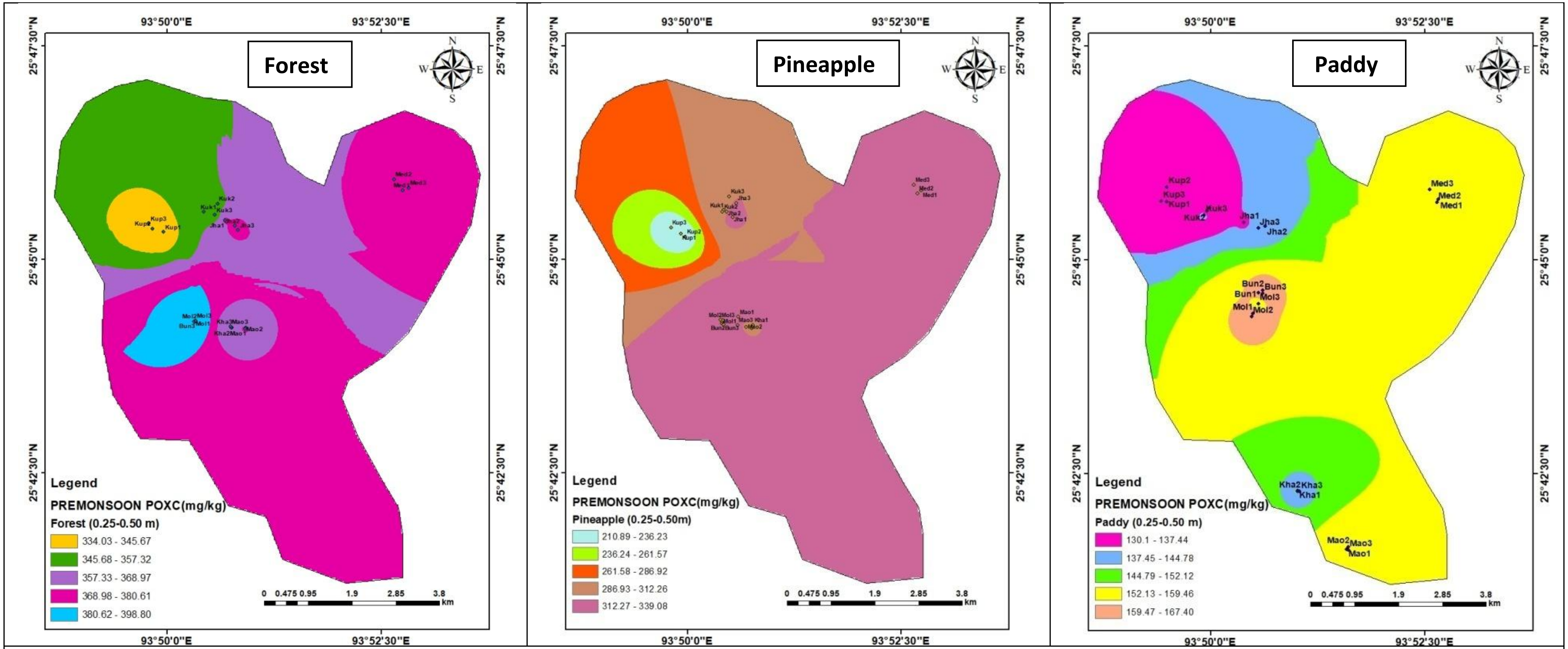


Fig 4.18 (b): Spatial distribution of POXC content in sub-surface soils (0.25–0.50 m) of different LUS during pre-monsoon season

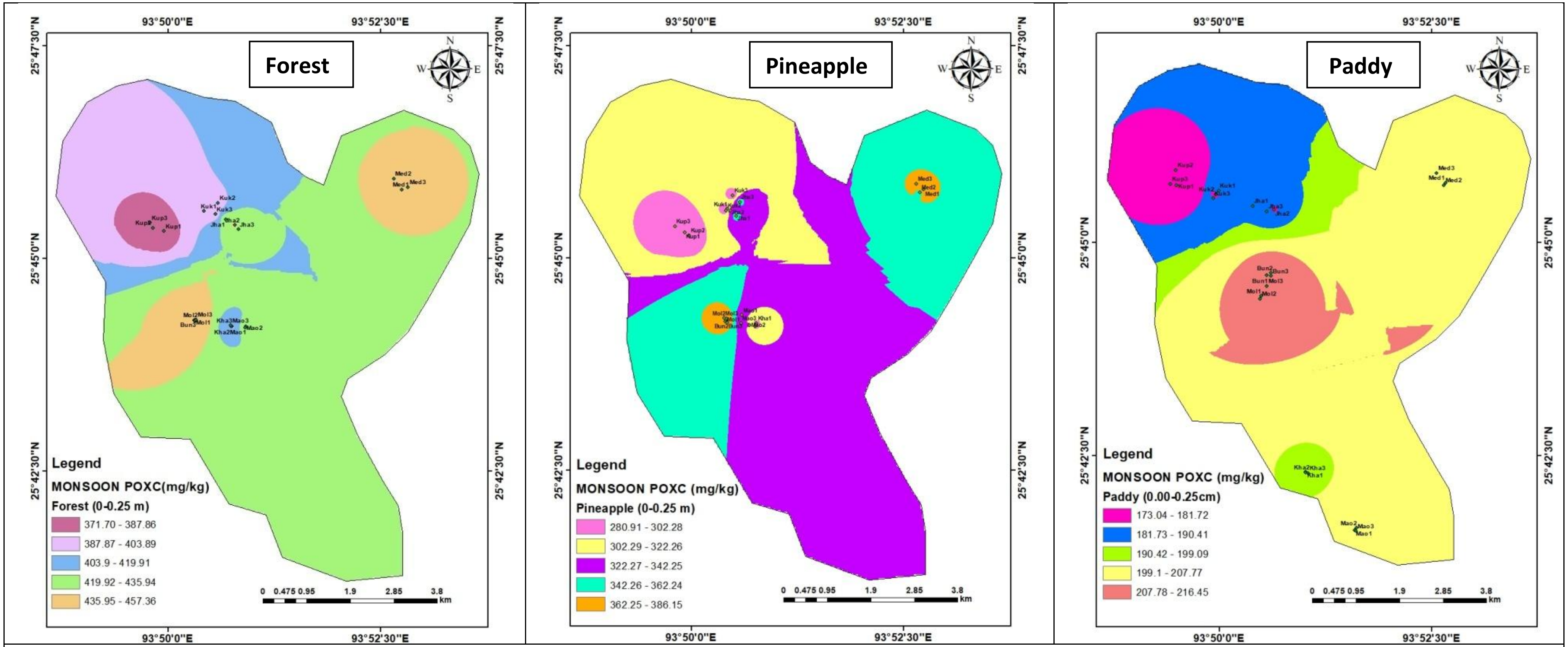


Fig 4.19 (a): Spatial distribution of POXC content in surface soils (0–0.25 m) of different LUS during monsoon season

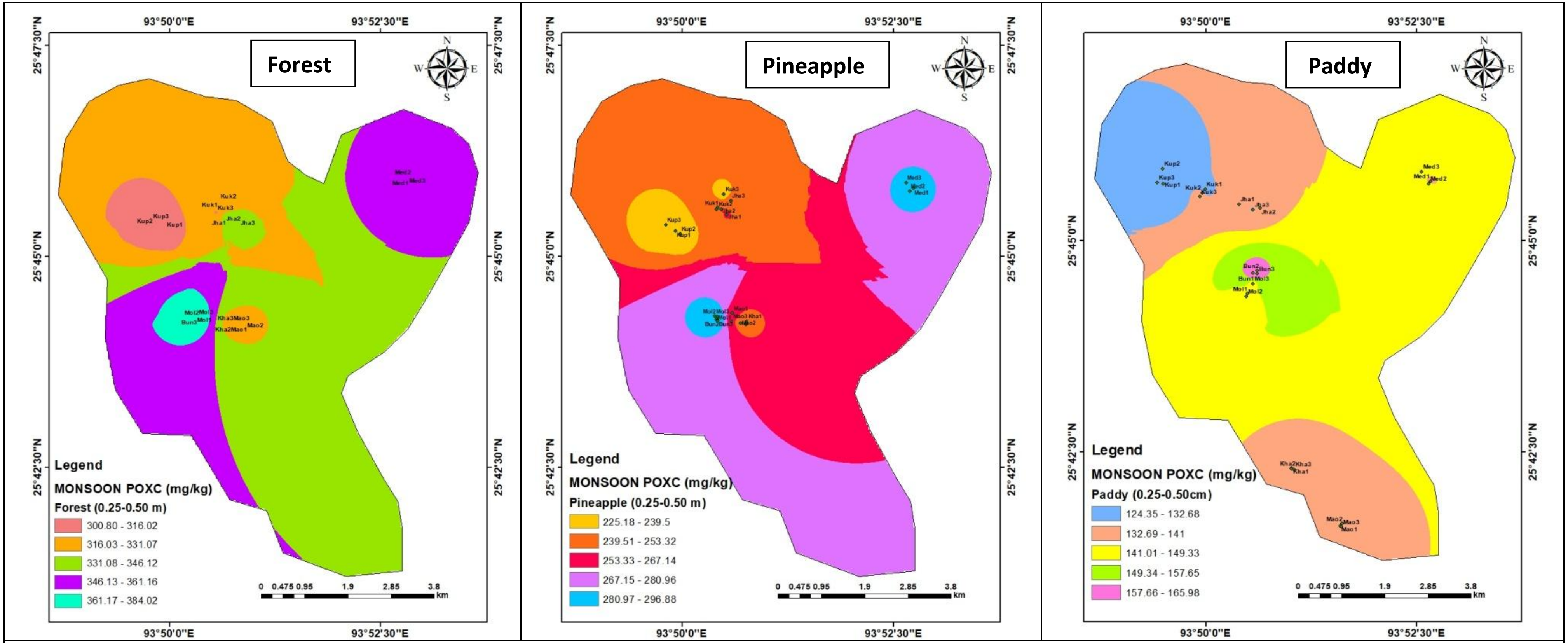


Fig 4.19 (b): Spatial distribution of POXC content in sub-surface soils (0.25–0.50 m) of different LUS during monsoon season

During monsoon season also, spatial variability of POXC in both the depths was evidenced. In the forest LUS it ranged from 371.70 to 457.36 mg kg^{-1} across the study area. Maximum content of POXC was observed in the sampling sites of Bungsung, Medziphema and Molvom village while, the sampling sites of Kupuhe village seen to contain minimum content of POXC (Fig 4.19 a). Similarly, pineapple LUS was seen to contain POXC ranging from 280.91 to 386.15 mg kg^{-1} in the surface soil during monsoon season. In the study area, paddy LUS was seen to have lowest POXC content among all LUS. Paddy LUS was seen to contain POXC in the range of 173.04 to 216.45 mg kg^{-1} in surface soils (Fig 4.19 a).

Spatial distribution of soil organic carbon stock:

Spatial variability of soil organic carbon stock (SOC stock) was observed in the study area as evidenced from interpolated data in the location maps in different season irrespective of the land use systems and depths. The SOC stock ranged from 51.75 to 56.53 Mg ha^{-1} during the post-monsoon season in the study site under forest LUS. Maximum SOC stock was observed in Bungsung, Medziphema and Molvom village, while minimum content of SOC stock was evidenced in sampling sites of Kupuhe and Kukidolong village in the surface soil under forest LUS (Fig 4.20 a). Pineapple LUS was seen to contain SOC stock in the critical range from 42.30 to 51.90 Mg ha^{-1}; maximum in Bungsung and Molvom village (Fig 4.20 a). Paddy LUS exhibited minimum SOC stock ranged from 38.81 to 42.58 Mg ha^{-1} with maximum spread area in the critical limit range of 40.39 to 41.08 Mg ha^{-1} in surface soil layer in the post-monsoon season (Fig 4.20 a).

Similarly, during pre-monsoon season, forest LUS exhibited SOC stock that ranged from 47.49 to 57.72 Mg ha^{-1}. It was also observed from the map that maximum sampling sites contained SOC stock in the critical limit range of 51.03 to 52.77 Mg ha^{-1} in the surface soil (Fig 4.21 a). Pineapple LUS was observed to contain SOC stock in the limit ranging from 38.12 to 53.34 Mg

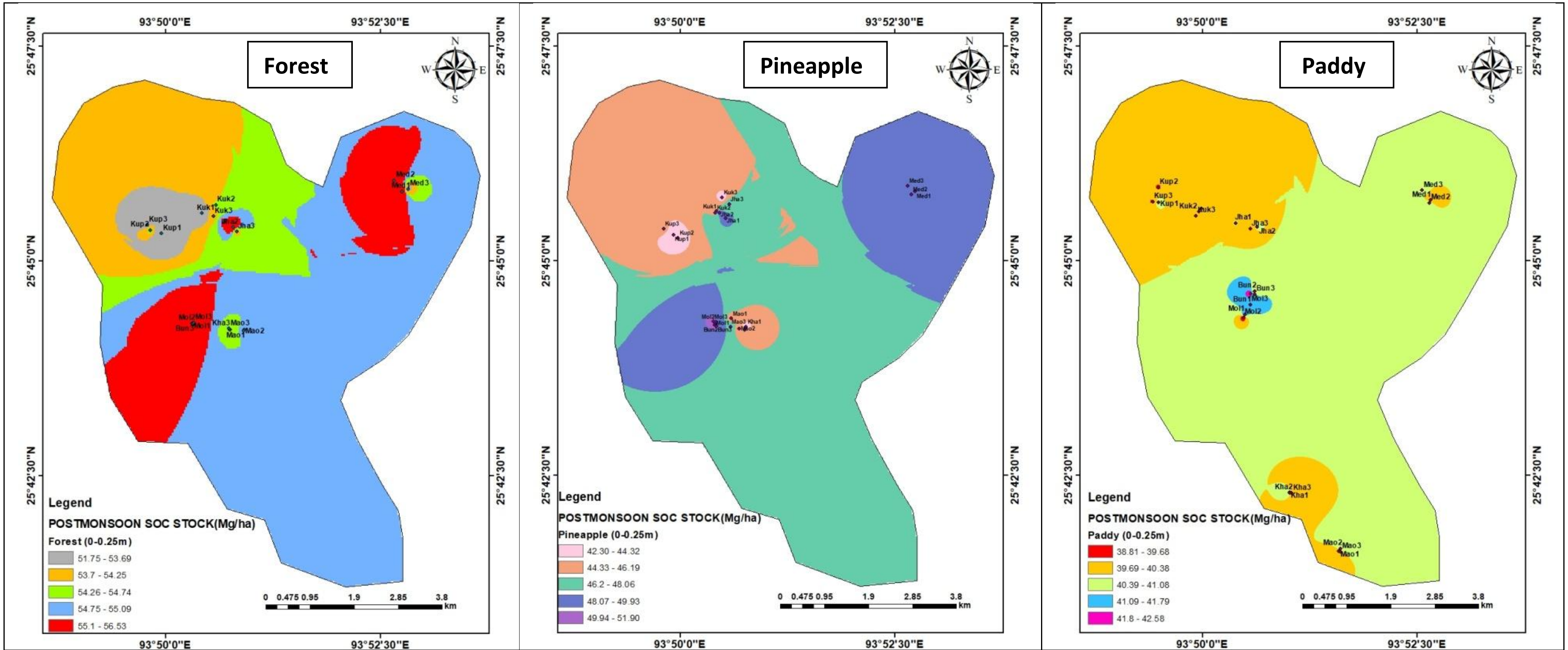


Fig 4.20 (a): Spatial distribution of SOC stock in surface soils (0–0.25 m) of different LUS during post-monsoon season

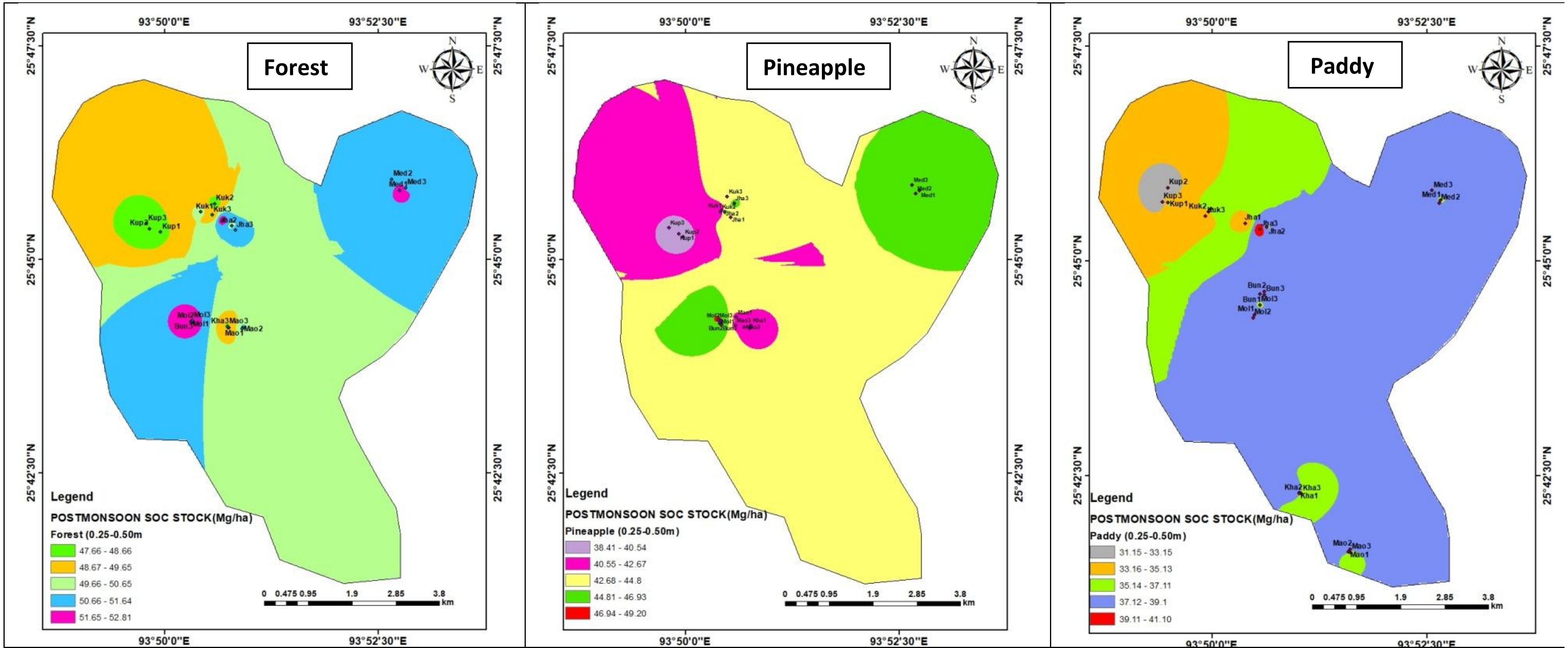


Fig 4.20 (b): Spatial distribution of SOC stock in sub-surface soils (0.25–0.50 m) of different LUS during post-monsoon season

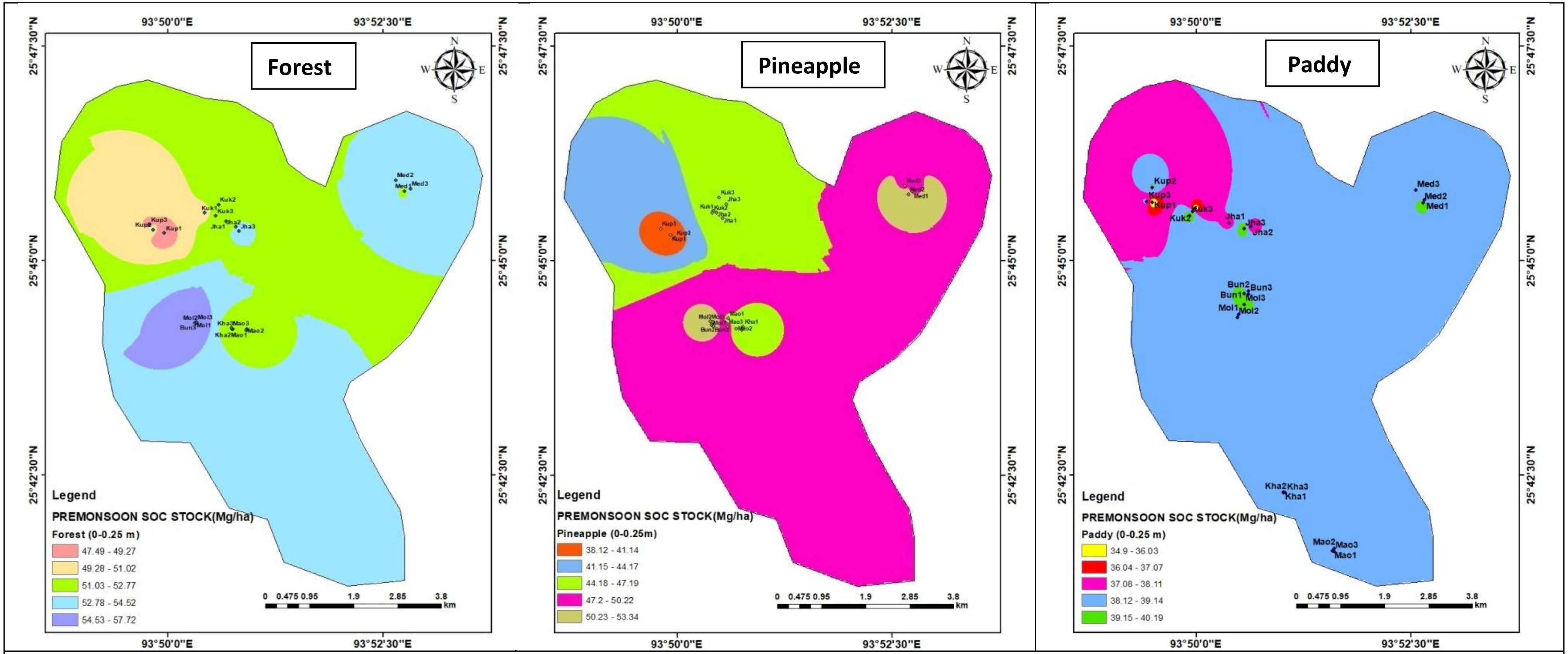


Fig 4.21 (a): Spatial distribution of SOC stock in surface soils (0–0.25 m) of different LUS during pre-monsoon season

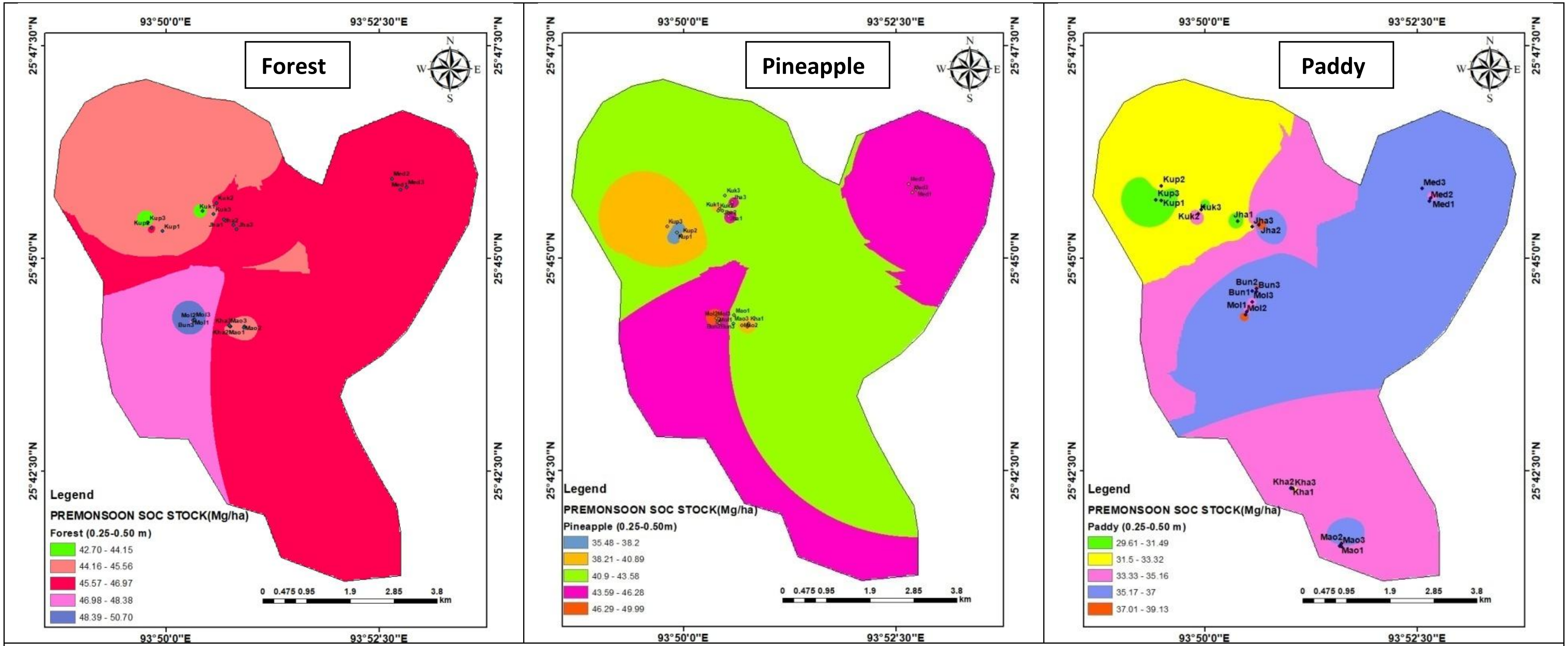


Fig 4.21(b): Spatial distribution of SOC stock in sub-surface soils (0.25–0.50 m) of different LUS during pre-monsoon season

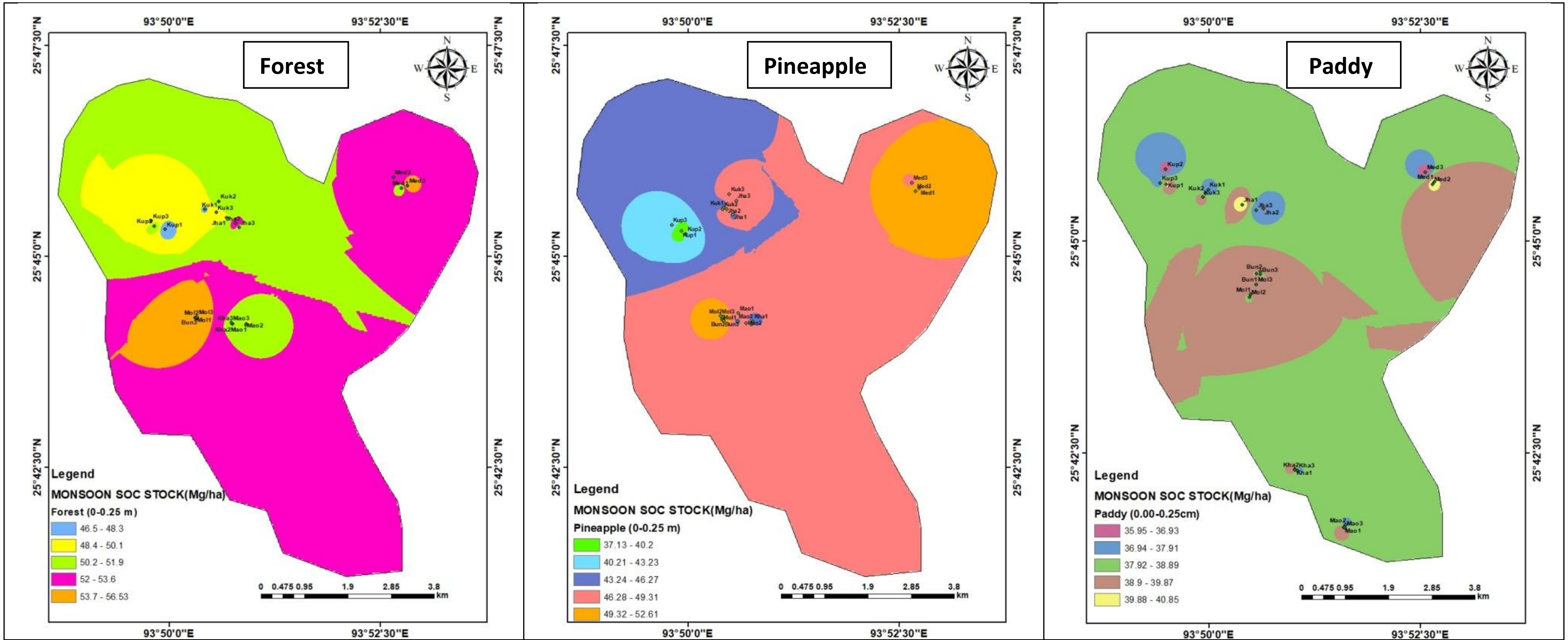


Fig 4.22 (a): Spatial distribution of SOC stock in surface soils (0–0.25 m) of different LUS during monsoon season

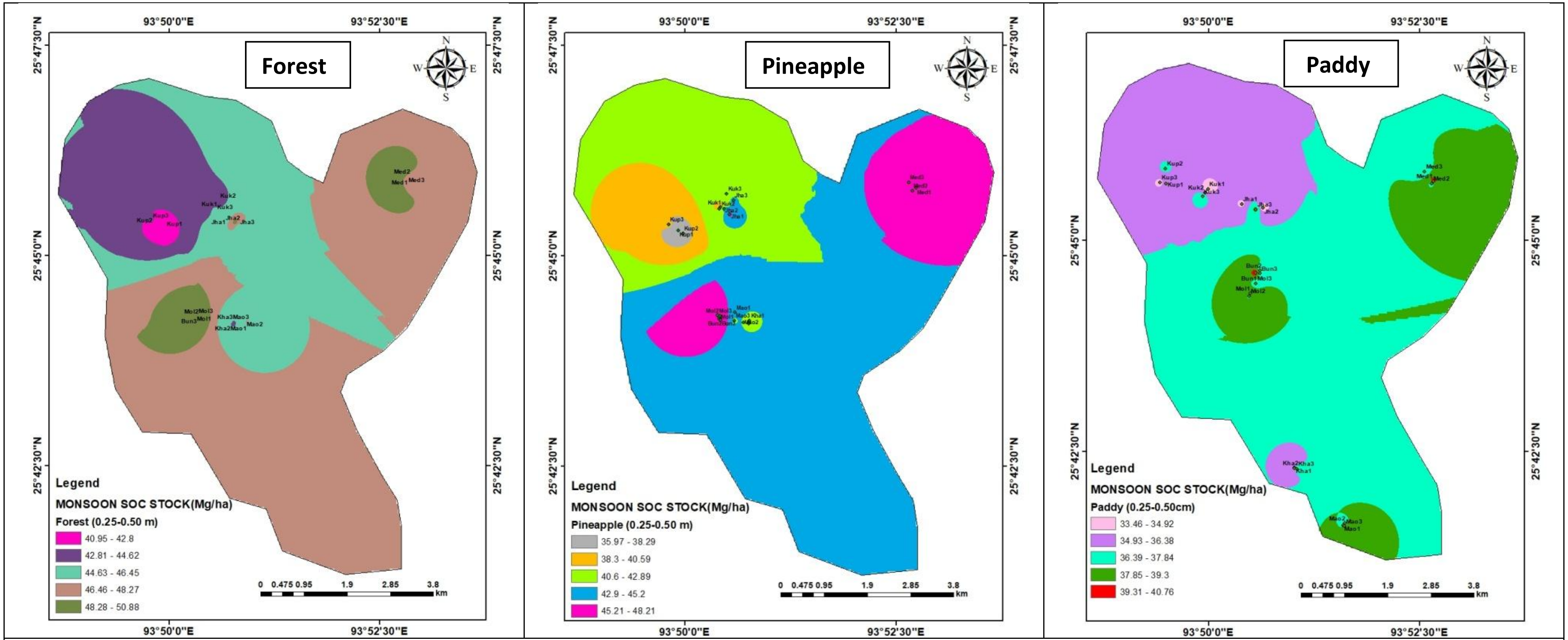


Fig 4.22 (b): Spatial distribution of SOC stock in sub-surface soils (0.25–0.50 m) of different LUS during monsoon season

ha^{-1}; with more sites under study area containing SOC stock in the range 47.20 to 50.22 Mg ha^{-1}. The SOC stock under paddy LUS ranged from 34.90 to 40.19 Mg ha^{-1} with maximum area in the range of 38.12 to 39.14 Mg ha^{-1} (Fig 4.21 a).

During monsoon season spatial variability of SOC stock was observed under different LUS in both the depths. In the forest LUS it ranged from 46.50 to 56.53 Mg ha^{-1} across the study area (Fig 4.22 a). Similarly, pineapple LUS contained the SOC stock ranging from 37.13 to 52.61 Mg ha^{-1} in the surface soil during monsoon season; maximum in the sites under Bungsung, Medziphema and Molvom village (Fig 4.22 a). Paddy LUS was seen to contain SOC stock in the range of 35.95 to 40.85 Mg ha^{-1} in surface soils. Erratic distribution of SOC stock was pronounced in paddy LUS even within the same village. However, most of the sampling sites contained SOC stock in the range of 37.92 to 38.89 Mg ha^{-1} under paddy cultivated areas of the study site.

4.6. Carbon mineralization pattern under different land uses

Soil basal respiration (SBR) reflects soil microbial activity which decreased due to the conversion of undisturbed land use to cultivated land uses. The high contents of BR generally indicate better soil quality as evolution of more amount of CO_2 is directly related to greater organic matter decomposition and hence higher nutrient availability. During the investigation, carbon mineralization pattern was studied through measurement of soil basal respiration (SBR) in an incubation experiment under laboratory setup. During 56 days incubation period, almost a similar pattern of CO_2 evolution was recorded for soils of different LUS at weekly interval; starting with an initial peak of CO_2 mineralization at second week of incubation followed by a gradual decline up to eighth week (56 days) with a static phase in between. Weekly SBR is presented in Table 4.23 a, 4.23 b and Table 4.23 c for pre-monsoon; Table 4.24 a, 4.24 b and Table 4.24 c for monsoon season and Table 4.25 a 4.25 b and Table 4.25 c for post-monsoon season respectively for different

LUS. Mean cumulative carbon mineralization was highest in forest LUS (97.68 μg CO_2-C g^{-1} h^{-1}) followed by pineapple LUS (49.44 μg CO_2-C g^{-1} h^{-1}) and paddy LUS (33.89 μg CO_2-C g^{-1} h^{-1}) irrespective of seasons and depths (Table 4.26 a). Sub-surface soils exhibited lower SBR and hence lower cumulative carbon mineralization rates. Mean maximum CO_2-C was recorded in surface soil of forest (105.97μg CO_2-C g^{-1} h^{-1}) and minimum was recorded in sub-surface soil of paddy LUS (31.68 μg CO_2-C g^{-1} h^{-1}). Variation in seasonal trend of CO_2-C evolution was also recorded during the investigation (Table 4.26 b and Fig 4.23 a, b; Fig 4.24 a, b; Fig 4.25 a, b). The pattern of seasonal variation was similar for forest and pineapple LUS; in which, mineralization started increasing with the increasing moisture and soil temperature in pre-monsoon season. Cumulative C- mineralization attained its peak in monsoon season and then declined towards the post-monsoon season as temperature drops and soil gets dried up (Table 4.26 a) On the other hand, paddy soil exhibited higher C-mineralization in pre-monsoon season that gradually declined to post-monsoon season through monsoon season. Significantly higher cumulative carbon mineralization was recorded as 114.64, 67.77 and 33.78 μg CO_2-C g^{-1} h^{-1} during monsoon season in surface soil of forest, pineapple and paddy LUS respectively (Table 4.26 b and Fig 4.26 a, Fig 4.26 b). The variation in pre-monsoon season was 105.47, 53.22 and 43.34 μg CO_2-C g^{-1} h^{-1} in forest, pineapple and paddy LUS. Post-monsoon season recorded least variation as 97.82, 39.32 and 31.18 μg CO_2-C g^{-1} hr^{-1} in surface soil of forest, pineapple and paddy LUS respectively.

Factors that simultaneously influence the production and consumption of organic matter are more important in controlling the overall rate of soil respiration than the tree and crop species. Availability of C source (substrate material), nutrient availability, soil temperature and soil moisture, biological factors such as soil fauna and soil microbial flora involved in C mineralization are some of these factors. The higher SBR and more CO_2 mineralization in

Table 4.23 (a). Carbon mineralization under forest land use system during pre-monsoon season

Sl. No.	Name of village	CO_2-C (μg g^{-1} h^{-1})								Cumulative CO_2-C (μg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	14.57	14.90	13.50	13.97	14.53	13.20	13.43	12.00	110.10
2	Jharnapani	13.70	14.20	13.40	13.40	13.40	12.60	12.60	11.53	104.83
3	Khaibung	13.53	14.07	13.00	12.47	13.53	13.03	13.00	11.40	104.03
4	Kukidolong	13.17	13.43	13.57	12.47	12.77	13.53	12.40	12.00	103.33
5	Kupuhe	13.60	13.60	13.33	12.57	13.87	12.53	12.03	11.50	103.03
6	Maova	13.63	15.13	13.33	13.33	12.80	12.53	12.80	11.20	104.77
7	Medziphema	14.20	14.17	13.63	13.10	13.10	12.60	12.83	11.23	104.87
8	Molvom	15.07	14.43	14.47	13.63	13.07	13.37	13.07	11.67	108.77
	Average	**13.93**	**14.24**	**13.53**	**13.12**	**13.38**	**12.93**	**12.77**	**11.57**	**105.47**
Sub-surface (0.25–0.50 m)										
1	Bungsung	12.80	13.27	11.99	11.97	11.37	11.17	10.43	9.07	92.06
2	Jharnapani	12.93	13.60	12.30	11.13	11.37	10.66	10.33	8.60	90.93
3	Khaibung	12.30	13.27	11.93	11.83	11.04	11.13	9.90	8.83	90.23
4	Kukidolong	12.23	13.23	11.34	10.93	10.77	10.47	10.17	9.27	88.40
5	Kupuhe	12.37	13.17	11.30	11.20	10.74	10.80	9.73	9.07	88.38
6	Maova	12.77	13.37	11.84	11.47	11.27	10.90	10.27	8.40	90.27
7	Medziphema	12.80	13.23	11.67	11.67	11.50	11.13	10.10	8.93	91.03
8	Molvom	13.10	13.90	12.11	11.83	11.54	11.18	9.73	8.30	91.70
	Average	**12.66**	**13.38**	**11.81**	**11.50**	**11.20**	**10.93**	**10.08**	**8.81**	**90.38**

Table 4.23 (b). Carbon mineralization under pineapple land use system during pre-monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	7.90	8.71	7.23	7.00	6.88	6.32	7.55	6.39	57.98
2	Jharnapani	6.92	8.27	6.90	6.51	6.33	6.11	6.57	5.76	53.36
3	Khaibung	6.39	7.82	6.70	6.32	6.13	5.97	5.83	5.50	50.65
4	Kukidolong	6.27	7.62	6.67	6.32	6.18	5.96	5.40	5.07	49.49
5	Kupuhe	6.19	7.41	6.51	6.10	5.83	5.66	5.27	5.07	48.03
6	Maova	6.39	7.92	6.75	6.32	6.17	5.97	5.83	5.50	50.84
7	Medziphema	7.50	8.57	6.93	6.59	6.31	6.10	7.27	6.28	55.55
8	Molvom	8.10	8.98	7.51	7.28	7.16	6.72	7.38	6.75	59.88
	Average	**6.96**	**8.16**	**6.90**	**6.55**	**6.37**	**6.10**	**6.39**	**5.79**	**53.22**
Sub-surface (0.25–0.50 m)										
1	Bungsung	6.43	7.53	5.71	5.56	5.19	5.15	4.82	5.03	45.43
2	Jharnapani	6.32	7.55	5.70	5.38	5.59	5.13	4.54	4.65	44.86
3	Khaibung	5.59	7.27	5.53	5.16	5.30	4.75	4.46	4.27	42.32
4	Kukidolong	5.26	7.18	5.53	4.98	4.96	4.45	4.24	4.13	40.74
5	Kupuhe	5.26	6.90	5.27	4.98	4.75	4.53	4.25	4.07	40.00
6	Maova	6.12	7.27	5.53	5.20	5.63	5.00	4.46	4.27	43.47
7	Medziphema	6.44	7.47	5.59	5.46	5.33	5.20	4.75	4.87	45.09
8	Molvom	6.33	7.38	6.44	5.97	5.34	5.50	5.33	5.08	47.37
	Average	**5.97**	**7.32**	**5.66**	**5.33**	**5.26**	**4.96**	**4.61**	**4.55**	**43.66**

Table 4.23 (c). Carbon mineralization under paddy land use system during pre-monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	6.44	7.38	6.11	5.75	5.58	5.34	5.35	5.07	47.01
2	Jharnapani	5.81	7.27	5.46	5.20	5.09	4.75	4.46	4.28	42.32
3	Khaibung	6.12	7.27	5.68	5.50	5.17	4.83	4.64	4.27	43.47
4	Kukidolong	5.82	6.57	5.37	4.99	4.93	4.93	4.63	4.45	41.68
5	Kupuhe	5.35	6.18	4.92	4.80	4.62	4.32	4.30	4.12	38.61
6	Maova	5.98	7.55	5.42	5.41	5.06	4.96	4.93	4.40	43.71
7	Medziphema	6.32	7.55	5.64	5.67	5.35	5.04	4.89	4.40	44.86
8	Molvom	6.44	7.47	5.59	5.46	5.34	5.00	5.18	4.62	45.09
	Average	**6.04**	**7.15**	**5.52**	**5.35**	**5.14**	**4.89**	**4.80**	**4.45**	**43.34**
Sub-surface (0.25–0.50 m)										
1	Bungsung	6.90	5.57	5.20	4.92	4.66	4.37	4.32	4.07	40.00
2	Jharnapani	6.38	4.88	4.65	4.32	4.25	4.12	4.13	3.53	36.27
3	Khaibung	6.45	4.98	4.93	4.63	4.40	4.25	4.38	3.90	37.93
4	Kukidolong	6.32	4.80	4.73	4.32	4.25	4.25	4.00	3.47	36.13
5	Kupuhe	6.40	5.02	4.53	4.27	4.18	4.18	4.07	3.18	35.83
6	Maova	5.96	5.67	5.31	5.12	4.78	4.20	4.02	3.58	38.63
7	Medziphema	5.73	5.28	5.10	5.00	4.80	4.33	4.58	4.27	39.09
8	Molvom	6.72	5.32	5.08	4.85	4.64	4.37	4.32	4.07	39.36
	Average	**6.36**	**5.19**	**4.94**	**4.68**	**4.50**	**4.26**	**4.23**	**3.76**	**37.90**

Table 4.24 (a). Carbon mineralization under forest land use system during monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	15.93	15.67	15.63	15.00	15.07	14.47	14.23	13.67	119.67
2	Jharnapani	14.93	15.07	14.80	13.67	14.00	14.27	14.23	13.10	114.07
3	Khaibung	14.53	15.43	15.93	14.57	14.17	13.63	13.07	12.50	113.83
4	Kukidolong	15.13	15.83	15.87	14.93	13.93	12.57	13.17	11.13	112.57
5	Kupuhe	14.83	14.90	14.90	14.00	13.20	13.97	13.43	12.00	111.23
6	Maova	14.90	15.97	16.20	14.17	13.20	13.47	13.47	12.57	113.93
7	Medziphema	15.53	16.73	17.07	15.43	13.53	12.57	12.27	11.50	114.63
8	Molvom	14.67	16.63	15.57	14.43	14.70	14.70	13.53	12.97	117.20
	Average	**15.06**	**15.78**	**15.75**	**14.53**	**13.98**	**13.70**	**13.43**	**12.43**	**114.64**
Sub-surface (0.25–0.50 m)										
1	Bungsung	12.50	13.83	12.77	12.23	12.47	12.40	11.30	11.20	98.70
2	Jharnapani	13.63	13.93	12.24	11.80	11.77	11.87	10.50	8.99	94.73
3	Khaibung	13.32	14.07	12.70	11.57	10.97	11.77	10.50	8.43	93.32
4	Kukidolong	13.45	14.18	12.18	11.83	11.18	11.87	10.10	8.33	93.13
5	Kupuhe	12.80	13.27	11.99	11.97	11.50	11.37	10.43	9.07	92.39
6	Maova	13.77	14.13	12.21	12.14	10.98	12.18	10.30	8.47	94.18
7	Medziphema	13.10	13.10	12.30	12.07	11.77	12.57	10.73	9.20	94.83
8	Molvom	13.07	13.77	12.80	12.27	11.73	11.47	11.47	9.40	95.97
	Average	**13.21**	**13.79**	**12.40**	**11.98**	**11.55**	**11.94**	**10.67**	**9.14**	**94.66**

Table 4.24 (b). Carbon mineralization under pineapple land use system during monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	9.83	10.36	8.96	8.39	8.13	7.60	8.27	7.87	69.41
2	Jharnapani	9.37	10.42	8.95	8.43	8.11	7.40	8.16	7.03	67.87
3	Khaibung	9.33	10.64	8.16	7.97	7.57	7.22	8.13	7.25	66.27
4	Kukidolong	9.30	10.10	8.75	8.23	7.89	7.40	7.40	7.17	66.25
5	Kupuhe	8.76	9.92	8.15	7.75	7.45	7.92	7.45	7.15	64.54
6	Maova	9.33	10.31	8.47	8.07	7.80	7.25	8.09	7.17	66.49
7	Medziphema	8.77	10.81	8.91	8.41	8.20	7.95	8.14	7.15	68.34
8	Molvom	9.57	10.46	9.80	9.64	9.13	8.64	8.51	7.24	72.99
	Average	**9.28**	**10.38**	**8.77**	**8.36**	**8.04**	**7.67**	**8.02**	**7.25**	**67.77**
Sub-surface (0.25–0.50 m)										
1	Bungsung	8.44	9.43	7.69	7.33	7.48	7.23	7.56	6.99	62.15
2	Jharnapani	8.41	9.20	7.77	7.32	7.51	7.20	6.55	6.81	60.77
3	Khaibung	7.90	8.71	7.23	7.00	7.55	6.88	6.32	6.39	57.98
4	Kukidolong	7.47	8.45	6.93	6.65	7.22	6.55	6.14	6.30	55.71
5	Kupuhe	7.50	8.57	6.93	6.59	7.27	6.31	6.10	6.28	55.55
6	Maova	8.17	8.95	7.46	7.19	7.39	7.08	6.54	6.54	59.30
7	Medziphema	8.60	9.10	7.59	7.42	7.22	7.33	6.92	6.74	60.92
8	Molvom	8.42	9.71	7.71	7.42	7.25	7.17	7.77	6.77	62.22
	Average	**8.11**	**9.02**	**7.41**	**7.11**	**7.36**	**6.97**	**6.74**	**6.60**	**59.32**

Table 4.24 (c). Carbon mineralization under paddy land use system during monsoon season

Sl. No.	Name of village	CO_2-C ($\mu g\ g^{-1}\ h^{-1}$)								Cumulative CO_2-C ($\mu g\ g^{-1}\ h^{-1}$)
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	5.32	5.60	4.55	4.37	4.30	4.33	3.95	3.45	35.86
2	Jharnapani	4.32	4.70	4.55	4.20	4.11	3.95	3.58	3.43	32.85
3	Khaibung	4.79	4.93	4.55	4.28	4.23	3.80	3.31	3.15	33.04
4	Kukidolong	4.68	5.15	4.23	4.20	3.77	3.50	3.65	3.30	32.48
5	Kupuhe	4.72	4.97	4.37	4.26	3.60	3.55	3.36	3.17	31.99
6	Maova	4.66	5.22	4.60	4.53	4.38	4.03	3.45	3.32	34.18
7	Medziphema	5.27	5.83	4.45	4.18	4.18	4.06	3.73	3.18	34.90
8	Molvom	4.91	5.40	4.70	4.62	4.33	4.12	3.52	3.32	34.91
	Average	**4.83**	**5.22**	**4.50**	**4.33**	**4.11**	**3.92**	**3.57**	**3.29**	**33.78**
Sub-surface (0.25–0.50 m)										
1	Bungsung	5.07	5.12	4.40	4.32	3.90	3.73	3.52	3.18	33.23
2	Jharnapani	4.40	4.65	4.12	4.00	3.87	3.38	3.27	2.98	30.67
3	Khaibung	4.58	5.02	4.17	4.03	3.38	3.22	3.18	3.08	30.67
4	Kukidolong	4.38	4.75	4.24	4.17	3.82	3.38	3.20	2.65	30.59
5	Kupuhe	4.45	4.68	4.32	4.25	3.60	3.25	3.18	2.73	30.47
6	Maova	4.40	4.60	4.18	4.06	3.78	3.67	3.45	2.98	31.12
7	Medziphema	4.58	4.97	4.33	4.26	3.60	3.55	3.25	3.17	31.71
8	Molvom	4.52	4.78	4.44	4.23	4.20	3.72	3.67	2.93	32.49
	Average	**4.55**	**4.82**	**4.27**	**4.16**	**3.77**	**3.49**	**3.34**	**2.96**	**31.37**

Table 4.25 (a). Carbon mineralization under forest land use system during post-monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	13.17	13.67	12.70	12.93	12.17	12.38	11.97	11.43	100.42
2	Jharnapani	12.77	14.17	12.60	12.56	12.90	12.63	11.63	9.77	99.03
3	Khaibung	13.00	13.57	12.53	11.57	12.86	11.33	12.40	9.82	97.07
4	Kukidolong	13.63	13.93	12.48	11.80	11.87	11.77	10.57	8.99	95.04
5	Kupuhe	13.00	13.60	12.54	12.19	11.80	11.23	11.30	9.30	94.97
6	Maova	12.67	14.27	12.10	12.02	12.57	11.45	11.87	10.23	97.17
7	Medziphema	12.30	14.17	12.83	12.53	11.93	13.07	11.17	11.13	99.13
8	Molvom	12.87	13.67	12.97	12.60	12.23	12.57	11.30	11.50	99.70
	Average	**12.93**	**13.88**	**12.59**	**12.28**	**12.29**	**12.05**	**11.53**	**10.27**	**97.82**
Sub-surface (0.25–0.50 m)										
1	Bungsung	11.49	12.56	11.03	10.71	10.83	10.29	10.00	8.98	85.88
2	Jharnapani	12.06	12.50	10.77	10.73	10.36	10.29	9.44	7.81	83.97
3	Khaibung	10.57	12.57	10.34	10.11	10.19	9.88	9.31	8.93	81.90
4	Kukidolong	10.83	12.28	10.07	9.84	9.77	9.62	8.96	8.63	80.00
5	Kupuhe	10.17	12.38	9.93	9.69	9.70	9.35	9.12	8.93	79.26
6	Maova	11.61	12.70	11.20	10.80	10.20	10.57	8.93	7.63	83.63
7	Medziphema	12.63	13.03	10.90	10.37	10.37	10.07	9.37	8.06	84.79
8	Molvom	12.49	12.93	11.93	11.10	10.27	10.53	8.88	7.58	85.73
	Average	**11.48**	**12.62**	**10.77**	**10.42**	**10.21**	**10.08**	**9.25**	**8.32**	**83.15**

Table 4.25 (b). Carbon mineralization under pineapple land use system during post-monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	5.53	7.27	5.59	5.16	4.75	5.30	4.46	4.27	42.32
2	Jharnapani	5.02	6.72	5.23	4.81	4.52	4.75	4.25	4.07	39.36
3	Khaibung	4.97	6.38	4.43	4.38	4.25	4.13	4.18	3.62	36.35
4	Kukidolong	4.97	6.32	4.43	4.38	4.25	4.13	4.18	3.47	36.13
5	Kupuhe	5.02	6.40	4.18	4.53	4.27	4.07	4.18	3.18	35.83
6	Maova	5.02	6.45	4.90	4.63	4.40	4.38	4.25	3.90	37.93
7	Medziphema	5.27	6.90	5.26	4.98	4.53	4.75	4.25	4.07	40.00
8	Molvom	6.23	7.38	5.96	5.82	5.49	5.34	5.33	5.08	46.63
	Average	**5.25**	**6.73**	**5.00**	**4.84**	**4.56**	**4.61**	**4.39**	**3.96**	**39.32**
Sub-surface (0.25–0.50 m)										
1	Bungsung	5.02	6.40	4.53	4.27	4.18	4.18	4.07	3.18	35.83
2	Jharnapani	4.82	5.78	4.18	3.92	3.85	3.85	3.70	3.18	33.28
3	Khaibung	4.32	5.38	4.12	3.72	3.60	3.52	3.30	3.17	31.12
4	Kukidolong	4.32	5.32	4.05	3.78	3.60	3.45	3.30	3.16	30.97
5	Kupuhe	4.25	5.05	3.87	3.52	3.27	3.32	3.22	3.16	29.64
6	Maova	4.68	5.72	4.12	3.72	3.60	3.52	3.30	3.17	31.82
7	Medziphema	4.93	6.13	4.32	4.00	3.85	3.85	3.70	3.18	33.97
8	Molvom	5.27	6.90	4.98	4.53	4.25	5.26	4.75	4.07	40.00
	Average	**4.70**	**5.84**	**4.27**	**3.93**	**3.78**	**3.87**	**3.67**	**3.28**	**33.33**

Table 4.25 (c). Carbon mineralization under paddy land use system during post-monsoon season

Sl. No.	Name of village	CO_2-C (µg g^{-1} h^{-1})								Cumulative CO_2-C (µg g^{-1} h^{-1})
		Surface (0–0.25 m)								
		Incubation days								
		7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	
1	Bungsung	4.87	4.93	4.55	4.33	4.18	3.91	3.55	3.25	33.58
2	Jharnapani	4.26	4.52	4.07	3.59	3.35	3.17	3.13	2.70	28.78
3	Khaibung	4.22	4.48	4.10	3.87	3.90	3.65	3.22	2.90	30.33
4	Kukidolong	3.96	4.40	3.90	3.67	3.27	3.20	3.12	2.95	28.46
5	Kupuhe	3.96	4.40	3.90	3.67	3.27	3.20	3.07	2.83	28.29
6	Maova	4.50	4.88	4.60	4.40	4.38	3.95	3.35	3.10	33.16
7	Medziphema	4.73	5.17	4.32	4.18	4.18	3.86	3.73	3.18	33.36
8	Molvom	4.61	4.68	4.58	4.60	4.30	4.12	3.47	3.10	33.46
	Average	**4.39**	**4.68**	**4.25**	**4.04**	**3.85**	**3.63**	**3.33**	**3.00**	**31.18**
Sub-surface (0.25–0.50 m)										
1	Bungsung	4.40	3.82	3.90	3.67	3.27	3.20	3.07	2.78	28.11
2	Jharnapani	3.80	3.38	3.15	3.12	3.07	2.92	2.75	2.35	24.54
3	Khaibung	3.61	3.38	3.35	3.27	3.12	3.00	2.77	2.55	25.05
4	Kukidolong	3.60	3.28	3.23	3.12	3.10	2.93	2.75	2.42	24.43
5	Kupuhe	3.27	3.27	3.12	3.12	3.00	2.59	2.43	2.15	22.94
6	Maova	4.15	4.00	3.68	3.37	3.25	2.95	2.75	2.48	26.64
7	Medziphema	3.97	3.56	3.63	3.42	3.40	3.20	3.00	2.72	26.90
8	Molvom	3.83	3.96	3.80	3.67	3.27	3.17	2.98	2.78	27.46
	Average	**3.83**	**3.58**	**3.48**	**3.34**	**3.18**	**3.00**	**2.81**	**2.53**	**25.76**

Table 4.26 (a). Soil basal respiration in relation to land use, sampling time and depth

Sl No.	Name of village	SBR (µg CO_2-C g^{-1} h^{-1})																	
		Forest land use						Pineapple land use						Paddy land use					
		0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m			0–0.25 m			0.25–0.50 m		
		Sampling time			Sampling time			Sampling time			Sampling time			Sampling time			Sampling time		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Bungsung	110.10	119.67	100.42	92.06	98.70	85.88	57.98	69.41	42.32	45.43	62.15	35.83	47.01	35.86	33.58	40.00	33.23	28.11
2	Jharnapani	104.83	114.07	99.03	90.93	94.73	83.97	53.36	67.87	39.36	44.86	60.77	33.28	42.32	32.85	28.78	36.27	30.67	24.54
3	Khaibung	104.03	113.83	97.07	90.23	93.32	81.90	50.65	66.27	36.35	42.32	57.98	31.12	43.47	33.04	30.33	37.93	30.67	25.05
4	Kukidolong	103.33	112.57	95.04	88.40	93.13	80.00	49.49	66.25	36.13	40.74	55.71	30.97	41.68	32.48	28.46	36.13	30.59	24.43
5	Kupuhe	103.03	111.23	94.97	88.38	92.39	79.26	48.03	64.54	35.83	40.00	55.55	29.64	38.61	31.99	28.29	35.83	30.47	22.94
6	Maova	104.77	113.93	97.17	90.27	94.18	83.63	50.84	66.49	37.93	43.47	59.30	31.82	43.71	34.18	33.16	38.63	31.12	26.64
7	Medziphema	104.87	114.63	99.13	91.03	94.83	84.79	55.55	68.34	40.00	45.09	60.92	33.97	44.86	34.90	33.36	39.09	31.71	26.90
8	Molvom	108.77	117.20	99.70	91.70	95.97	85.73	59.88	72.99	46.63	47.37	62.22	40.00	45.09	34.91	33.46	39.36	32.49	27.46
Average *(ST)		**105.47**	**114.64**	**97.82**	**90.38**	**94.66**	**83.15**	**53.22**	**67.77**	**39.32**	**43.66**	**59.33**	**33.33**	**43.34**	**33.78**	**31.18**	**37.91**	**31.37**	**25.76**
Range (Depth)		94.97–119.67			79.26–98.70			35.83–72.99			29.64–62.22			28.29–47.01			22.94–40.00		
Average (Depth)		**105.97**			**89.39**			**53.44**			**45.44**			**36.10**			**31.68**		
Range **(LU)		79.26–119.67						29.64–72.99						22.94–47.01					
Average (LU)		**97.68**						**49.44**						**33.89**					

*ST :Sampling time **LU: Land Use I: Pre-monsoon II: Monsoon III: Post-monsoon

Table 4.26 (b). Variation in soil basal respiration (µg CO_2-C g^{-1} h^{-1}) under different land use systems in different seasons

Sl No.	Land use	Pre-monsoon		Monsoon		Post-monsoon	
		0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m	0–0.25 m	0.25–0.50 m
1	Forest	105.47[a]	90.38[a]	114.64[a]	94.66[a]	97.82[a]	83.15[a]
2	Pineapple	53.22[b]	43.66[b]	67.77[b]	59.33[b]	39.32[b]	33.33[b]
3	Paddy	43.34[c]	37.91[c]	33.78[c]	31.37[c]	31.18[c]	25.76[c]

Values followed by different letters under different land uses are significantly different (P<0.05) by the Duncan's multiple range test

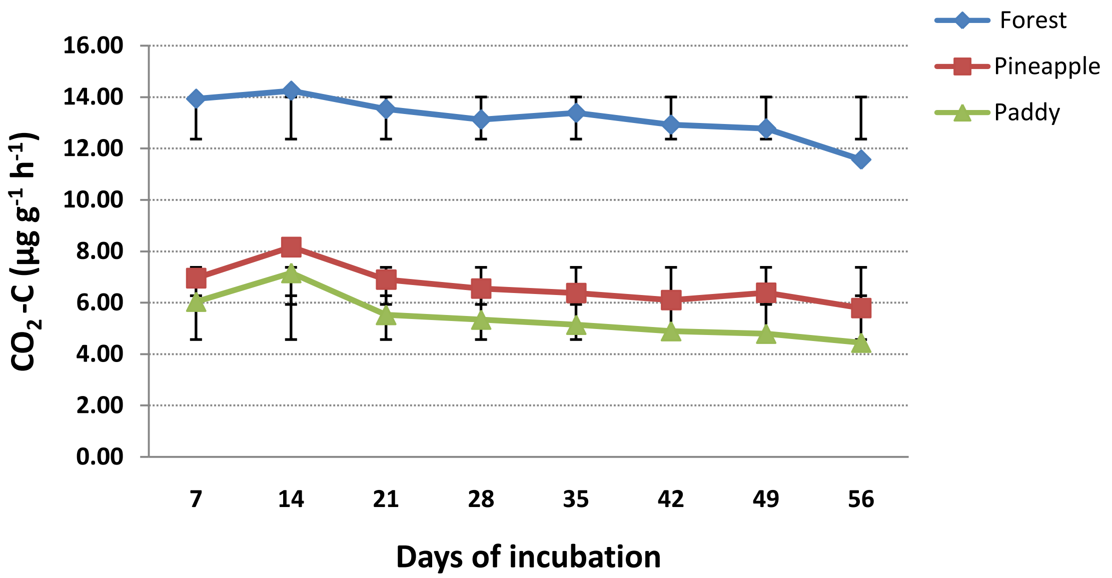


Fig 4.23 (a): Carbon mineralization pattern in surface soils (0-0.25 m) of different land use systems during pre-monsoon season

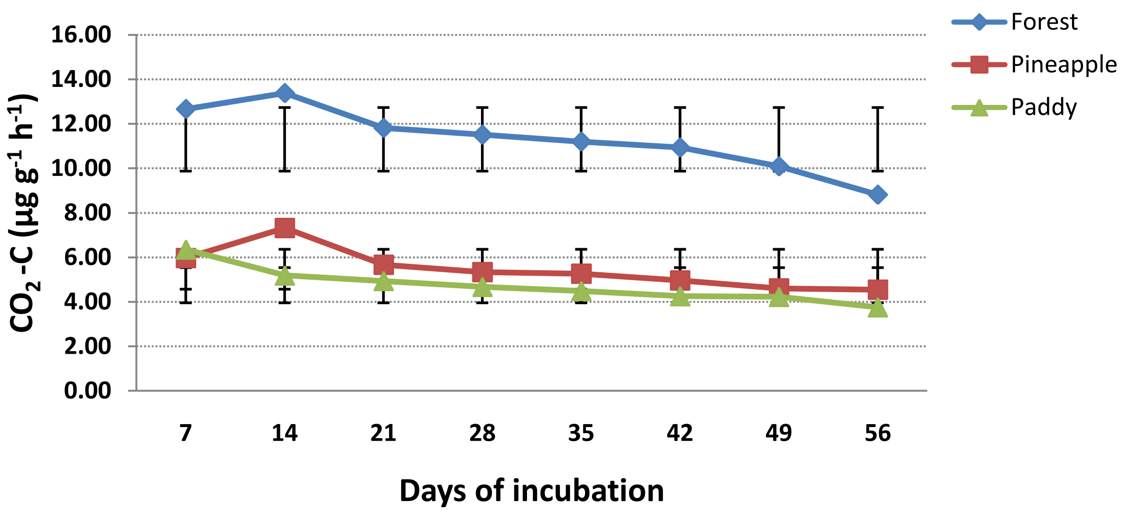


Fig 4.23 (b): Carbon mineralization pattern in sub-surface soils (0.25–0.50 m) of different land use systems during pre-monsoon season

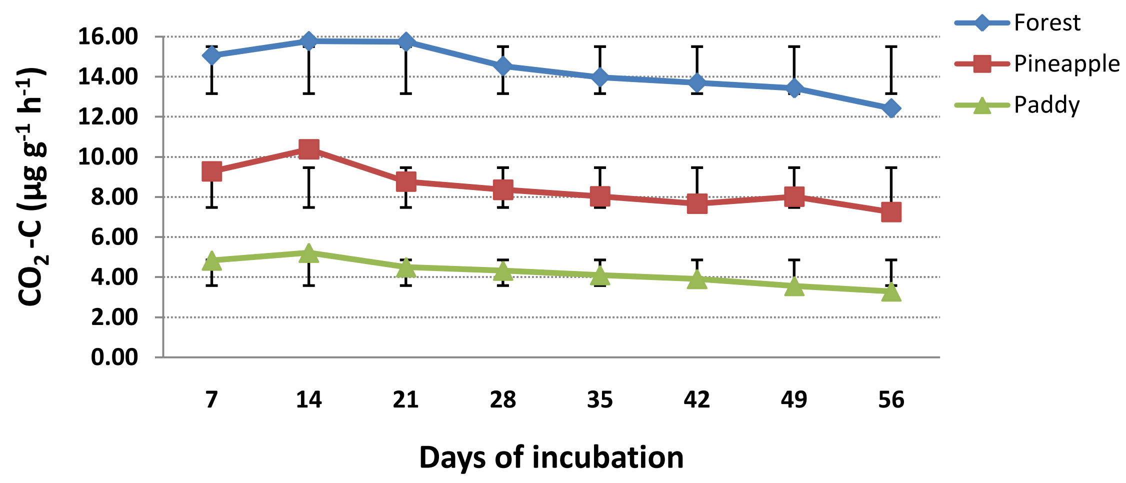


Fig 4.24 (a): Carbon mineralization pattern in surface soils (0-0.25 m) of different land use systems during monsoon season

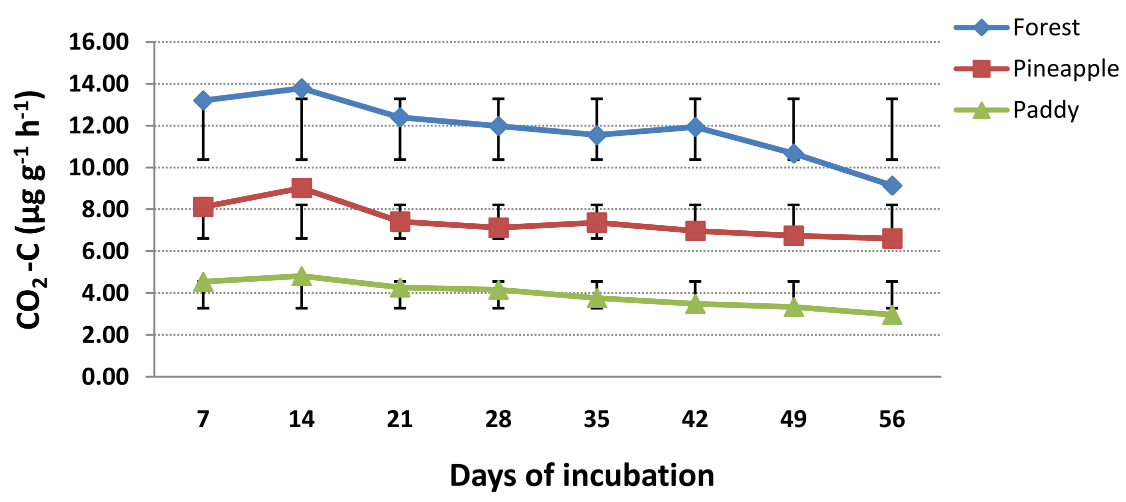


Fig 4.24 (b): Carbon mineralization pattern in sub-surface soils (0.25–0.50 m) of different land use systems during monsoon season

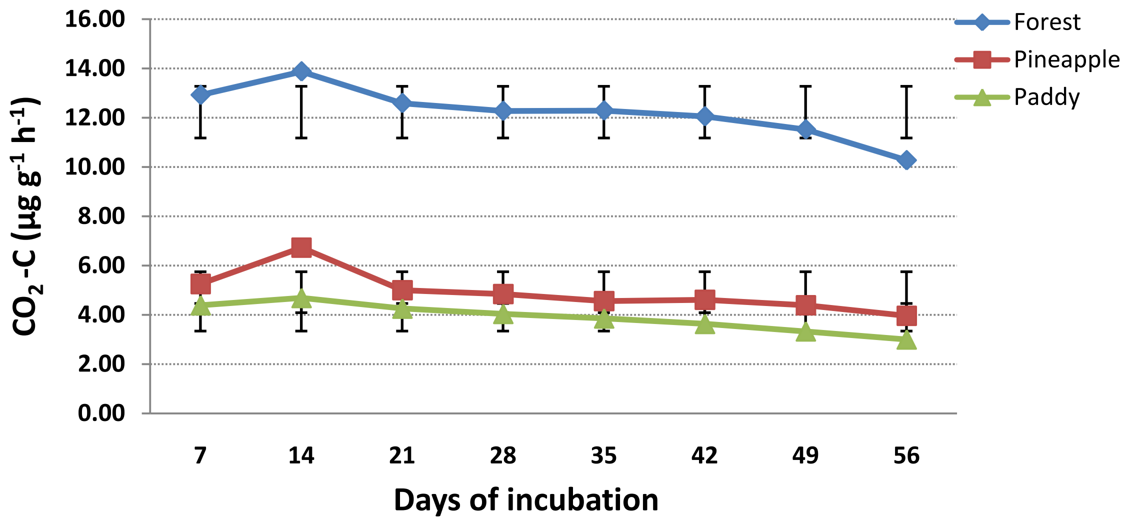


Fig 4.25 (a): Carbon mineralization pattern in surface soils (0-0.25 m) of different land use systems during post-monsoon season

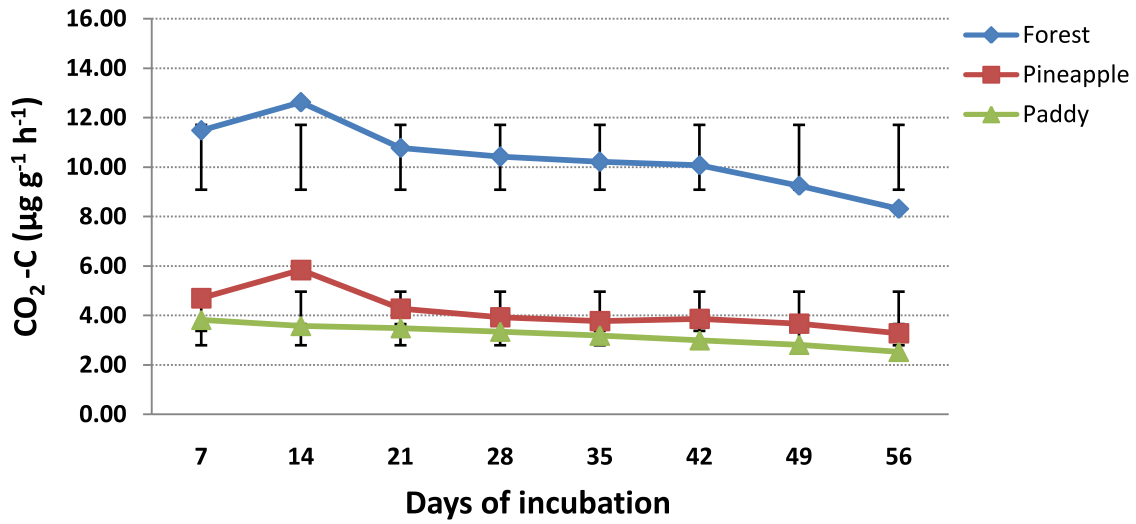


Fig 4.25 (b): Carbon mineralization pattern in sub-surface soils (0.25–0.50 m) of different land use systems during post-monsoon season

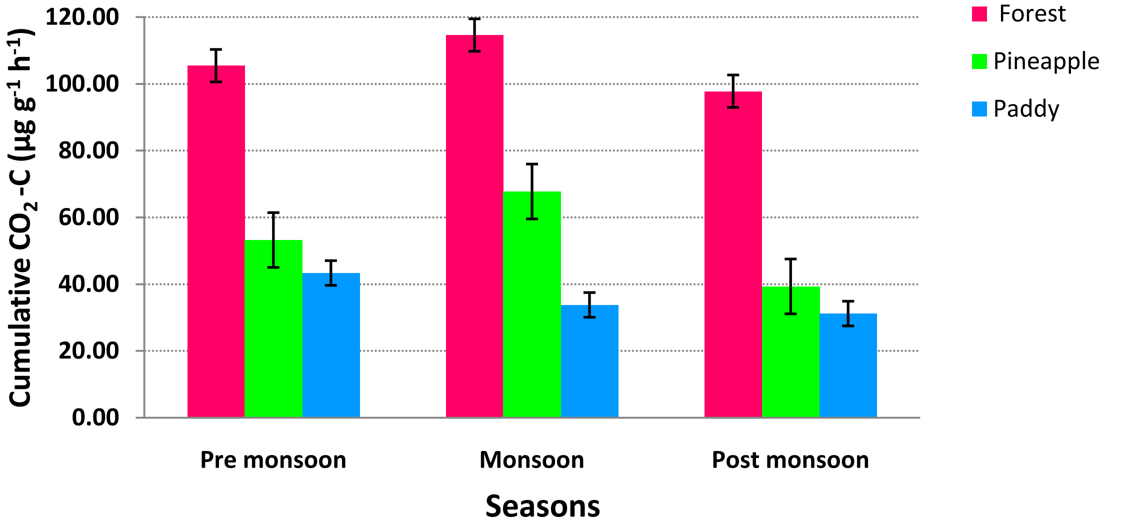


Fig 4.26 (a): Cumulative carbon mineralization in surface soils (0–0.25 m) of different land use systems during various sampling seasons

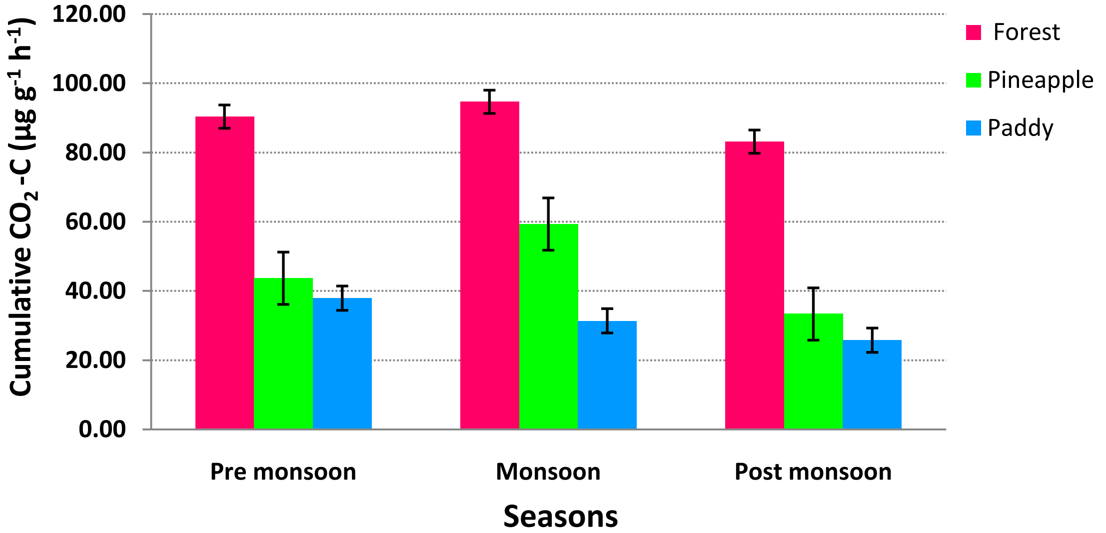


Fig 4.26 (b): Cumulative carbon mineralization in sub-surface soils (0.25-0.50 m) of different land use systems during various sampling seasons

forest LUS compared to other two land uses may be attributed to accumulation of diverse kind of litter materials in the forest floor along with below ground root biomass that served as the C-rich substrate materials to the microorganisms, which increased their population as well as activity. Higher MBC content and large pool of labile C in the forest LUS can also be attributed to high rate of respiration and C mineralization. The decreased rate of C- mineralization in 0.25–0.50 m might be due to lower organic carbon content and relatively smaller number of microbes as soil depth increases.

A relationship between soil respiration rate and temperature was observed during the investigation. The highest soil respiration rate was recorded in the monsoon season (August sampling), and the lowest in post-monsoon season (November sampling); indicating that SBR increased with increase in temperature that facilitates the microbial proliferation and activity. During winter / post-monsoon season, many species of microorganisms might have got inactivated and hence lower C- mineralization rate was recorded. In conformity with the results of present investigation, Xiangmin *et al.* (2014) have reported higher C- mineralization rate of natural mixed forest (NF) soil than ginseng farmland (GF), spruce plantation (SP) cropland (CL) and oak young forest (YF). They have revealed that the mineralization rate of SOC significantly decreased when the zonal forest was cut down and replaced by other land use types. Similarly, Wang *et al.* (2013) have reported higher soil respiration rate under *Pinus massoniana* (PM) plantation compared to *Cinnamomum camphora* (CC) and *Schima superba* (SS) in subtropical China. They opined that overall rate of soil respiration depend more on some factors like C availability, nutrient availability, soil temperature and soil moisture rather than the tree species. Total carbon mineralized and the mineralization rates were consistently higher in grasslands in both 0–10 cm and 10–20 cm as compared to the other land uses and management systems. The cumulative CO_2 release followed the order: grassland > cropland > Eucalyptus > fallow land >

limed land (Desalegn *et al.,* 2019). The higher CO_2 release in grassland could be attributed to the higher organic matter content as compared to other land uses.

Similar weekly pattern of C-mineralization rates were reported by Desalegn *et al.* (2019), where carbon dioxide-C mineralization rates during the 62-days incubation period followed a general pattern across in all land uses and management systems in which an initial increase at the beginning of the incubation followed gradual decline as the incubation time progresses. Evolution of higher amount of CO_2 at initial stage indicated a rapid depletion of an easily mineralizable fraction (labile SOC) while the slow-steady phases in which mineralization declined to a fairly constant rate indicate that the most active fraction has exhausted and the resistant and stable fraction of SOC was being mineralized. In corroboration with the present findings, Fan *et al.* (2015) have also reported highest soil respiration rate in the month of July / August (rainy season) and the lowest in January (winter / dry season) while studying soil respiration under different land uses in Eastern China.

4.7. Relationship between organic carbon fractions and carbon stock with physico-chemical and biological properties of soil

The Pearson correlation was calculated to establish the relationship between carbon fractions, carbon stock and other physico-chemical properties. The degree of linear relationship between soil quality parameters is measured by the simple correlation coefficient (*r*) along with two levels of significance (2-tailed). It was presented in Table 4.27 a to Table 4.29 f. Similar relationship was observed among the soil quality parameters under different LUS irrespective of seasons and depths.

For all the three seasons, a negative correlation was observed for sand-clay pair. On the other hand, strong positive correlation was observed for clay-silt pair. The inference indicated a significant negative correlation between OC-BD and OC-PD; while a strong positive correlation between OC-porosity and

OC-WHC was evident irrespective of LUS. The positive correlation between OC and WHC indicated that OM increased aggregation of soil particles and water retention capacity of soil. WHC increased with parallel increase in organic matter; might be due to large number of pores in organic matter rich soils help in retaining more soil water.

A positive correlation was observed between soil pH and organic matter for all the different LUS across the seasons and depths. This might be due to amphotaric nature of organic matter that tries to buffer the soil pH. When pH of soil tends to increase, the hydroxyl ions from the carboxylic group of organic matter react with hydrogen ions to from water and neutralize the pH. Moreover, increase in organic matter content increased the CEC of soils and checks the rise in H^+ ions concentration in soil solution. Positive correlation between soil pH-OC was also reported by Singh *et al.* (2014) while studying land use impact on soil quality in Dimapur, Nagaland in Eastern Himalayan region of India. Similarly, Temsurenla and Ajungla (2017) have reported positive correlation between pH and OC while studying soil physico-chemical properties in tea growing areas of Mokokchung District, Nagaland, Reza *et al.* (2014) corroborated present findings with positive correlation between pH-OC in a study conducted at the Bhandari or lower range of Wokha district of Nagaland in North Eastern India.

A positive correlation was observed between organic carbon and available N, P, K, S, Exch. Ca and Mg indicating that organic matter was the major source of these nutrients under different LUS. Singh *et al.* (2014) also reported significant positive correlation between above parameters. Since both S and N are the integral constituents of amino acids in the organic matter, these two elements use to maintain a definite N: S ratio in the organic matter. Hence, significant and positive relationship of available S with total N and organic carbon content were imminent (Paul and Mukhopadhyay, 2015). Patel *et al.*

(2015) have reported similar positive correlation between OC and macronutrients in their study.

Organic carbon content of soil was found to be significantly and positively correlated with TOC and labile carbon (POXC); indicating that both OC and POXC are just the fractions of TOC content of soil and increase or decrease of TOC content directly effects the content of its different fractions. Mandal *et al.* (2011) reported the close relationship between active carbon (POXC) and other soil quality parameters like OC, MBC and dehydrogenase enzyme activity.

Significant positive correlation was obtained between organic carbon content and soil biological properties including MBC, bacterial population, soil respiration and soil enzymes *viz*. dehydrogenase, β-glucosidase and acid phosphatase. This indicates that the organic matter is the source of energy for soil organisms and their activities. The availability of substrate materials in the form of organic matter regulated the microorganism population and hence determines the extent of availability of soil enzymes. Tomar and Baishya (2020) also reported positive correlation between MBC and soil microbiological and physical variables including dehydrogenase, phenol oxidase, soil respiration, soil moisture and temperature. Vishnu Priya *et al.* (2020) reported positive correlation between SOC and respiration / CO_2 evolution. Verma *et al.* (2017) reported that organic carbon fraction and soil enzymes were highly correlated ($P=0.01$) with each other. However, correlation values were more in case of labile fractions of organic carbon with the soil enzymes in a study conducted in Meghalaya, India.

Pearson's correlation analysis of SOC concentration showed positive significant relationship with SOC stock during the present investigation. Similar observations were reported by Kenye *et al.* (2019) in a study conducted in Mizoram, North East India.

Table 4.27 (a). Correlation among properties of surface soil (0–0.25 m) of paddy land use system during pre-monsoon season

	OC	TC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re
OC	1																						
TC	0.86**	1																					
PoxC	0.81*	0.82*	1																				
Sand	0.01	-0.05	-0.18	1																			
Silt	-0.14	0.01	0.23	-0.73*	1																		
Clay	0.17	0.07	0.23	-0.72*	0.40	1																	
BD	-0.79*	-0.78*	-0.75*	0.37	-0.12	0.02	1																
PD	-0.77*	-0.75*	-0.78*	0.33	-0.34	-0.16	0.80*	1															
Poro	0.89**	0.85**	0.79*	0.12	0.37	0.42	-0.83*	-0.72*	1														
WHC	0.89**	0.86**	0.82*	0.14	0.28	0.44	-0.85**	-0.74*	0.79*	1													
pH	0.76*	0.78*	0.73*	-0.08	0.03	0.10	0.55	0.50	0.79*	0.79*	1												
Av N	0.85**	0.87**	0.86**	0.02	0.02	0.06	-0.77*	-0.71*	0.77*	0.78*	0.74*	1											
Av P_2O_5	0.74*	0.76*	0.70*	0.05	0.00	0.07	-0.53	-0.49	0.69*	0.69*	0.88**	0.73*	1										
Av K_2O	0.75*	0.74*	0.79*	-0.09	0.01	0.15	-0.71*	-0.68*	0.65*	0.75*	0.67*	0.81*	0.69*	1									
Av. S	0.81*	0.88**	0.86**	-0.08	0.09	0.02	-0.79*	-0.62	0.62	0.84**	0.69*	0.86**	0.77*	0.65*	1								
Ex. Ca	0.72*	0.61*	0.65*	0.28	0.22	0.22	-0.69*	-0.36	0.71*	0.71*	0.75*	0.78*	0.83*	0.65*	0.61	1							
Ex. Mg	0.70*	0.62*	0.60	-0.32	0.35	0.12	-0.60	-0.34	0.72*	0.71*	0.77*	0.76*	0.78*	0.67*	0.65*	0.86**	1						
SMBC	0.81*	0.82*	0.85**	-0.07	0.14	0.05	-0.89**	-0.71*	0.72*	0.84**	0.77*	0.75*	0.65*	0.73*	0.79*	0.72*	0.68*	1					
DHA	0.79*	0.80*	0.84**	-0.31	0.32	0.13	-0.80*	-0.77*	0.68*	0.68*	0.88**	0.74*	0.79*	0.71*	0.75*	0.74*	0.59	0.86**	1				
PHA	0.89**	0.83*	0.89**	-0.09	-0.02	0.19	-0.65*	-0.57	0.79*	0.60	0.88**	0.77*	0.86**	0.77*	0.87**	0.73*	0.61	0.85**	0.82*	1			
GSA	0.85**	0.87**	0.80*	0.11	-0.14	-0.03	-0.72*	-0.74*	0.78*	0.97**	0.84**	0.87**	0.73*	0.79*	0.84**	0.86**	0.78*	0.93**	0.73*	0.93**	1		
Bact.	0.87**	0.85**	0.84**	-0.17	0.26	0.22	-0.77*	-0.72*	0.88**	0.89**	0.86**	0.81*	0.73*	0.61	0.77*	0.84**	0.62	0.89**	0.89**	0.92**	0.89**	1	
Resp.	0.85**	0.76*	0.85**	-0.06	0.00	0.10	-0.70*	-0.63	0.89**	0.79*	0.88**	0.82*	0.76*	0.63	0.75*	0.73*	0.59	0.94**	0.84**	0.94**	0.96**	0.93**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.27 (b). Correlation among properties of sub-surface soil (0.25–0.50 m) of paddy land use system during pre-monsoon season

	OC	TC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																						
TC	0.82*	1																					
PoxC	0.84*	0.83*	1																				
Sand	0.17	0.05	0.14	1																			
Silt	0.13	-0.02	0.03	-0.28	1																		
Clay	0.24	-0.07	0.33	-0.51	0.36	1																	
BD	-0.77*	-0.78*	-0.79*	0.36	0.19	0.21	1																
PD	-0.76*	-0.72*	-0.77*	0.22	0.23	0.13	0.78*	1															
Porosity	0.82*	0.81*	0.89**	0.12	0.38	0.49	-0.89**	-0.77*	1														
WHC	0.83*	0.82*	0.84**	-0.09	0.29	0.35	-0.81*	-0.79*	0.89**	1													
pH	0.79*	0.77*	0.74*	0.29	0.24	0.22	0.49	0.53	0.74*	0.66*	1												
Av N	0.83*	0.84**	0.84**	-0.21	0.08	0.29	-0.68*	-0.73*	0.82*	0.63*	0.78*	1											
Av P_2O_5	0.75*	0.77*	0.77*	0.17	0.03	0.29	-0.53	-0.65*	0.66*	0.67*	0.85**	0.77*	1										
Av K_2O	0.71*	0.78*	0.71*	-0.04	0.12	0.44	-0.69*	-0.65*	0.69*	0.62	0.68*	0.77*	0.76*	1									
Av. S	0.89**	0.81*	0.86**	0.21	-0.14	0.21	-0.68*	-0.76*	0.64*	0.75*	0.69*	0.87**	0.77*	0.61	1								
Ex. Ca	0.75*	0.77*	0.72*	0.04	0.02	-0.06	-0.63	-0.63	0.49	0.61*	0.84**	0.69*	0.76*	0.68*	0.65*	1							
Ex. Mg	0.79*	0.76*	0.74*	0.14	-0.05	-0.21	-0.64*	-0.66*	0.29	0.64*	0.84**	0.61*	0.76*	0.65*	0.67*	0.85**	1						
SMBC	0.84**	0.81*	0.83*	0.13	-0.01	0.25	-0.86*	-0.79*	0.71*	0.73*	0.75*	0.85**	0.79*	0.67*	0.85**	0.76*	0.66*	1					
DHA	0.84**	0.79*	0.81*	0.05	-0.02	0.07	-0.75*	-0.71*	0.88**	0.80*	0.74*	0.76*	0.80*	0.78*	0.73*	0.79*	0.65*	0.95**	1				
PHA	0.82*	0.84**	0.85**	-0.03	0.01	0.03	-0.61	-0.66*	0.83*	0.87**	0.80*	0.78*	0.81*	0.73*	0.73*	0.76*	0.74*	0.83**	0.96**	1			
GSA	0.87**	0.88**	0.87**	0.09	0.01	0.17	-0.73*	-0.65*	0.85**	0.86**	0.86**	0.82*	0.78*	0.77*	0.87**	0.79*	0.77*	0.86**	0.88**	0.84**	1		
Bact.	0.88**	0.84**	0.86**	-0.18	0.13	0.15	-0.84**	-0.52	0.82*	0.84**	0.88**	0.86**	0.85**	0.79*	0.79*	0.74*	0.65*	0.93**	0.92**	0.94**	0.86**	1	
Resp.	0.84**	0.84**	0.88**	-0.09	0.06	0.29	-0.72*	-0.62	0.77*	0.78*	0.85**	0.88**	0.79*	0.74*	0.77*	0.73*	0.64*	0.87*	0.91**	0.91**	0.86**	0.86**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.27 (c). Correlation among properties of surface soil (0–0.25 m) of paddy land use system during monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.85**	1																		
PoxC	0.84**	0.86**	1																	
BD	-0.88**	-0.77*	-0.76*	1																
PD	-0.80*	-0.77*	-0.75*	0.74*	1															
Porosity	0.81*	0.84**	0.81*	-0.77*	-0.85**	1														
WHC	0.84**	0.83*	0.84**	-0.77*	-0.86**	0.89**	1													
pH	0.76*	0.74*	0.78*	-0.47	-0.49	0.70*	0.63	1												
Av N	0.89**	0.81*	0.88**	-0.71*	-0.62	0.75*	0.79*	0.78*	1											
Av P_2O_5	0.76*	0.75*	0.72*	-0.31	-0.39	0.72*	0.72*	0.82*	0.78*	1										
Av K_2O	0.72*	0.73*	0.79*	-0.63	-0.66*	0.65*	0.69*	0.77*	0.86**	0.65*	1									
Av. S	0.86**	0.81*	0.88**	-0.75*	-0.71*	0.78*	0.62	0.79*	0.88**	0.77*	0.56	1								
Ex. Ca	0.77*	0.75*	0.76*	-0.67*	-0.66*	0.68*	0.69*	0.87**	0.62	0.84**	0.66*	0.75*	1							
Ex. Mg	0.76**	0.77*	0.70*	-0.64*	-0.61	0.64*	0.66*	0.81*	0.65*	0.83*	0.61	0.71*	0.87**	1						
SMBC	0.89**	0.87**	0.85**	-0.87**	-0.83*	0.73*	0.75*	0.85**	0.79*	0.69*	0.68*	0.84**	0.74*	0.66*	1					
DHA	0.87**	0.83*	0.82*	-0.76*	-0.75*	0.75*	0.77*	0.83*	0.86**	0.72*	0.63	0.81*	0.69*	0.68*	0.87**	1				
PHA	0.87**	0.85**	0.84**	-0.69*	-0.67*	0.79*	0.82*	0.81*	0.79*	0.85**	0.67*	0.79*	0.75*	0.79*	0.83*	0.84**	1			
GSA	0.82*	0.86**	0.82*	-0.79*	-0.59	0.89**	0.78*	0.71*	0.86**	0.76*	0.78*	0.88**	0.71*	0.77*	0.79*	0.89**	0.84**	1		
Bact.	0.84**	0.86**	0.87**	-0.75*	-0.77*	0.87**	0.80*	0.88**	0.87**	0.76*	0.79*	0.87**	0.77*	0.66*	0.88**	0.93**	0.85**	0.89**	1	
Resp.	0.82*	0.86**	0.86**	-0.73*	-0.69*	0.87**	0.87**	0.86**	0.84**	0.86**	0.75*	0.84**	0.78*	0.63	0.82*	0.85**	0.85**	0.89**	0.87**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.27 (d). Correlation among properties of sub-surface soil (0.25–0.50 m) of paddy land use system during monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.87**	1																		
PoxC	0.80*	0.81*	1																	
BD	-0.75*	-0.74*	-0.73*	1																
PD	-0.72*	-0.75*	-0.77*	0.77*	1															
Porosity	0.73*	-0.76*	0.78*	-0.71*	-0.69*	1														
WHC	0.72*	0.72*	0.84**	-0.74*	-0.77*	0.88**	1													
pH	0.79*	0.74*	0.75*	-0.32	-0.42	0.78*	0.69*	1												
Av N	0.84**	0.83*	0.84**	-0.63	-0.55	0.75*	0.74*	0.78*	1											
Av P_2O_5	0.73*	0.71*	0.71*	-0.40	-0.39	0.65*	0.74*	0.77*	0.78*	1										
Av K_2O	0.76*	0.76*	0.70*	-0.66*	-0.54	0.78*	0.61	0.65*	0.86**	0.72*	1									
Av. S	0.88**	0.82*	0.89**	-0.79*	-0.68*	0.65*	0.73*	0.76*	0.86**	0.72*	0.69*	1								
Ex. Ca	0.71*	0.75*	0.72*	-0.61	-0.57	0.63	0.66*	0.85**	0.70*	0.81*	0.60	0.62	1							
Ex. Mg	0.76*	0.76*	0.75*	-0.57	-0.41	0.57	0.62	0.73*	0.69*	0.82*	0.63	0.69*	0.87**	1						
SMBC	0.84**	0.84**	0.80*	-0.76*	-0.76*	0.71*	0.76*	0.81*	0.89**	0.77*	0.78*	0.82*	0.74*	0.61	1					
DHA	0.88**	0.85**	0.87*	-0.75*	-0.83*	0.85**	0.89**	0.85**	0.81*	0.78*	0.75*	0.87**	0.77*	0.78*	0.83*	1				
PHA	0.88**	0.83*	0.89**	-0.67*	-0.63	0.79*	0.81*	0.85**	0.73*	0.80*	0.78*	0.79*	0.79*	0.63	0.97**	0.85**	1			
GSA	0.79*	0.71*	0.81*	-0.67*	-0.65*	0.84**	0.89**	0.86**	0.87**	0.78*	0.79*	0.85**	0.78*	0.64*	0.82*	0.87**	0.88**	1		
Bact.	0.87**	0.83*	0.88**	-0.65*	-0.58	0.72*	0.79*	0.82*	0.85**	0.87**	0.85**	0.78*	0.78*	0.64*	0.87**	0.85**	0.94**	0.87**	1	
Resp.	0.86**	0.81*	0.85**	-0.64	-0.52	0.65	0.74*	0.78*	0.80*	0.88**	0.72*	0.73*	0.73*	0.72*	0.87**	0.91**	0.92**	0.81*	0.88**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.27 (e). Correlation among properties of surface soil (0–0.25 m) of paddy land use system during post-monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.80*	1																		
PoxC	0.86**	0.81*	1																	
BD	-0.81*	-0.80*	-0.80*	1																
PD	-0.75*	-0.82*	-0.79*	0.83*	1															
Porosity	0.65*	0.79*	0.82*	-0.86**	-0.86**	1														
WHC	0.75*	0.72*	0.82*	-0.81*	-0.96**	0.83*	1													
pH	0.78*	0.76*	0.78*	-0.55	-0.48	0.79*	0.74*	1												
Av N	0.80*	0.85**	0.87**	-0.72*	-0.54	0.77*	0.83*	0.76*	1											
Av P_2O_5	0.71*	0.73*	0.77*	-0.33	-0.42	0.77*	0.76*	0.88**	0.71*	1										
Av K_2O	0.74*	0.73*	0.79*	-0.65*	-0.61	0.69*	0.67*	0.72*	0.79*	0.67*	1									
Av. S	0.80*	0.89**	0.79*	-0.75*	-0.71*	0.69*	0.79*	0.88**	0.87**	0.74*	0.66*	1								
Ex. Ca	0.77*	0.74*	0.76*	-0.62	-0.57	0.72*	0.68*	0.86**	0.75*	0.85**	0.66*	0.69*	1							
Ex. Mg	0.71*	0.74*	0.76*	-0.64	-0.51	-0.66*	0.67*	0.85**	0.70*	0.87**	0.65*	0.63	0.88**	1						
SMBC	0.72*	0.78*	0.82*	-0.78*	-0.74*	0.81*	0.75*	0.81*	0.81*	0.81*	0.71*	0.89**	0.82*	0.63	1					
DHA	0.83*	0.86**	0.80*	-0.87**	-0.72*	0.88**	0.75*	0.83*	-0.81*	0.74*	0.71*	0.86**	0.74*	0.67*	0.85**	1				
PHA	0.84**	0.83*	0.83*	-0.61	-0.52	0.85**	0.79*	0.84**	0.75*	0.85**	0.78*	0.72*	0.79*	0.67*	0.84**	0.85**	1			
GSA	0.69*	0.76*	0.82*	-0.66*	-0.46	0.82*	0.70*	0.82*	0.85**	0.75*	0.76*	0.88**	0.81*	0.71*	0.89**	0.84**	0.89**	1		
Bact.	0.77*	0.76*	0.85**	-0.78*	-0.32	0.75*	0.80*	0.89**	0.85**	0.86**	0.66*	0.74*	0.84**	0.77*	0.76*	0.91**	0.81*	0.92**	1	
Resp.	0.64*	0.67*	0.78*	-0.66*	-0.39	0.76*	-0.72*	0.81*	0.83*	0.77*	0.77*	0.75*	0.81*	0.77*	0.88**	0.92**	0.83*	0.88**	0.73*	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.27 (f). Correlation among properties of sub-surface soil (0.25–0.50 m) of paddy land use system during post-monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	Gls	Bact.	Re.
OC	1																			
TC	0.88**	1																		
PoxC	0.79*	0.81*	1																	
BD	-0.76*	-0.85**	-0.83*	1																
PD	-0.65*	-0.89**	-0.81**	0.79*	1															
Porosity	0.88**	0.85**	0.81*	-0.85**	-0.65*	1														
WHC	0.86**	0.83*	0.88**	-0.79*	-0.77*	0.88**	1													
pH	0.77*	0.78*	0.76*	-0.56	-0.46	0.78*	0.69*	1												
Av N	0.87**	0.81*	0.86**	-0.71*	-0.72*	0.82*	0.70*	0.79*	1											
Av P_2O_5	0.74*	0.78*	0.76*	-0.42	-0.39	0.76*	0.71*	0.82*	0.69*	1										
Av K_2O	0.72*	0.71*	0.73*	-0.72*	-0.55	0.64*	0.70*	0.79*	0.78*	0.67*	1									
Av. S	0.85**	0.79*	0.88**	-0.81*	-0.73*	0.71*	0.69*	0.79*	0.89**	0.70*	0.69*	1								
Ex. Ca	0.77*	0.74*	0.76*	-0.74*	-0.73*	0.68*	0.64*	0.83*	0.78*	0.78*	0.69*	0.79*	1							
Ex. Mg	0.71*	0.76*	0.75*	-0.69*	-0.66*	0.69*	0.65*	0.84*	0.76*	0.75*	0.63	0.65*	0.86**	1						
SMBC	0.81*	0.81*	0.85**	-0.82*	-0.66*	0.85**	0.77*	0.85**	0.84**	0.71*	0.79*	0.74*	0.78*	0.68*	1					
DHA	0.86**	0.87**	0.83*	-0.76*	-0.63	0.77*	0.76*	0.73*	0.82*	0.74*	0.71*	0.79*	0.75*	0.61	0.87**	1				
PHA	0.75*	0.81*	0.84**	-0.77*	-0.57	0.75*	0.84**	0.81*	0.71*	0.81*	0.78*	0.82*	0.76*	0.68*	0.84**	0.72*	1			
Gls	0.83*	0.82*	0.84**	-0.77*	-0.76*	0.74*	0.77*	0.77*	0.83*	0.77*	0.77*	0.83*	0.69*	0.65*	0.90**	0.80*	0.82*	1		
Bact.	0.84**	0.86**	0.85**	-0.83*	-0.54	0.87**	0.85**	0.84**	0.76*	0.75*	0.76*	0.77*	0.75*	0.60	0.95**	0.87**	0.82*	0.86**	1	
Resp.	0.88**	0.81*	0.88**	-0.77*	-0.53	0.89**	0.73*	0.71*	0.73*	0.75*	0.74*	0.65*	0.75*	0.65*	0.88**	0.82*	0.89**	0.86**	0.87**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (a). Correlation among properties of surface soil (0–0.25 m) of pineapple land use system during pre-monsoon season

	OC	TC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																						
TC	0.97**	1																					
PoxC	0.99**	0.88**	1																				
Sand	-0.03	-0.19	-0.07	1																			
Silt	-0.32	-0.15	-0.27	-0.51	1																		
Clay	0.58	0.55	0.55	-0.61	0.40	1																	
BD	-0.82*	-0.84**	-0.89**	0.39	0.21	-0.47	1																
PD	-0.81*	-0.85**	-0.89**	0.24	0.45	-0.53	0.80*	1															
Poro	0.88**	0.81*	-0.81*	-0.47	0.05	0.34	-0.81*	-0.89**	1														
WHC	0.83*	0.87**	0.87**	-0.20	0.07	0.43	-0.87**	-0.84**	0.96**	1													
pH	0.74*	0.72*	0.79*	-0.25	0.06	0.29	-0.63	-0.54	0.74*	0.77*	1												
Av N	0.91**	0.89**	0.90**	-0.14	0.17	0.49	-0.89**	-0.75*	0.87**	0.89**	0.73*	1											
Av P_2O_5	0.75*	0.80*	0.80*	-0.18	0.02	0.25	-0.62	-0.56	0.75*	0.77*	0.99**	0.78*	1										
Av K_2O	0.77*	0.76*	0.77*	0.10	0.26	0.59	-075*	-0.66*	0.87**	0.73*	0.79*	0.89**	0.89**	1									
Av. S	0.95**	0.88**	0.97**	-0.19	-0.18	0.58	-0.79*	-0.70*	0.87**	0.86**	0.83*	0.89**	0.81*	0.77*	1								
Ex. Ca	0.72*	0.74*	0.76*	0.15	-0.15	0.47	-0.79*	-0.83*	0.81*	0.77*	0.83*	0.75*	0.86**	0.77*	0.86**	1							
Ex. Mg	0.78*	0.76*	0.79*	0.02	-0.31	0.48	-0.69*	-0.73*	0.84**	0.66*	0.81*	0.71*	0.82*	0.76*	0.85**	0.95**	1						
SMBC	0.95**	0.88**	0.96**	-0.19	0.21	0.65*	-0.88**	-0.81*	0.84**	0.83*	0.89**	0.89**	0.87**	0.78*	0.89**	0.84**	0.73*	1					
DHA	0.95**	0.86**	0.95**	0.13	0.23	0.58	-0.87**	-0.83*	0.86**	0.83*	0.89**	0.94**	0.90**	0.79*	0.88**	0.77*	0.75*	0.99**	1				
PHA	0.93**	0.82*	0.89**	0.08	0.26	0.55	-0.69*	-0.62*	0.85**	0.83*	0.87**	0.95**	0.90**	0.78*	0.86**	0.89**	0.74*	0.95**	0.97**	1			
GSA	0.93**	0.86**	0.96**	0.04	0.44	0.68*	-0.76*	-0.65*	0.82*	0.82*	0.69*	0.92**	0.73*	0.73*	0.84**	0.86**	0.71*	0.86**	0.89**	0.89**	1		
Bact.	0.97**	0.98**	0.99**	-0.16	0.20	0.58	-0.79*	-0.52	0.87**	0.81**	0.89**	0.87**	0.88**	0.75*	0.87**	0.84**	0.75*	0.96**	0.94**	0.94**	0.86**	1	
Resp.	0.95**	0.98**	0.97**	0.19	0.14	0.52	-0.73*	-0.51	0.91**	0.80**	0.96**	0.87**	0.94**	0.75*	0.89**	0.86**	0.76*	0.98**	0.97**	0.94**	0.82*	0.97**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (b). Correlation among properties of sub-surface soil (0.25- 0.50 m) of pineapple land use system during pre-monsoon season

	OC	TC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																						
TC	0.98**	1																					
PoxC	0.79*	0.80*	1																				
Sand	0.19	0.19	-0.66*	1																			
Silt	-0.41	-0.37	0.69*	-0.39	1																		
Clay	0.43	0.34	0.26	-0.64	0.13	1																	
BD	-0.86**	-0.77*	-0.79*	0.43	0.45	0.46	1																
PD	-0.89**	-0.79*	-0.77*	0.17	0.37	0.41	0.95**	1															
Porosity	0.95**	0.84**	0.73*	-0.23	0.38	0.30	-0.93**	-0.97**	1														
WHC	0.99**	0.87**	0.78*	-0.22	0.42	0.39	-0.95**	-0.97**	0.98**	1													
pH	0.87**	0.88**	0.58	-0.12	-0.09	0.45	-0.59	-0.49	0.79*	0.74*	1												
Av N	0.97**	0.86**	0.85*	-0.18	0.40	0.43	-0.79*	-0.67*	0.86**	0.88**	0.78*	1											
Av P_2O_5	0.82*	0.80*	0.79*	-0.07	0.17	0.51	-0.47	-0.45	0.88**	0.79*	0.97**	0.86**	1										
Av K_2O	0.74*	0.81*	0.76*	-0.23	0.43	0.39	-0.88**	-0.81*	0.79*	0.62	0.74*	0.87**	0.79*	1									
Av. S	0.98**	0.84**	0.88**	0.06	-0.32	0.55	-0.82*	-0.78*	0.79*	0.78*	0.91**	0.95**	0.87**	0.78*	1								
Ex. Ca	0.76*	0.78*	0.84**	0.29	-0.50	0.39	-0.79*	-0.66*	0.72*	0.66*	0.82*	0.76*	0.86**	0.69*	0.82*	1							
Ex. Mg	0.74*	0.74*	0.78*	0.26	-0.46	0.38	-0.77*	-0.61	0.71*	0.64*	0.79*	0.68*	0.76*	0.68*	0.88**	0.94**	1						
SMBC	0.97**	0.87**	0.80*	-0.27	0.47	0.39	-0.87**	-0.77*	0.87**	0.78*	0.85**	0.86**	0.71*	0.93**	0.86**	0.86**	0.62	1					
DHA	0.98**	0.87**	0.82*	-0.08	0.29	0.43	-0.83*	-0.69*	0.76*	0.88**	0.93**	0.84**	0.79*	0.79**	0.89**	0.84**	0.78*	0.98**	1				
PHA	-0.99**	0.86**	0.84**	-0.13	0.37	0.47	-0.78*	-0.59	0.86**	0.79*	0.86**	0.89**	0.92**	0.75*	0.89**	0.87**	0.85**	0.98**	0.98**	1			
GSA	0.98**	0.88**	0.86**	0.27	0.45	0.34	-0.75*	-0.78*	0.82**	0.87**	0.89**	0.93**	0.82*	0.70*	0.95**	0.77*	0.89**	0.98**	0.97**	0.96**	1		
Bact.	0.94**	0.82*	0.89**	-0.15	0.35	0.41	-0.81*	-0.68*	0.87**	0.87**	0.86**	0.83*	0.74*	0.85**	0.86**	0.72*	0.85**	0.97**	0.97**	0.95**	0.93**	1	
Resp.	0.98**	0.89**	0.79*	0.17	0.37	0.39	-0.85**	-0.66*	0.82*	0.86**	0.86**	0.86**	0.88**	0.77**	0.74*	0.79*	0.75*	0.96**	0.96**	0.98**	0.97**	0.90**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (c). Correlation among properties of surface soil (0-0.25 m) of pineapple land use system during monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.99**	1																		
PoxC	0.90**	0.83*	1																	
BD	-0.88**	-0.88**	-0.81*	1																
PD	-0.89**	-0.87**	-0.85**	0.98**	1															
Porosity	0.96**	0.98**	0.89**	-0.98**	-0.96**	1														
WHC	0.82*	0.89**	0.92**	-0.83*	-0.76*	0.85**	1													
pH	0.86**	0.81*	0.81*	-0.46	-0.39	0.78*	0.78*	1												
Av N	0.89**	0.91**	0.89**	-0.76*	-0.68*	0.85**	0.78*	0.71*	1											
Av P_2O_5	0.82*	0.89**	0.82*	-0.42	-0.36	0.84**	0.79*	0.97**	0.76*	1										
Av K_2O	0.71*	0.73*	0.79*	-0.72*	-0.65*	0.79*	0.79*	0.70*	0.89**	0.79*	1									
Av. S	0.85**	0.90**	0.95**	-0.84**	-0.79*	0.78*	0.79*	0.76*	0.83*	0.78*	0.72*	1								
Ex. Ca	0.92**	0.86**	0.83*	-0.75*	-0.72*	0.65*	0.65*	0.87**	0.71*	0.83*	0.63	0.75*	1							
Ex. Mg	0.91**	0.88**	0.84**	-0.67*	-0.65*	0.66*	0.59	0.84**	0.78*	0.82*	0.61	0.79*	0.98**	1						
SMBC	0.95**	0.86**	0.95**	-0.88**	-0.63	0.85**	0.87**	0.88**	0.96**	0.85**	0.74*	0.82*	0.76*	0.65*	1					
DHA	0.94**	0.87**	0.95**	-0.87**	-0.61	0.87**	0.81*	0.89**	0.95**	0.89**	0.76*	0.82*	0.78*	0.69*	0.96**	1				
PHA	0.86**	0.81*	0.87**	-0.67*	-0.79*	0.85**	0.79*	0.98**	0.82*	0.97**	0.76*	0.78*	0.86**	0.71*	0.91**	0.93**	1			
GSA	0.99**	0.89**	0.91**	-0.69*	-0.59	0.89**	0.82*	0.85**	0.93**	0.82*	0.61	0.85**	0.83*	0.69*	0.95**	0.96**	0.85**	1		
Bact.	0.94**	0.87**	0.84**	-0.84**	-0.79*	0.83*	0.92**	0.85**	0.90**	0.81*	0.65*	0.82*	0.89**	0.86**	0.95**	0.97**	0.95**	0.93**	1	
Resp.	0.84**	0.80*	0.88**	-0.73*	-0.59	0.86**	0.98**	0.86**	0.73*	0.89**	0.66*	0.86**	0.82*	0.82*	0.83*	0.89**	0.94**	0.84**	0.89**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (d). Correlation among properties of sub-surface soil (0.25–0.50 m) of pineapple land use system during monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.99**	1																		
PoxC	0.93**	0.85**	1																	
BD	-0.89**	-0.88**	-0.89**	1																
PD	-0.88**	-0.89**	-0.82*	0.97**	1															
Porosity	0.89**	0.89**	0.88**	-0.93**	-0.88**	1														
WHC	0.98**	0.97**	0.96**	-0.96**	-0.84**	0.91**	1													
pH	0.89**	0.81*	0.85**	-0.48	-0.31	0.72*	0.71*	1												
Av N	0.98**	0.87**	0.95**	-0.77*	-0.69*	0.83*	0.89**	0.84**	1											
Av P_2O_5	0.87**	0.87**	0.87**	-0.39	-0.36	0.79*	0.88**	0.92**	0.81*	1										
Av K_2O	0.79*	0.78*	0.71*	-0.78*	-0.66*	0.77*	0.76*	0.77*	0.85**	0.73*	1									
Av. S	0.91**	0.83*	0.97**	-0.81*	-0.63	0.71*	0.73*	0.89**	0.96**	0.71*	0.69*	1								
Ex. Ca	0.82*	0.82*	0.81*	-0.73*	-0.65*	0.65*	0.61	0.97**	0.75*	0.85**	0.60	0.77*	1							
Ex. Mg	0.82*	0.81*	0.82*	-0.65*	-0.61	0.65*	0.61	0.81*	0.71*	0.82*	0.63	0.75*	0.90**	1						
SMBC	0.95**	0.85**	0.83*	-0.84**	-0.74*	0.82*	0.89**	0.79*	0.89**	0.79*	0.75*	0.83*	0.86**	0.78*	1					
DHA	0.84**	0.84**	0.89**	-0.81*	-0.62	0.79*	0.89**	0.92**	0.91**	0.98**	0.79*	0.92**	0.82*	0.75*	0.72*	1				
PHA	0.83*	0.82*	0.93**	-0.72*	-0.68*	0.73*	0.78*	0.89**	0.97**	0.91**	0.89**	0.91**	0.89**	0.73*	0.84**	0.94**	1			
GSA	0.98**	0.99**	0.92**	-0.78*	-0.79*	0.91**	0.95**	0.94**	0.97**	0.88**	0.78*	0.85**	0.87**	0.75*	0.94**	0.84**	0.89**	1		
Bact.	0.92**	0.83*	0.99**	-0.85**	-0.69*	0.88**	0.96**	0.94**	0.95**	0.87**	0.89**	0.89**	0.89**	0.79*	0.79*	0.91**	0.93**	0.89**	1	
Resp.	0.92**	0.87**	0.92**	-0.78*	-0.55	0.89**	0.98**	0.89**	0.97**	0.84**	0.79*	0.81*	0.80*	0.79*	0.92**	0.83*	0.94**	0.90**	0.97**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (e). Correlation among properties of surface soil (0–0.25 m) of pineapple land use system during post-monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.99^{**}	1																		
PoxC	0.93^{**}	0.83^{*}	1																	
BD	-0.81^{*}	-0.83^{*}	-0.85^{**}	1																
PD	-0.88^{**}	-0.89^{**}	-0.85^{**}	0.89^{**}	1															
Porosity	0.87^{**}	0.88^{**}	0.83^{*}	-0.98^{**}	-0.89^{**}	1														
WHC	0.85^{**}	0.86^{**}	0.98^{**}	-0.93^{**}	-0.96^{**}	0.89^{**}	1													
pH	0.85^{**}	0.86^{**}	0.91^{**}	-0.49	-0.43	0.79^{*}	0.75^{*}	1												
Av N	0.98^{**}	0.89^{**}	0.96^{**}	-0.81^{*}	-0.70^{*}	0.86^{**}	0.88^{**}	0.75^{*}	1											
Av P_2O_5	0.81^{*}	0.81^{*}	0.84^{**}	-0.39	-0.32	0.79^{*}	0.71^{*}	0.89^{**}	0.89^{**}	1										
Av K_2O	0.77^{*}	0.77^{*}	0.78^{*}	-0.73^{*}	-0.54	0.69^{*}	0.79^{*}	0.77^{*}	0.92^{**}	0.72^{*}	1									
Av. S	0.97^{**}	0.97^{**}	0.92^{**}	-0.77^{*}	-0.62	0.84^{**}	0.69^{*}	0.79^{*}	0.96^{**}	0.79^{*}	0.68^{*}	1								
Ex. Ca	0.72^{*}	0.74^{*}	0.74^{*}	-0.67^{*}	-0.66^{*}	0.66^{*}	0.74^{*}	0.88^{**}	0.64^{*}	0.87^{**}	0.79^{*}	0.78^{*}	1							
Ex. Mg	0.89^{**}	0.70^{*}	0.75^{*}	-0.69^{*}	-0.59	0.60	0.76^{*}	0.82^{*}	0.62	0.88^{**}	0.73^{*}	0.71^{*}	0.95^{**}	1						
SMBC	0.90^{**}	0.82^{*}	0.81^{*}	-0.86^{**}	-0.82^{*}	0.89^{**}	0.89^{**}	0.83^{*}	0.89^{**}	0.82^{**}	0.79^{*}	0.83^{*}	0.89^{**}	0.63	1					
DHA	0.94^{**}	0.85^{**}	0.89^{**}	-0.77^{*}	-0.72^{*}	0.83^{*}	0.84^{**}	0.89^{**}	0.94^{**}	0.86^{**}	0.76^{*}	0.89^{**}	0.87^{**}	0.69^{*}	0.93^{**}	1				
PHA	0.95^{**}	0.96^{**}	0.92^{**}	-0.69^{*}	-0.63	0.84^{**}	0.89^{**}	0.93^{**}	0.99^{**}	0.86^{**}	0.78^{*}	0.84^{**}	0.79^{*}	0.62	0.89^{**}	0.92^{**}	1			
GSA	0.76^{*}	0.78^{*}	0.91^{**}	-0.73^{*}	-0.71^{*}	0.73^{*}	0.89^{**}	0.77^{*}	0.82^{*}	0.70^{*}	0.84^{**}	0.77^{*}	0.85^{**}	0.73^{*}	0.86^{**}	0.78^{*}	0.86^{**}	1		
Bact.	0.89^{**}	0.81^{*}	0.90^{**}	-0.83^{*}	-0.62	0.97^{**}	0.95^{**}	0.87^{**}	0.90^{**}	0.86^{**}	0.74^{*}	0.84^{**}	0.79^{*}	0.74^{*}	0.91^{**}	0.92^{**}	0.91^{**}	0.79^{*}	1	
Resp.	$.0.88^{**}$	0.88^{**}	0.82^{*}	-0.78^{*}	-0.67^{*}	0.99^{**}	0.89^{**}	0.88^{**}	0.86^{**}	0.89^{**}	0.70^{*}	0.85^{**}	0.85^{**}	0.87^{**}	0.92^{**}	0.94^{**}	0.84^{**}	0.78^{*}	0.97^{**}	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.28 (f). Correlation among properties of sub-surface soil (0.25–0.50 m) of pineapple land use system during post-monsoon season

	OC	TC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TC	0.89**	1																		
PoxC	0.89**	0.86**	1																	
BD	-0.82*	-0.86**	-0.83*	1																
PD	-0.89**	-0.89**	-0.87**	0.90**	1															
Porosity	0.88**	0.88**	0.82*	-0.80*	-0.94**	1														
WHC	0.94**	0.83*	0.85**	-0.96**	-0.92**	0.86**	1													
pH	0.80*	0.81*	0.85**	-0.40	-0.32	0.78*	0.78*	1												
Av N	0.89**	0.89**	0.99**	-0.80*	-0.79*	0.77*	0.85**	0.70*	1											
Av P_2O_5	0.79*	0.79*	0.72*	-0.59	-0.47	0.75*	0.78*	0.87**	0.78*	1										
Av K_2O	0.74*	0.74*	0.78*	-0.76*	-0.66*	0.77*	0.72*	0.77*	0.84**	0.65*	1									
Av. S	0.86**	0.81*	0.89**	-0.81*	-0.77*	0.73*	0.73*	0.79*	0.85**	0.74*	0.61	1								
Ex. Ca	0.77*	0.75*	0.89**	-0.65*	-0.66*	0.69*	0.68*	0.80*	0.77*	0.79*	0.64	0.89**	1							
Ex. Mg	0.71*	0.73*	0.89**	-0.61	-0.67*	0.59	0.67*	0.73*	0.77*	0.79*	0.69**	0.83*	0.94**	1						
SMBC	0.89**	0.87**	0.87**	-0.83*	-0.72*	0.80*	0.86**	0.82*	0.88**	0.83*	0.73*	0.84**	0.88**	0.73*	1					
DHA	0.97**	0.88**	0.83*	-0.82*	-0.62	0.82*	0.85**	0.86**	0.87**	0.86**	0.75*	0.78*	0.86**	0.70*	0.97**	1				
PHA	0.96**	0.86**	0.83*	-0.71*	-0.58	0.82*	0.84**	0.92**	0.85**	0.84**	0.89**	0.85**	0.88**	0.74*	0.97**	0.97**	1			
GSA	0.94**	0.89**	0.96**	-0.78*	-0.62	0.88**	0.85**	0.88**	0.94**	0.80*	0.97**	0.92**	0.86**	0.86**	0.97**	0.90**	0.93**	1		
Bact.	0.96**	0.87**	0.93**	-0.83*	-0.75*	0.82*	0.84**	0.93**	0.86**	0.84**	0.87**	0.84**	0.86**	0.73*	0.95**	0.98**	0.98**	0.90**	1	
Resp.	0.89**	0.81*	0.84**	-0.79*	-0.63	0.79*	0.87**	0.89**	0.89**	0.97**	0.77*	0.82*	0.90**	0.74*	0.91**	0.95**	0.93**	0.87**	0.94**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (a). Correlation among properties of surface soil (0–0.25 m) of forest land use system during pre-monsoon season

	OC	TC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																						
TC	0.95**	1																					
PoxC	0.94**	0.88**	1																				
Sand	-0.42	-0.31	-0.43	1																			
Silt	-0.07	0.17	0.10	0.35	1																		
Clay	0.20	-0.04	0.46	-0.65*	0.75*	1																	
BD	-0.85**	-0.78*	-0.81*	0.65*	0.19	-0.57	1																
PD	-0.85**	-0.89**	-0.84**	0.32	-0.06	-0.05	0.87**	1															
Porosity	0.87**	0.89**	0.91**	-0.45	-0.00	0.15	-0.91**	-0.88**	1														
WHC	0.79*	0.87**	0.83*	-0.58	0.16	0.06	-0.89**	-0.83*	0.85**	1													
pH	0.75*	0.80*	0.85**	0.52	0.01	0.17	-0.44	-0.36	0.73*	0.75*	1												
Av N	0.87**	0.87**	0.92**	-0.52	0.16	0.30	-0.75*	-0.73*	0.73*	0.79*	0.77*	1											
Av P_2O_5	0.79*	0.79*	0.86**	-0.51	0.00	0.17	-0.38	-0.35	0.71*	0.74**	0.84**	0.81*	1										
Av K_2O	0.74*	0.74*	0.71*	-0.63	0.18	0.36	-0.77*	-0.68*	0.79*	0.69*	0.76*	0.91**	0.70*	1									
Av. S	0.86**	0.83*	0.87**	-0.48	0.17	0.30	-0.74*	-0.73*	0.85**	0.79*	0.86**	0.89**	0.88**	0.73*	1								
Ex. Ca	0.83*	0.89**	0.88**	-0.52	0.01	0.18	-0.62	-0.59	0.81*	0.73*	0.87**	0.84**	0.98**	0.69*	0.79*	1							
Ex. Mg	0.73*	0.82*	0.70*	-0.54	0.06	0.13	-0.61	-0.59	0.77*	0.75*	0.79*	0.89**	0.87**	0.68*	0.70*	0.88**	1						
SMBC	0.97**	0.93**	0.87**	-0.51	-0.07	0.23	-0.87**	-0.84**	0.84**	0.92**	0.89**	0.99**	0.85**	0.75*	0.85**	0.89**	0.60	1					
DHA	0.96**	0.89**	0.93**	-0.59	0.12	0.30	-0.85**	-0.82*	0.85**	0.94**	0.86**	0.98**	0.84**	0.78*	0.88**	0.76*	0.73*	0.98**	1				
PHA	0.87**	0.84**	0.87**	-0.54	-0.03	0.21	-0.77*	-0.61	0.81*	0.82*	0.83*	0.88**	0.93**	0.77*	0.73*	0.87**	0.79*	0.99**	0.98**	1			
GSA	0.89**	0.89**	0.95**	-0.54	0.13	0.29	-0.65*	-0.58	0.97**	0.78*	0.77*	0.72*	0.84**	0.79*	0.86**	0.79*	0.73*	0.98**	0.99**	0.96**	1		
Bact.	0.97**	0.89**	0.92**	-0.54	0.13	0.29	-0.86**	-0.67*	0.93**	0.90**	0.84**	0.97**	0.71*	0.79*	0.88**	0.74*	0.70*	0.98**	0.99**	0.98**	0.97**	1	
Resp.	0.92**	0.79*	0.83*	-0.41	0.11	0.23	-0.78*	-0.58	0.87**	0.89**	0.72*	0.93**	0.86**	0.78*	0.89**	0.85**	0.80*	0.91**	0.94**	0.87**	0.94**	0.93**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (b). Correlation among properties of sub-surface soil (0.25–0.50 m) of forest land use system during pre-monsoon season

	OC	TOC	PoxC	Sand	Silt	Clay	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																						
TOC	0.98**	1																					
PoxC	0.97**	0 .88**	1																				
Sand	-0.06	0.06	0.03	1																			
Silt	-0.16	-0.12	-0.05	0.19	1																		
Clay	0.36	0.09	0.35	-0.39	0.78*	1																	
BD	-0.89**	-0.72*	-0.84**	0.17	-0.00	-0.04	1																
PD	-0.73*	-0.93**	-0.74*	0.13	0.31	-0.32	0.93**	1															
Porosity	0.89**	0.83*	0.83*	-0.51	0.15	0.38	-0.94**	-0.87**	1														
WHC	0.84**	0.87**	0.87**	-0.43	0.08	0.38	-0.97**	-0.86**	0.97**	1													
pH	0.71*	0.80*	0.83*	-0.09	0.32	0.32	-0.49	-0.38	0.74*	0.71*	1												
Av N	0.89**	0.92**	0.93**	-0.01	0.18	0.17	-0.84**	-0.77*	0.79*	0.89**	0.75*	1											
Av P_2O_5	0.81*	0.74*	0.76*	-0.11	0.01	0.01	-0.39	-0.34	0.79*	0.79*	0.80*	0.74*	1										
Av K_2O	0.78*	0.78*	0.79*	-0.06	0.46	0.44	-0.81*	-0.67*	0.72*	0.71*	0.75*	0.84**	0.76*	1									
Av. S	0.95**	0.95**	0.94**	-0.15	0.34	0.35	-0.83*	-0.79*	0.93**	0.85**	0.86**	0.94**	0.73*	0.77*	1								
Ex. Ca	0.85**	0.79*	0.79*	0.01	0.34	0.32	-0.74*	-0.68*	0.75*	0.85**	0.86**	0.76*	0.90**	0.79*	0.80*	1							
Ex. Mg	0.83*	0.75*	0.81*	0.06	0.28	0.25	-0.72*	-0.59	0.74*	0.85**	0.79*	0.74*	0.84**	0.75*	0.72*	0.94**	1						
SMBC	0.87**	0.86**	0.93**	-0.19	0.13	0.17	-0.72*	-0.74*	0.80*	0.82*	0.84**	0.82*	0.85**	0.79*	0.81**	0.88**	0.78*	1					
DHA	0.96**	0.95**	0.95**	-0.22	0.19	0.23	-0.72*	-0.68*	0.74*	0.77*	0.83*	0.84**	0.79*	0.72*	0.89**	0.85**	0.88**	0.93**	1				
PHA	0.91**	0.81*	0.85**	-0.14	0.16	0.18	-0.64*	-0.58	0.76*	0.75*	0.88**	0.87**	0.86**	0.72*	0.74*	0.83**	0.85**	0.97**	0.95**	1			
GSA	0.93**	0.81*	0.92**	-0.14	0.39	0.40	-0.78*	-0.69*	0.82*	0.82*	0.78*	0.83*	0.89**	0.79*	0.89**	0.89**	0.88**	0.93**	0.96**	0.95**	1		
Bact.	0.92**	0.82*	0.86**	-0.06	0.18	0.18	-0.83*	-0.58	0.87**	0.86**	0.98**	0.77*	0.84**	0.74*	0.84**	0.75*	0.84**	0.97**	0.95**	0.99**	0.96**	1	
Resp.	0.91**	0.89**	0.93**	-0.30	0.15	0.20	-0.56	-0.55	0.81*	0.72*	0.84**	0.79*	0.86**	0.87**	0.75*	0.80*	0.86**	0.96**	0.97**	0.97**	0.93**	0.94**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (c). Correlation among properties of surface soil (0–0.25 m) of forest land use system during monsoon season

	OC	TOC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TOC	0.97*	1																		
PoxC	0.91**	0.89**	1																	
BD	-0.84**	-0.85**	-0.82*	1																
PD	-0.89**	-0.86**	-0.80*	0.91**	1															
Porosity	0.82*	0.73*	0.71*	-0.95**	-0.89**	1														
WHC	0.82*	0.84**	0.83*	-0.92**	-0.88**	0.88**	1													
pH	0.78*	0.79*	0.76*	-0.45	-0.36	0.76*	0.76*	1												
Av N	0.92**	0.88**	0.79*	-0.83*	-0.74*	0.74*	0.84**	0.88**	1											
Av P_2O_5	0.88**	0.88**	0.84**	-0.42	-0.38	0.73*	0.73*	0.99**	0.71*	1										
Av K_2O	0.76*	0.78*	0.74*	-0.73*	-0.66*	0.70*	0.89**	0.77*	0.80*	0.77*	1									
Av. S	0.93**	0.97**	0.96**	-0.82*	-0.73*	0.71*	0.82*	0.86**	0.89**	0.84**	0.76*	1								
Ex. Ca	0.87**	0.84**	0.88**	-0.74*	-0.68*	0.82*	0.72*	0.83*	0.77*	0.96**	0.73*	0.88**	1							
Ex. Mg	0.86**	0.89**	0.85**	-0.67*	-0.55	0.74*	0.74*	0.88**	0.76*	0.96**	0.79*	0.87**	0.91**	1						
SMBC	0.92**	0.88**	0.97**	-0.81*	-0.63	0.89**	0.88**	0.96**	0.86**	0.86**	0.77*	0.85**	0.81*	0.86**	1					
DHA	0.93**	0.89**	0.97**	-0.82*	-0.53	0.90**	0.91**	0.97**	0.87**	0.86**	0.78*	0.84**	0.81*	0.98**	0.98**	1				
PHA	0.84**	0.89**	0.82*	-0.77*	-0.66*	0.77*	0.75*	0.89**	0.99**	0.93**	0.70*	0.81*	0.89**	0.87**	0.88**	0.88**	1			
GSA	0.97**	0.84**	0.86**	-0.84**	-0.67*	0.86**	0.84**	0.94**	0.98**	0.86**.	0.85**	0.86**	0.78*	0.83*	0.90**	0.92**	0.98**	1		
Bact.	0.93**	0.85**	0.89**	-0.84**	-0.55	0.85**	0.82*	0.93**	0.93**	0.95**	0.89**	0.92**	0.84**	0.86**	0.96**	0.96**	0.92**	0.95**	1	
Resp.	0.96**	0.81*	0.84**	-0.81*	-0.52	0.82*	0.84**	0.92**	0.97**	0.94**	0.82*	0.85**	0.87**	0.81*	0.86**	0.89**	0.96**	0.99**	0.91**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (d). Correlation among properties of sub-surface soil (0.25–0.50 m) of forest land use system during monsoon season

	OC	TOC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TOC	0.87**	1																		
PoxC	0.87**	0.89**	1																	
BD	-0.79*	-0.74*	-0.75*	1																
PD	-0.79*	-0.74*	-0.74*	0.89**	1															
Porosity	0.88**	0.86**	0.85**	-0.86**	-0.86**	1														
WHC	0.83*	0.80*	0.85**	-0.84**	-0.83*	0.84**	1													
pH	0.86**	0.85**	0.84**	-0.34	-0.35	0.79*	0.73*	1												
Av N	0.97**	0.97**	0.98**	-0.76*	-0.75*	0.88**	0.87**	0.87**	1											
Av P_2O_5	0.88**	0.83*	0.83*	-0.39	-0.39	0.74*	0.72*	0.91**	0.83*	1										
Av K_2O	0.78*	0.79*	0.79*	-0.66*	-0.56	0.77*	0.76*	0.87**	0.89**	0.74*	1									
Av. S	0.94**	0.95**	0.98**	-0.74*	-0.63	0.82*	0.77*	0.82*	0.98**	0.82*	0.77*	1								
Ex. Ca	0.75*	0.87**	0.89**	-0.66*	-0.61	0.76*	0.67*	0.83*	0.74*	0.85**	0.70*	0.81*	1							
Ex. Mg	0.72*	0.82*	0.86**	-0.64*	-0.53	0.76*	0.71*	0.82*	0.79*	0.85**	0.77*	0.71*	0.94**	1						
SMBC	0.94**	0.84**	0.93**	-0.83*	-0.72*	0.86**	0.82*	0.83*	0.94**	0.83*	0.74*	0.89**	0.81*	0.83*	1					
DHA	0.95**	0.83*	0.93**	-0.74*	-0.64*	0.89**	0.86**	0.87**	0.97**	0.83*	0.74*	0.82*	0.87**	0.87**	0.97**	1				
PHA	0.97**	0.86**	0.85**	-0.66*	-0.57	0.89**	0.95**	0.98**	0.98**	0.94**	0.78*	0.84**	0.85**	0.89**	0.96**	0.98**	1			
GSA	0.97**	0.93**	0.93**	-0.57	-0.48	0.86**	0.85**	0.94**	0.96**	0.88**	0.85**	0.83*	0.77*	0.74*	0.96**	0.97**	0.98**	1		
Bact.	0.97**	0.98**	0.97**	-0.75*	-0.66*	0.87**	0.83*	0.98**	0.98**	0.83*	.089**	0.96**	0.81*	0.86**	0.94**	0.95**	0.99**	0.96**	1	
Resp.	0.89**	0.83*	0.86**	-0.67*	-0.55	0.81*	0.85**	0.81*	0.97**	0.85**	0.84**	0.86**	0.87**	0.80*	0.90**	0.92**	0.91**	0.88**	0.92**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (e). Correlation among properties of surface soil (0–0.25 m) of forest land use system during post-monsoon season

	OC	TOC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re.
OC	1																			
TOC	0.96**	1																		
PoxC	0.89**	0.74*	1																	
BD	-0.89**	-0.87**	-0.76*	1																
PD	-0.86**	-0.87**	-0.75*	0.94**	1															
Porosity	0.88**	0.85**	0.84**	-0.97**	-0.95**	1														
WHC	0.88**	0.83*	0.82*	-0.96**	-0.95**	0.99**	1													
pH	0.79*	0.78*	0.73*	-0.49	-0.45	0.76*	0.76*	1												
Av N	0.96**	0.92**	0.88**	-0.82*	-0.73*	0.86**	0.89**	0.85**	1											
Av P_2O_5	0.85**	0.86**	0.86**	-0.37	-0.31	0.72*	0.88**	0.87**	0.86**	1										
Av K_2O	0.78*	0.78*	0.72*	-0.78*	-0.66*	0.75*	0.79*	0.77*	0.85**	0.75*	1									
Av. S	0.89**	0.88**	0.89**	-0.81*	-0.62	0.80*	0.84**	0.88**	0.96**	0.79*	0.71*	1								
Ex. Ca	0.74*	0.76*	0.76*	-0.71*	-0.69*	0.72*	0.71*	0.83*	0.79*	0.91**	0.74*	0.75*	1							
Ex. Mg	0.75*	0.78*	0.78*	-0.70*	-0.62	0.75*	0.74*	0.85**	0.72*	0.91**	0.76*	0.77*	0.98**	1						
SMBC	0.97**	0.87**	0.81*	-0.82*	-0.63	0.82*	0.80*	0.87**	0.88**	0.89**	0.77*	0.82*	0.83*	0.83*	1					
DHA	0.97**	0.89**	0.88**	-0.80*	-0.56	0.84**	0.83*	0.98**	0.91**	0.88**	0.79*	0.85**	0.86**	0.87**	0.99**	1				
PHA	0.98**	0.87**	0.81*	-0.77*	-0.54	0.75*	0.83*	0.98**	0.90**	0.98**	0.76*	0.80*	0.84**	0.85**	0.99**	0.98**	1			
GSA	0.98**	0.95**	0.84**	-0.76*	-0.64*	0.79*	0.84**	0.99**	0.91**	0.86**	0.84**	0.82*	0.73*	0.74*	0.96**	0.96**	0.99**	1		
Bact.	0.98**	0.87**	0.86**	-0.82*	-0.66*	0.88**	0.87**	0.98**	0.93**	0.85**	0.88**	0.86**	0.86**	0.88**	0.97**	0.99**	0.99**	0.97**	1	
Resp.	0.98**	0.88**	0.81*	-0.76*	-0.59	0.85**	0.84**	0.97**	0.92**	0.86**	0.77*	0.88**	0.88**	0.86**	0.97**	0.98**	0.97**	0.96**	0.97**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

Table 4.29 (f). Correlation among properties of sub-surface soil (0.25–0.50 m) of forest land use system during post-monsoon season

	OC	TOC	PoxC	BD	PD	Poro	WHC	pH	Av N	Av P_2O_5	Av K_2O	Av. S	Ex. Ca	Ex. Mg	SMBC	DHA	PHA	GSA	Bact.	Re
OC	1																			
TOC	0.98**	1																		
PoxC	0.97**	0.85**	1																	
BD	-0.88**	-0.86**	-0.89**	1																
PD	-0.81*	-0.84**	-0.84**	0.94**	1															
Porosity	0.84**	0.80*	0.75*	-0.95**	-0.94**	1														
WHC	0.83*	0.82*	0.83*	-0.87**	-0.88**	0.91**	1													
pH	0.76*	0.76*	0.77*	-0.48	-0.37	0.75*	0.76*	1												
Av N	0.98**	0.97**	0.97**	-0.79*	-0.63	0.84**	0.87**	0.88**	1											
Av P_2O_5	0.89**	0.87**	0.85**	-0.36	-0.32	0.72*	0.77*	0.85**	0.77*	1										
Av K_2O	0.75*	0.74*	0.75*	-0.67*	-0.53	0.72*	0.79*	0.78*	0.87**	0.76*	1									
Av. S	0.91**	0.93**	0.95**	-0.76*	-0.69*	0.84*	0.85**	0.88**	0.84**	0.80*	0.75*	1								
Ex. Ca	0.71*	0.72*	0.89**	-0.64*	-0.51	0.77*	0.82*	0.83*	0.86**	0.87**	0.83*	0.79*	1							
Ex. Mg	0.79*	0.77*	0.77*	-0.63	-0.53	0.76*	0.82*	0.87**	0.82*	0.87**	0.82*	0.73*	0.95**	1						
SMBC	0.91**	0.81*	0.84**	-0.74*	-0.68*	0.88**	0.82*	0.95**	0.91**	0.88**	0.81*	0.87**	0.88**	0.83*	1					
DHA	0.93**	0.81*	0.89**	-0.75*	-0.51	0.82*	0.81*	0.93**	0.94**	0.87**	0.71*	0.84**	0.86**	0.84**	0.92**	1				
PHA	0.87**	0.84**	0.89**	-0.69*	-0.52	0.81*	0.71*	0.73*	0.88**	0.91**	0.71*	0.85**	0.85**	0.86**	0.88**	0.87**	1			
Gls	0.96**	0.91**	0.97**	-0.68*	-0.59	0.84**	0.82*	0.76*	0.97**	0.95**	0.77*	0.82*	0.89**	0.88**	0.90**	0.95**	0.83*	1		
Bact.	0.92**	0.85**	0.86**	-0.75*	-0.54	0.86**	0.74*	0.85**	0.92**	0.91**	0.73*	0.86**	0.86**	0.81*	0.89**	0.95**	0.97**	0.89**	1	
Resp.	0.95**	0.87**	0.87**	-0.68*	-0.50	0.80*	0.79*	0.89**	0.97**	0.85**	0.77*	0.87**	0.92**	0.85**	0.92**	0.95**	0.96**	0.94**	0.95**	1

**P= significant at 0.01 level (two tailed); *P =significant at 0.05 level (two tailed)

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present investigation, **“Soil Organic Carbon Fractions under Different Land Uses in Dystrudepts of Nagaland”** was conducted with the surface and sub-surface soil samples collected from three land uses from eight different villages of Medziphema block in three seasons. All analytical procedures were performed in the laboratory of the Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University. Findings of the investigation are summarized in this chapter as follows:

- Significant difference in pH, bulk density and particle density under different land uses were recorded irrespective of the seasons. Paddy soils recorded maximum pH values in pre-monsoon season followed by forest soils. During monsoon season, slight reduction in pH values was recorded compared to pre-monsoon and post-monsoon season for all the three different land uses in both the depths.
- The soils of different land uses under study were mostly belongs to ‘loam’ texture. While soils of forest lands were ‘sandy clay loam’ and ‘sandy loam’; soils of pineapple land use were found mostly as ‘sandy clay loam’ and ‘clay loam’ in their textural class. However, dominant textural class of soils of paddy land use was ‘clay loam’. The difference in clay content of pineapple and paddy LUS was found non-significant at both the depths. Variation in silt content at both the depth for different LUS was also found non-significant.
- Higher bulk density and particle density was recorded in soils under paddy land use. Lowest values of BD and PD were obtained in forest lands. However, values of these parameters increased with depths irrespective of land uses and seasons. For all three LUS, seasonal variation of BD indicated minimum values in post-monsoon season,

followed by increased values in pre-monsoon season which was further increased in monsoon season. Significantly lower values of BD was recorded in forest LUS followed by higher BD in pineapple and maximum in paddy LUS during post-monsoon season in both the depths.

- Porosity of soils was found maximum under forest LUS irrespective of depth and season of sampling. Enhancement in percent pore space was recorded during post-monsoon season in all the three LUS. Significantly higher porosity was recorded in forest followed by pineapple and paddy LUS at both the depths during post-monsoon season. However, the variation in porosity of pineapple and paddy LUS was found non-significant. Percent pore space decreased with depth. Significantly higher values of WHC were recorded in case of forest followed by pineapple and paddy for both the soil layers during post-monsoon season. The variation in WHC between pineapple and paddy LUS was however non-significant during post-monsoon season in both the depths.
- Significant differences among soil fertility attributes *viz.* available nitrogen, phosphorus, potassium, sulphur and exchangeable calcium and magnesium content were observed among three land uses. Maximum values of available N, P and Exch. Ca, Mg were observed in soils of forest land use. However, sulphur and potassium content in soils under pineapple land use found to be high followed by forest and paddy land use systems. Significantly higher available N content was recorded under forest LUS during post-monsoon season in surface soils followed by pineapple and paddy LUS. Least content of available N was recorded during monsoon season.
- Significant seasonal variation in available P content was recorded between forest LUS and pineapple LUS as well as forest LUS and paddy LUS; maximum being recorded in pre-monsoon season. Phosphorus

content of pineapple and paddy LUS was at par in all the three sampling seasons. Available P content was found maximum in forest LUS followed by paddy and pineapple during pre-monsoon season. Minimum content of available phosphorus in soils of different LUS was found during monsoon season.

- Pineapple LUS recorded maximum available K in the form of K_2O. Average available K content under paddy LUS was in low range while it was in medium range under pineapple and forest LUS in different villages of the Medziphema block. Sub-surface soil layer exhibited lesser amount of potassium content than the surface soil layers in all the three LUS. Seasonal variation in available K was found significant among various LUS. The pattern of seasonal variation in available K was pre-monsoon > post-monsoon > monsoon for all three LUS.
- Maximum content of available S was recorded in pineapple LUS followed by forest and paddy LUS. Available S content exhibited a decreasing trend down the soil profile. Significant seasonal variation in available S content was evident among the different LUS.
- Maximum exchangeable Ca and Mg content were recorded in forest LUS and minimum were recorded in paddy LUS across the seasons and depths. Lesser content of Exch. Ca was recorded in sub-surface soil compared to surface soil. Significantly higher content of Exch. Ca and Mg was recorded in surface soil of forest LUS during pre-monsoon season.
- High values of microbial biomass carbon, bacterial population, dehydrogenase and beta-glucosidase activity were found in soils of forest land use followed by pineapple and paddy land use. Acid phosphatase activity was found more in forest land use followed by paddy land use. A unique trend of seasonal pattern of change in MBC was observed where MBC started increasing with the pre-monsoon

shower, which attained its maximum during monsoon season and then declined in post-monsoon season in case of forest and pineapple LUS. Conversely, in case of paddy LUS, a gradual decline in MBC content was recorded from pre-monsoon to monsoon to post-monsoon season.

- Soil enzyme activity *viz.* dehydrogenase, β-glucosidase and acid phosphatase activity as well as bacterial population was found significantly higher in forest LUS during monsoon season. Significantly higher DHA and GSA were recorded in surface soils of forest LUS followed by pineapple and paddy LUS during monsoon season. Paddy LUS recorded more PHA activity compared to pineapple LUS. On an average, maximum number of bacteria were recorded in surface soils of forest LUS and minimum in sub-surface soils of paddy LUS. Significant seasonal variation of bacterial population was recorded during the period of investigation where bacterial population in monsoon season > pre-monsoon season > post-monsoon in case of both forest and pineapple LUS. On the other hand, the trend of seasonal change of bacterial population in paddy LUS was pre-monsoon > monsoon > post-monsoon.
- Soil carbon fractions including OC, TOC and POXC contents significantly varied among three land uses. Across the different season and depth, forest LUS recorded maximum average content of OC, TOC and POXC followed by pineapple and paddy LUS. Gradual decline in organic carbon fractions along the depth was recorded in all the LUS; maximum being recorded in surface soils of forest LUS and minimum was recorded in sub-surface soils of paddy LUS. Significant seasonal variation was also recorded for these attributes. Maximum variation was recorded during post-monsoon season by pre-monsoon season and least but significant variation was recorded in monsoon season in case of forest, pineapple and paddy LUS.

- Soil organic carbon stock was found to be significantly high in forest soil during post-monsoon season followed by pineapple and paddy land use. Less carbon stock was recorded in sub-surface soils of all the three land uses.
- Carbon management index was found high under pineapple land use indicating better rehabilitation of soil carbon in soils under pineapple cultivation than paddy. A marginal increase in average CMI value in surface soils was recorded for both pineapple and paddy LUS. However, the trend was not same for all the study sites. In case of pineapple LUS, higher CMI was calculated in pre-monsoon followed by monsoon and by post-monsoon whereas, the same in case of paddy LUS was more in post-monsoon followed by monsoon and pre-monsoon.
- The organic carbon fractions *viz*. OC, TOC, POXC and SOC stock under different LUS for both the soil layers were interpolated in location maps obtained through ArcGIS 10.8.1 software with the help of spatial coordinates to assess the spatial variability and spread across the study area in different seasons. Interpolation results indicated spatial dynamics of organic carbon fractions under different LUS in different seasons of the experimental year.
- Maximum amount of cumulative carbon mineralization was recorded in forest land use and minimum in paddy land use during monsoon. Weekly studies on carbon di oxide evolution indicated a similar trend in all the three LUS; with a peak in second week followed by an almost static phase and finally declined as the time of incubation proceed.
- Significant correlation with high values of Pearson's correlation coefficient (*r*) was obtained with all the physico-chemical, fertility, biological attributes and soil carbon fractions in all three land uses under study. However, comparatively low '*r*' value was obtained for soil quality attributes of paddy land use.

With the above deliberations on the findings of the present investigation, the following **conclusions** may be drawn:

1. Forest LUS recorded least densities of soil, while the same were maximum under paddy LUS. Porosity and water holding capacity of forest soils were found maximum irrespective of seasons and depths of sampling.
2. Among the three land use systems studied, forest LUS exhibited better soil fertility status with higher content of available nitrogen, phosphorus and exchangeable calcium and magnesium with significant seasonal variation of these parameters among various LUS. However, available potassium and sulphur content were found higher in pineapple LUS. A decrease in available nutrient contents with depth was also observed.
3. Soil biological attributes *viz.* microbial biomass carbon, dehydrogenase, beta glucosidase and acid phosphatase enzyme activities as well as bacterial population were found higher in forest LUS. The values of these parameters exhibited an increasing trend in the pre-monsoon season, which attained their maximum in monsoon season and declined towards post-monsoon. In paddy LUS a gradual decline in values of biological parameters from pre-monsoon to post-monsoon season was observed. Seasonal variation of these parameters in different LUS was found statistically significant.
4. Soil organic carbon along with its fractions plays a major role in availability of nutrients in different land uses. Among the three land uses studied, forest land use exhibited superiority over pineapple and paddy LUS with significant seasonal variation in terms of organic carbon, total carbon, permanganate oxidizable carbon and carbon stock. Moreover, high CMI of pineapple land use exhibited a fairly good carbon sequestering system that can sustain nutrient transformation and soil health effectively.

5. Labile fraction of soil organic carbon *i.e.* permanganate oxidizable carbon can serve as the most sensitive indicator for assessing soil health, quality and changes in overall stock of soil organic carbon. Hence, frequent and precise analysis of this parameter is required for effective soil management for sustainable production.
6. Maximum amount of cumulative carbon mineralization measured in terms of soil basal respiration was recorded in forest land use and minimum in paddy land use during monsoon season. Weekly carbon di oxide evolution exhibited a peak in second week followed by an almost static phase and finally declined as the time of incubation proceeds.

Based on the present study, it was revealed that pineapple land use system followed in the Medziphema block can be considered as a sustainable land use system owing to its comparable soil physico-chemical, fertility, biological parameters, carbon fractions, carbon stock and CMI index with the forest land use. A meagre change in soil carbon sequestration can have a drastic impact on the global carbon cycle and climate change. Identification of location specific, suitable land use and management practices for the district and state as a whole and large scale adoption can modify carbon sequestration in the soil and mitigate the impact of the climate change. More researches should be conducted to find out similar carbon sequestering LUS for sustainable agricultural production and management of soil health in the district in particular and the state as a whole.

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APPENDICES

Appendix-A: Statistical analysis of the soil parameters (surface soil, 0-0.25 m) of pre monsoon season including ANOVA, Post Hoc test and Homogeneous subsets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	171.781	2	85.890	73.518	.000
	Within Groups	24.534	21	1.168		
	Total	196.315	23			
TC	Between Groups	225.338	2	112.669	46.886	.000
	Within Groups	50.464	21	2.403		
	Total	275.802	23			
PoxC	Between Groups	293065.946	2	146532.973	122.074	.000
	Within Groups	25207.647	21	1200.364		
	Total	318273.593	23			
sand	Between Groups	367.364	2	183.682	8.360	.002
	Within Groups	461.409	21	21.972		
	Total	828.773	23			
silt	Between Groups	27.752	2	13.876	.631	.542
	Within Groups	461.448	21	21.974		
	Total	489.200	23			
clay	Between Groups	194.612	2	97.306	5.518	.012
	Within Groups	370.298	21	17.633		
	Total	564.910	23			
BD	Between Groups	.147	2	.073	232.801	.000
	Within Groups	.007	21	.000		
	Total	.154	23			
PD	Between Groups	.216	2	.108	17.068	.000
	Within Groups	.133	21	.006		
	Total	.348	23			
porosity	Between Groups	126.312	2	63.156	45.008	.000
	Within Groups	29.468	21	1.403		
	Total	155.780	23			
WHC	Between Groups	190.820	2	95.410	94.601	.000
	Within Groups	21.180	21	1.009		
	Total	212.000	23			
pH	Between Groups	.108	2	.054	5.882	.009
	Within Groups	.192	21	.009		
	Total	.300	23			
AvN	Between Groups	15967.690	2	7983.845	51.764	.000
	Within Groups	3238.930	21	154.235		
	Total	19206.620	23			
AvP2O5	Between Groups	439.145	2	219.573	16.151	.000
	Within Groups	285.487	21	13.595		
	Total	724.632	23			
AvK2O	Between Groups	31459.853	2	15729.927	121.228	.000
	Within Groups	2724.857	21	129.755		
	Total	34184.710	23			

Av S	Between Groups	705.436	2	352.718	16.026	.000
	Within Groups	462.190	21	22.009		
	Total	1167.626	23			
Ex ca	Between Groups	8.630	2	4.315	126.368	.000
	Within Groups	.717	21	.034		
	Total	9.347	23			
Ex.Mg	Between Groups	2.634	2	1.317	66.292	.000
	Within Groups	.417	21	.020		
	Total	3.052	23			
SMBC	Between Groups	235777.526	2	117888.763	35.268	.000
	Within Groups	70196.077	21	3342.670		
	Total	305973.603	23			
DHA	Between Groups	32.130	2	16.065	5.349	.013
	Within Groups	63.067	21	3.003		
	Total	95.197	23			
PHA	Between Groups	9560.629	2	4780.315	59.334	.000
	Within Groups	1691.878	21	80.566		
	Total	11252.507	23			
Glucosidase	Between Groups	2736.956	2	1368.478	30.704	.000
	Within Groups	935.956	21	44.569		
	Total	3672.911	23			
Bacterial popucfu	Between Groups	1418.176	2	709.088	16.331	.000
	Within Groups	911.819	21	43.420		
	Total	2329.995	23			
Respiration	Between Groups	17830.066	2	8915.033	863.108	.000
	Within Groups	216.909	21	10.329		
	Total	18046.975	23			
Carbon Stock	Between Groups	804.662	2	402.331	50.850	.000
	Within Groups	166.155	21	7.912		
	Total	970.817	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
OC	LSD	Forest	Pineapple	2.70041667*	.54043858	.000	1.57651311	3.82432022
			Paddy	6.52124997*	.54043858	.000	5.39734644	7.64515355
		Pineapple	Forest	-2.70041667*	.54043858	.000	-3.82432022	-1.57651311
			Paddy	3.82083329*	.54043858	.000	2.69692977	4.94473688
		Paddy	Forest	-6.52124997*	.54043858	.000	-7.64515355	-5.39734644
			Pineapple	-3.82083329*	.54043858	.000	-4.94473688	-2.69692977
TC	LSD	Forest	Pineapple	3.59083332*	.77508925	.000	1.97894697	5.20271968
			Paddy	7.50333332*	.77508925	.000	5.89144697	9.11521968
		Pineapple	Forest	-3.59083332*	.77508925	.000	-5.2027196	-1.97894697
			Paddy	3.91250000*	.77508925	.000	2.3006136	5.52438635
		Paddy	Forest	-7.50333332*	.77508925	.000	-9.11521968	-5.89144697
			Pineapple	-3.91250000*	.77508925	.000	-5.52438635	-2.30061364
PoxC	LSD	Forest	Pineapple	88.398750000*	17.323135	.000	52.3733167	124.4241832
			Paddy	265.7600000*	17.323135	.000	229.734566	301.785433
		Pineapple	Forest	-88.398750000*	17.3231358	.000	-124.424183	-52.373316
			Paddy	177.3612500000*	17.3231358	.000	141.335816	213.38668

		Paddy	Forest	-265.76000*	17.323135	.000	-301.785433	-229.734566
			Pineapple	-177.36125000*	17.323135	.000	-213.38668	-141.335816
sand	LSD	Forest	Pineapple	6.2133338*	2.34370633	.015	1.33932919	11.0873374
			Paddy	9.425416663*	2.34370633	.001	4.55141252	14.2994208
		Pineapple	Forest	-6.21333338*	2.34370633	.015	-11.0873374	-1.33932919
			Paddy	3.212083325	2.34370633	.185	-1.66192080	8.08608747
		Paddy	Forest	-9.425416663*	2.34370633	.001	-14.2994208	-4.55141252
			Pineapple	-3.212083325	2.34370633	.185	-8.08608747	1.66192080
silt	LSD	Forest	Pineapple	-1.8616665	2.34380695	.436	-6.73588006	3.01254673
			Paddy	-2.54458332	2.34380695	.290	-7.41879673	2.32963006
		Pineapple	Forest	1.861666665	2.34380695	.436	-3.01254673	6.73588006
			Paddy	-.682916667	2.34380695	.774	-5.55713006	4.19129673
		Paddy	Forest	2.544583332	2.34380695	.290	-2.32963006	7.41879673
			Pineapple	.682916667	2.34380695	.774	-4.19129673	5.55713006
clay	LSD	Forest	Pineapple	-4.35208329	2.09959758	.051	-8.71843553	.014268873
			Paddy	-6.8966665*	2.09959758	.004	-11.2630188	-2.53031446
		Pineapple	Forest	4.352083	2.09959758	.051	-.01426887	8.71843553
			Paddy	-2.54458335	2.09959758	.239	-6.91093553	1.82176887
		Paddy	Forest	6.89666665*	2.09959758	.004	2.53031446	11.2630188
			Pineapple	2.54458335	2.09959758	.239	-1.82176887	6.9109355
BD	LSD	Forest	Pineapple	-.06333333*	.00888268	.000	-.08180589	-.04486077
			Paddy	-.18833333*	.00888268	.000	-.20680589	-.16986077
		Pineapple	Forest	.06333333*	.00888268	.000	.04486077	.08180589
			Paddy	-.12500000*	.00888268	.000	-.14347255	-.10652744
		Paddy	Forest	.18833333*	.00888268	.000	.16986077	.20680589
			Pineapple	.12500000*	.00888268	.000	.10652744	.14347255
PD	LSD	Forest	Pineapple	.10999999*	.03974081	.012	.02735446	.19264553
			Paddy	-.12208334*	.03974081	.006	-.20472887	-.03943779
		Pineapple	Forest	-.10999999*	.03974081	.012	-.19264553	-.02735446
			Paddy	-.23208334*	.03974081	.000	-.31472887	-.14943779
		Paddy	Forest	.12208334*	.03974081	.006	.03943779	.20472887
			Pineapple	.23208334*	.03974081	.000	.14943779	.31472887
porosity	LSD	Forest	Pineapple	4.69672675*	.59228871	.000	3.4649967	5.9284603
			Paddy	5.02027102*	.59228871	.000	3.7885436	6.2520072
		Pineapple	Forest	-4.696728675*	.59228871	.000	-5.92846033	-3.46499670
			Paddy	.323546928	.59228871	.591	-.90818487	1.55527875
		Paddy	Forest	-5.020275102*	.59228871	.000	-6.25200727	-3.78854364
			Pineapple	-.32354628	.59228871	.591	-1.55527875	.90818487
WHC	LSD	Forest	Pineapple	5.617646985*	.50213492	.000	4.5733994	6.6618929
			Paddy	6.288817809*	.50213492	.000	5.2445706	7.3330641
		Pineapple	Forest	-5.617646985*	.50213492	.000	-6.66189295	-4.57339945
			Paddy	.671171224	.50213492	.196	-.37307551	1.71541798
		Paddy	Forest	-6.28881809*	.50213492	.000	-7.33306419	-5.2445706
			Pineapple	-.671171224	.50213492	.196	-1.71541798	.37307551
pH	LSD	Forest	Pineapple	.118749999*	.04785390	.022	.01923234	.21826765
			Paddy	-.038750000	.04785390	.427	-.13826765	.06076765
		Pineapple	Forest	-.118749999*	.04785390	.022	-.21826765	-.01923234
			Paddy	-.157500000*	.04785390	.003	-.25701765	-.05798234
		Paddy	Forest	.03875000	.04785390	.427	-.06076765	.13826765
			Pineapple	.15750000*	.04785390	.003	.05798234	.25701765
AvN	LSD	Forest	Pineapple	37.18000064*	6.2095641	.000	24.2665043	50.0934956
			Paddy	62.82999984*	6.2095641	.000	49.9165043	75.7434956
		Pineapple	Forest	-37.18000064*	6.20956418	.000	-50.0934956	-24.2665043
			Paddy	25.64999920*	6.20956418	.000	12.7365043	38.5634956
		Paddy	Forest	-62.82999984*	6.20956418	.000	-75.7434956	-49.9165043

			Pineapple	-25.64999920*	6.20956418	.000	-38.5634956	-12.7365043
AvP2O5	LSD	Forest	Pineapple	9.22791673*	1.84354306	.000	5.39405898	13.0617743
			Paddy	8.91208342*	1.84354306	.000	5.07822565	12.7459410
		Pineapple	Forest	-9.22791673*	1.84354306	.000	-13.0617743	-5.39405898
			Paddy	-.31583330	1.84354306	.866	-4.14969101	3.51802434
		Paddy	Forest	-8.91208342*	1.84354306	.000	-12.7459410	-5.07822565
			Pineapple	.31583330	1.84354306	.866	-3.51802434	4.14969101
AvK2O	LSD	Forest	Pineapple	-64.13958350*	5.69550468	.000	-75.9840337	-52.2951329
			Paddy	20.97083330*	5.69550468	.001	9.1263829	32.8152837
		Pineapple	Forest	64.13958350*	5.69550468	.000	52.2951329	75.9840337
			Paddy	85.11041680*	5.69550468	.000	73.2659662	96.9548670
		Paddy	Forest	-20.97083330*	5.69550468	.001	-32.8152837	-9.12638294
			Pineapple	-85.11041680*	5.69550468	.000	-96.9548670	-73.2659662
Av S	LSD	Forest	Pineapple	-5.77624997*	2.34568915	.023	-10.6543776	-.898122357
			Paddy	7.467812501*	2.34568915	.004	2.58968485	12.3459401
		Pineapple	Forest	5.77624997*	2.34568915	.023	.89812235	10.6543776
			Paddy	13.2440624998*	2.34568915	.000	8.36593485	18.1221901
		Paddy	Forest	-7.4678125001*	2.34568915	.004	-12.3459401	-2.58968485
			Pineapple	-13.244062498*	2.34568915	.000	-18.1221901	-8.36593485
Ex ca	LSD	Forest	Pineapple	1.13708333*	.092392419	.000	.944942779	1.32922388
			Paddy	1.37375000*	.092392419	.000	1.18160944	1.56589055
		Pineapple	Forest	-1.13708333*	.092392419	.000	-1.32922388	-.944942779
			Paddy	.23666667*	.092392419	.018	.044526112	.428807220
		Paddy	Forest	-1.37375000*	.092392419	.000	-1.56589055	-1.18160944
			Pineapple	-.23666667*	.092392419	.018	-.428807220	-.044526112
Ex.Mg	LSD	Forest	Pineapple	.58083333*	.070479508	.000	.434263171	.727403494
			Paddy	.78125000*	.070479508	.000	.634679838	.927820161
		Pineapple	Forest	-.58083333*	.070479508	.000	-.727403494	-.434263171
			Paddy	.20041667*	.070479508	.010	.053846505	.346986828
		Paddy	Forest	-.78125000*	.070479508	.000	-.927820161	-.63467983
			Pineapple	-.20041667*	.070479508	.010	-.346986828	-.05384650
SMBC	LSD	Forest	Pineapple	242.61333340*	28.9079156	.000	182.49603178	302.73063488
			Paddy	113.40958390*	28.9079156	.001	53.29228178	173.52688488
		Pineapple	Forest	-242.61333340*	28.9079156	.000	-302.7306348	-182.4960317
			Paddy	-129.20374960*	28.9079156	.000	-189.3210515	-69.0864484
		Paddy	Forest	-113.40958390*	28.9079156	.001	-173.5268848	-53.2922817
			Pineapple	129.20374960*	28.9079156	.000	69.0864484	189.3210515
DHA	LSD	Forest	Pineapple	2.82750002*	.866485806	.004	1.0255441	4.62945587
			Paddy	1.24541669	.866485806	.165	-.55653921	3.04737254
		Pineapple	Forest	-2.82750002*	.86648580	.004	-4.62945587	-1.02554412
			Paddy	-1.58208333	.86648580	.082	-3.38403921	.219872545
		Paddy	Forest	-1.24541669	.86648580	.165	-3.04737254	.55653921
			Pineapple	1.58208333	.86648580	.082	-.219872545	3.38403921
PHA	LSD	Forest	Pineapple	48.881250000*	4.4879172	.000	39.5481151	58.2143848
			Paddy	25.20583330*	4.4879172	.000	15.8726984	34.5389681
		Pineapple	Forest	-48.88125000*	4.4879172	.000	-58.2143848	-39.5481151
			Paddy	-23.67541670*	4.4879172	.000	-33.0085515	-14.3422818
		Paddy	Forest	-25.20583330*	4.4879172	.000	-34.5389681	-15.8726984
			Pineapple	23.67541670*	4.4879172	.000	14.3422818	33.0085515
Glucosidase	LSD	Forest	Pineapple	10.62416667*	3.3380126	.004	3.6823893	17.5659439
			Paddy	26.012916676*	3.3380126	.000	19.0711393	32.9546939
		Pineapple	Forest	-10.62416667*	3.3380126	.004	-17.5659439	-3.6823893
			Paddy	15.38875009*	3.3380126	.000	8.44697270	22.3305272
		Paddy	Forest	-26.01291676*	3.3380126	.000	-32.9546939	-19.0711393
			Pineapple	-15.38875009*	3.3380126	.000	-22.3305272	-8.4469727

Bacterial popucfu	LSD	Forest	Pineapple	17.58333320*	3.2946916	.000	10.7316468	24.4350198
			Paddy	14.62499986*	3.2946916	.000	7.7733135	21.4766864
		Pineapple	Forest	-17.58333320*	3.2946916	.000	-24.4350198	-10.7316468
			Paddy	-2.95833336	3.2946916	.379	-9.81001980	3.8933531
		Paddy	Forest	-14.62499986*	3.2946916	.000	-21.4766864	-7.7733135
			Pineapple	2.95833336	3.2946916	.379	-3.8933531	9.8100198
Respiration	LSD	Forest	Pineapple	52.244583340*	1.6069373	.000	48.9027742	55.5863924
			Paddy	62.122500000*	1.6069373	.000	58.7806909	65.4643090
		Pineapple	Forest	-52.244583340*	1.6069373	.000	-55.5863924	-48.9027742
			Paddy	9.877916664*	1.6069373	.000	6.53610757	13.2197257
		Paddy	Forest	-62.12250000*	1.6069373	.000	-65.4643090	-58.7806909
			Pineapple	-9.87791664*	1.6069373	.000	-13.2197257	-6.5361075
Carbon Stock	LSD	Forest	Pineapple	5.678989333*	1.4064256	.001	2.7541672	8.6038119
			Paddy	14.09497961*	1.4064256	.000	11.1701568	17.0198015
		Pineapple	Forest	-5.678989333*	1.4064256	.001	-8.6038119	-2.7541672
			Paddy	8.415989328*	1.4064256	.000	5.4911672	11.3408119
		Paddy	Forest	-14.094979161*	1.4064256	.000	-17.0198015	-11.1701568
			Pineapple	-8.415989328*	1.4064256	.000	-11.3408119	-5.4911672

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	11.195		
	Pineapple	8		15.016	
	Forest	8			17.717
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	14.462		
	Pineapple	8		18.375	
	Forest	8			21.965
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	202.216		
	Pineapple	8		379.577	
	Forest	8			467.976
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Sand

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	40.932	
	Pineapple	8	44.145	
	Forest	8		50.358
	Sig.		.185	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

silt

	Land Use	N	Subset for alpha = 0.05
			1
Duncan[a]	Forest	8	23.595
	Pineapple	8	25.457
	Paddy	8	26.140
	Sig.		.317

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

clay

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Forest	8	26.049	
	Pineapple	8	30.401	30.401
	Paddy	8		32.946
	Sig.		.051	.239

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.189		
	Pineapple	8		1.252	
	Paddy	8			1.377
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	2.374		
	Forest	8		2.484	
	Paddy	8			2.6066
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

porosity

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	47.094	
	Pineapple	8	47.418	
	Forest	8		52.115
	Sig.		.591	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	41.042	
	Pineapple	8	41.714	
	Forest	8		47.3316 6
	Sig.		.196	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	4.7508	
	Forest	8		4.8695
	Paddy	8		4.9083
	Sig.		1.000	.427

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	252.677		
	Pineapple	8		278.327	
	Forest	8			315.507
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	25.82708	
	Paddy	8	26.14291	
	Forest	8		35.055
	Sig.		.866	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	145.133		
	Forest	8		166.104	
	Pineapple	8			230.244
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	25.070		
	Forest	8		32.538	
	Pineapple	8			38.314
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.4075		
	Pineapple	8		1.644	
	Forest	8			2.7812
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	.63083		
	Pineapple	8		.83125	
	Forest	8			1.4120
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	274.440		
	Paddy	8		403.644	
	Forest	8			517.053
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	12.81541	
	Paddy	8	14.39749	14.39749
	Forest	8		15.64291
	Sig.		.082	.165

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	63.60		
	Paddy	8		87.27	
	Forest	8			112.48
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	39.703		
	Pineapple	8		55.092	
	Forest	8			65.716
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	47.083	
	Paddy	8	50.041	
	Forest	8		64.666
	Sig.		.379	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	43.344		
	Pineapple	8		53.222	
	Forest	8			105.466
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	38.542		
	Pineapple	8		46.958	
	Forest	8			52.637
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix- B: Statistical analysis of the soil parameters (sub surface soil, 0.25 -0.50 m) of pre monsoon season including ANOVA, Post Hoc test and Homogeneous subsets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	124.721	2	62.361	73.002	.000
	Within Groups	17.939	21	.854		
	Total	142.660	23			
TC	Between Groups	174.032	2	87.016	52.573	.000
	Within Groups	34.758	21	1.655		
	Total	208.790	23			
PoxC	Between Groups	203727.492	2	101863.746	148.523	.000
	Within Groups	14402.767	21	685.846		
	Total	218130.259	23			
sand	Between Groups	452.906	2	226.453	11.605	.000
	Within Groups	409.789	21	19.514		
	Total	862.694	23			
silt	Between Groups	71.499	2	35.749	1.537	.238
	Within Groups	488.291	21	23.252		
	Total	559.789	23			
clay	Between Groups	246.580	2	123.290	8.185	.002
	Within Groups	316.322	21	15.063		
	Total	562.902	23			
BD	Between Groups	.151	2	.075	194.305	.000
	Within Groups	.008	21	.000		
	Total	.159	23			
PD	Between Groups	.278	2	.139	30.343	.000
	Within Groups	.096	21	.005		
	Total	.374	23			
porosity	Between Groups	35.519	2	17.760	19.448	.000
	Within Groups	19.177	21	.913		
	Total	54.696	23			
WHC	Between Groups	157.288	2	78.644	116.214	.000
	Within Groups	14.211	21	.677		
	Total	171.499	23			
pH	Between Groups	.211	2	.105	12.358	.000
	Within Groups	.179	21	.009		
	Total	.390	23			
AvN	Between Groups	12860.448	2	6430.224	67.499	.000
	Within Groups	2000.552	21	95.264		
	Total	14861.001	23			
AvP2O5	Between Groups	475.288	2	237.644	22.975	.000
	Within Groups	217.214	21	10.344		
	Total	692.502	23			
AvK2O	Between Groups	26367.338	2	13183.669	113.699	.000
	Within Groups	2434.989	21	115.952		
	Total	28802.327	23			
Av S	Between Groups	263.375	2	131.688	10.499	.001
	Within Groups	263.392	21	12.542		
	Total	526.767	23			

Ex ca	Between Groups	6.031	2	3.015	90.691	.000
	Within Groups	.698	21	.033		
	Total	6.729	23			
Ex.Mg	Between Groups	2.237	2	1.119	75.100	.000
	Within Groups	.313	21	.015		
	Total	2.550	23			
SMBC	Between Groups	66427.686	2	33213.843	14.438	.000
	Within Groups	48308.836	21	2300.421		
	Total	114736.523	23			
DHA	Between Groups	98.957	2	49.478	20.419	.000
	Within Groups	50.887	21	2.423		
	Total	149.844	23			
PHA	Between Groups	2715.348	2	1357.674	23.722	.000
	Within Groups	1201.889	21	57.233		
	Total	3917.237	23			
Glucosidase	Between Groups	2518.516	2	1259.258	27.433	.000
	Within Groups	963.959	21	45.903		
	Total	3482.475	23			
Bacterial popucfu	Between Groups	2042.898	2	1021.449	21.063	.000
	Within Groups	1018.417	21	48.496		
	Total	3061.315	23			
Respiration	Between Groups	13250.377	2	6625.188	1832.756	.000
	Within Groups	75.912	21	3.615		
	Total	13326.289	23			
Carbon Stock	Between Groups	612.081	2	306.041	51.566	.000
	Within Groups	124.633	21	5.935		
	Total	736.714	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
OC	LSD	Forest	Pineapple	1.955208331*	.46212437	.000	.99416807	2.91624858
			Paddy	5.507291664*	.46212437	.000	4.5462514	6.46833192
		Pineapple	Forest	-1.955208331*	.46212437	.000	-2.91624858	-.99416807
			Paddy	3.552083332*	.46212437	.000	2.59104307	4.51312358
		Paddy	Forest	-5.507291664*	.46212437	.000	-6.46833192	-4.54625141
			Pineapple	-3.552083332*	.46212437	.000	-4.51312358	-2.59104307
TC	LSD	Forest	Pineapple	3.145833336*	.64326068	.000	1.80809950	4.48356715
			Paddy	6.593750004*	.64326068	.000	5.25601617	7.93148382
		Pineapple	Forest	-3.145833336*	.64326068	.000	-4.48356715	-1.80809950
			Paddy	3.447916668*	.64326068	.000	2.11018284	4.78565049
		Paddy	Forest	-6.593750004*	.64326068	.000	-7.93148382	-5.25601617
			Pineapple	-3.447916668*	.64326068	.000	-4.78565049	-2.11018284
PoxC	LSD	Forest	Pineapple	59.517416634*	13.09433129	.000	32.28626401	86.74856931
			Paddy	218.285000000*	13.09433129	.000	191.0538473	245.5161526
		Pineapple	Forest	-59.517416634*	13.09433129	.000	-86.74856931	-32.28626401
			Paddy	158.767583360*	13.09433129	.000	131.53643068	185.9987359
		Paddy	Forest	-218.285000000*	13.09433129	.000	-245.51615264	-191.05384735
			Pineapple	-158.76758360*	13.09433129	.000	-185.99873598	-131.53643068
sand	LSD	Forest	Pineapple	4.860833332*	2.20871860	.039	.26755154	9.45411512

			Paddy	10.627916657*	2.20871860	.000	6.03463487	15.2211984
		Pineapple	Forest	-4.860833332*	2.20871860	.039	-9.45411512	-.26755154
			Paddy	5.767083325*	2.20871860	.016	1.17380154	10.36036512
		Paddy	Forest	-10.627916657*	2.20871860	.000	-15.22119845	-6.03463487
			Pineapple	-5.767083325*	2.20871860	.016	-10.36036512	-1.17380154
silt	LSD	Forest	Pineapple	.886666670	2.41101294	.717	-4.12730922	5.90064255
			Paddy	-3.136666667	2.41101294	.207	-8.15064255	1.87730922
		Pineapple	Forest	-.886666670	2.41101294	.717	-5.90064255	4.12730922
			Paddy	-4.02333337	2.41101294	.110	-9.03730922	.99064255
		Paddy	Forest	3.136666667	2.41101294	.207	-1.87730922	8.15064255
			Pineapple	4.023333337	2.41101294	.110	-.99064255	9.03730922
clay	LSD	Forest	Pineapple	-5.762499992*	1.94054976	.007	-9.79809415	-1.72690584
			Paddy	-7.499583330*	1.94054976	.001	-11.53517748	-3.46398917
		Pineapple	Forest	5.762499992*	1.94054976	.007	1.72690584	9.79809415
			Paddy	-1.737083338	1.94054976	.381	-5.77267748	2.29851082
		Paddy	Forest	7.499583330*	1.94054976	.001	3.46398917	11.53517748
			Pineapple	1.737083338	1.94054976	.381	-2.29851082	5.77267748
BD	LSD	Forest	Pineapple	-.077083334*	.00985174	.000	-.09757115	-.05659550
			Paddy	-.192916667*	.00985174	.000	-.21340449	-.17242884
		Pineapple	Forest	.077083334*	.00985174	.000	.05659550	.09757115
			Paddy	-.115833333*	.00985174	.000	-.13632115	-.09534550
		Paddy	Forest	.192916667*	.00985174	.000	.17242884	.21340449
			Pineapple	.115833333*	.00985174	.000	.09534550	.13632115
PD	LSD	Forest	Pineapple	-.071250000*	.03383819	.047	-.14162036	-.00087963
			Paddy	-.255416667*	.03383819	.000	-.32578703	-.18504629
		Pineapple	Forest	.071250000*	.03383819	.047	.00087963	.14162036
			Paddy	-.184166667*	.03383819	.000	-.25453703	-.11379629
		Paddy	Forest	.255416667*	.03383819	.000	.18504629	.32578703
			Pineapple	.184166667*	.03383819	.000	.11379629	.25453703
porosity	LSD	Forest	Pineapple	1.863614642*	.47780546	.001	.86996363	2.85726536
			Paddy	2.945517070*	.47780546	.000	1.95186705	3.93916879
		Pineapple	Forest	-1.863614642*	.47780546	.001	-2.85726536	-.86996363
			Paddy	1.081903428*	.47780546	.034	.08825256	2.07555429
		Paddy	Forest	-2.945517070*	.477805467	.000	-3.93916879	-1.95186705
			Pineapple	-1.081903428*	.47780546	.034	-2.07555429	-.08825256
WHC	LSD	Forest	Pineapple	5.073067217*	.41131379	.000	4.21769348	5.92844122
			Paddy	5.728635169*	.41131379	.000	4.87326135	6.58400909
		Pineapple	Forest	-5.073067217*	.41131379	.000	-5.92844122	-4.21769348
			Paddy	.655567853	.41131379	.126	-.19980599	1.51094174
		Paddy	Forest	-5.728635169*	.41131379	.000	-6.58400909	-4.87326135
			Pineapple	-.655567853	.41131379	.126	-1.51094174	.19980599
pH	LSD	Forest	Pineapple	.229166666*	.04617011	.000	.13315064	.32518268
			Paddy	.103333333*	.04617011	.036	.00731731	.19934935
		Pineapple	Forest	-.229166666*	.04617011	.000	-.32518268	-.13315064
			Paddy	-.125833333*	.04617011	.013	-.22184935	-.02981731
		Paddy	Forest	-.103333333*	.04617011	.036	-.19934935	-.00731731
			Pineapple	.125833333*	.04617011	.013	.02981731	.22184935
AvN	LSD	Forest	Pineapple	31.928333285*	4.88017396	.000	21.77945599	42.07721067
			Paddy	56.544583350*	4.88017396	.000	46.39570599	66.69346067
		Pineapple	Forest	-31.928333285*	4.88017396	.000	-42.07721067	-21.77945599
			Paddy	24.616250065*	4.88017396	.000	14.46737266	34.76512733
		Paddy	Forest	-56.544583350*	4.88017396	.000	-66.69346067	-46.39570599
			Pineapple	-24.616250065*	4.88017396	.000	-34.76512733	-14.46737266
AvP2O5	LSD	Forest	Pineapple	9.670416672*	1.60806763	.000	6.32625695	13.01457638
			Paddy	9.191666674*	1.60806763	.000	5.84750695	12.53582638

		Pineapple	Forest	-9.670416672*	1.60806763	.000	-13.01457638	-6.32625695
			Paddy	-.478749998	1.60806763	.769	-3.82290971	2.86540971
		Paddy	Forest	-9.191666674*	1.60806763	.000	-12.53582638	-5.84750695
			Pineapple	.478749998	1.60806763	.769	-2.86540971	3.82290971
AvK2O	LSD	Forest	Pineapple	-61.875833360*	5.38404771	.000	-73.07257350	-50.67909316
			Paddy	14.585833340*	5.38404771	.013	3.38909316	25.78257350
		Pineapple	Forest	61.875833360*	5.38404771	.000	50.67909316	73.07257350
			Paddy	76.461666700*	5.38404771	.000	65.26492649	87.65840683
		Paddy	Forest	-14.585833340*	5.38404771	.013	-25.78257350	-3.38909316
			Pineapple	-76.461666700*	5.38404771	.000	-87.65840683	-65.26492649
Av S	LSD	Forest	Pineapple	-3.267708335	1.77076714	.079	-6.95022019	.41480352
			Paddy	4.798437499*	1.77076714	.013	1.11592563	8.48094936
		Pineapple	Forest	3.267708335	1.77076714	.079	-.41480352	6.95022019
			Paddy	8.066145834*	1.77076714	.000	4.38363397	11.74865769
		Paddy	Forest	-4.798437499*	1.77076714	.013	-8.48094936	-1.11592563
			Pineapple	-8.066145834*	1.77076714	.000	-11.74865769	-4.38363397
Ex ca	LSD	Forest	Pineapple	.915833334*	.09117282	.000	.72622907	1.10543759
			Paddy	1.166250000*	.09117282	.000	.97664573	1.35585426
		Pineapple	Forest	-.9158333334*	.09117282	.000	-1.10543759	-.72622907
			Paddy	.250416667*	.09117282	.012	.06081240	.44002092
		Paddy	Forest	-1.166250000*	.09117282	.000	-1.35585426	-.97664573
			Pineapple	-.250416667*	.09117282	.012	-.44002092	-.06081240
Ex.Mg	LSD	Forest	Pineapple	.495416667*	.06102437	.000	.36850952	.62232381
			Paddy	.732916667*	.06102437	.000	.60600952	.85982381
		Pineapple	Forest	-.495416667*	.06102437	.000	-.62232381	-.36850952
			Paddy	.237500000*	.06102437	.001	.11059285	.36440714
		Paddy	Forest	-.732916667*	.06102437	.000	-.85982381	-.60600952
			Pineapple	-.237500000*	.06102437	.001	-.36440714	-.11059285
SMBC	LSD	Forest	Pineapple	128.264583380*	23.98135091	.000	78.39263394	178.13653271
			Paddy	53.346250000*	23.98135091	.037	3.47430061	103.21819938
		Pineapple	Forest	-128.264583380*	23.98135091	.000	-178.13653271	-78.392633947
			Paddy	-74.918333380*	23.98135091	.005	-124.79028271	-25.04638394
		Paddy	Forest	-53.346250000*	23.98135091	.037	-103.21819938	-3.47430061
			Pineapple	74.918333380*	23.98135091	.005	25.04638394	124.79028271
DHA	LSD	Forest	Pineapple	1.764583333*	.77832885	.034	.14595987	3.38320678
			Paddy	4.909583332*	.77832885	.000	3.29095987	6.52820678
		Pineapple	Forest	-1.764583333*	.77832885	.034	-3.38320678	-.14595987
			Paddy	3.145000000*	.77832885	.001	1.52637654	4.76362345
		Paddy	Forest	-4.909583332*	.77832885	.000	-6.52820678	-3.29095987
			Pineapple	-3.145000000*	.77832885	.001	-4.76362345	-1.52637654
PHA	LSD	Forest	Pineapple	25.975833334*	3.78261867	.000	18.10944716	33.84221950
			Paddy	11.235833332*	3.78261867	.007	3.36944716	19.10221950
		Pineapple	Forest	-25.975833334*	3.78261867	.000	-33.84221950	-18.10944716
			Paddy	-14.740000002*	3.78261867	.001	-22.60638616	-6.87361383
		Paddy	Forest	-11.235833332*	3.78261867	.007	-19.10221950	-3.36944716
			Pineapple	14.740000002*	3.78261867	.001	6.87361383	22.60638616
Glucosidase	LSD	Forest	Pineapple	11.375833340*	3.38758070	.003	4.33097360	18.42069306
			Paddy	25.057083340*	3.38758070	.000	18.01222360	32.10194306
		Pineapple	Forest	-11.375833340*	3.38758070	.003	-18.42069306	-4.33097360
			Paddy	13.681249999*	3.38758070	.001	6.63639027	20.72610972
		Paddy	Forest	-25.057083340*	3.38758070	.000	-32.10194306	-18.01222360
			Pineapple	-13.681249999*	3.38758070	.001	-20.72610972	-6.63639027
Bacterial popucfu	LSD	Forest	Pineapple	17.125000007*	3.48195461	.000	9.88387897	24.36612102
			Paddy	21.333333343*	3.48195461	.000	14.09221231	28.57445435
		Pineapple	Forest	-17.125000007*	3.48195461	.000	-24.36612102	-9.88387897

			Paddy	4.208333336	3.48195461	.240	-3.03278768	11.44945435
		Paddy	Forest	-21.333333343*	3.48195461	.000	-28.57445435	-14.09221231
			Pineapple	-4.208333336	3.48195461	.240	-11.44945435	3.03278768
Respiration	LSD	Forest	Pineapple	46.716666660*	.95064147	.000	44.73969949	48.69363383
			Paddy	52.472083330*	.95064147	.000	50.49511616	54.44905050
		Pineapple	Forest	-46.716666660*	.95064147	.000	-48.69363383	-44.73969949
			Paddy	5.755416669*	.95064147	.000	3.77844949	7.73238383
		Paddy	Forest	-52.472083330*	.95064147	.000	-54.44905050	-50.49511616
			Pineapple	-5.755416669*	.95064147	.000	-7.73238383	-3.77844949
Carbon Stock	LSD	Forest	Pineapple	3.402432671*	1.21808257	.011	.86929090	5.93557367
			Paddy	12.000866666*	1.21808257	.000	9.46772840	14.53401117
		Pineapple	Forest	-3.402432671*	1.21808257	.011	-5.93557367	-.86929090
			Paddy	8.598437996*	1.21808257	.000	6.06529611	11.13157888
		Paddy	Forest	-12.000866666*	1.21808257	.000	-14.53401117	-9.46772840
			Pineapple	-8.598437996*	1.21808257	.000	-11.13157888	-6.06529611

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	9.747		
	Pineapple	8		13.300	
	Forest	8			15.255
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TOC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	12.852		
	Pineapple	8		16.300	
	Forest	8			19.445
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	148.689		
	Pineapple	8		307.457	
	Forest	8			366.974
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Sand

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	39.866		
	Pineapple	8		45.633	
	Forest	8			50.494
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

silt

	Land Use	N	Subset for alpha = 0.05
			1
Duncan[a]	Pineapple	8	22.415
	Forest	8	23.302
	Paddy	8	26.439
	Sig.		.128

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

clay

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Forest	8	26.203	
	Pineapple	8		31.965
	Paddy	8		33.702
	Sig.		1.000	.381

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.213		
	Pineapple	8		1.290	
	Paddy	8			1.406
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	2.389		
	Pineapple	8		2.460	
	Paddy	8			2.645
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

porosity

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	46.259		
	Pineapple	8		47.341	
	Forest	8			49.205
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	39.981	
	Pineapple	8	40.636	
	Forest	8		45.710
	Sig.		.126	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	4.937		
	Paddy	8		5.063	
	Forest	8			5.166
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	236.909		
	Pineapple	8		261.525	
	Forest	8			293.453
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	22.745	
	Paddy	8	23.224	
	Forest	8		32.416
	Sig.		.769	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	133.391		
	Forest	8		147.977	
	Pineapple	8			209.852
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	17.730	
	Forest	8		22.528
	Pineapple	8		25.796
	Sig.		1.000	.079

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.300		
	Pineapple	8		1.550	
	Forest	8			2.466
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	.5062		
	Pineapple	8		.7437	
	Forest	8			1.2391
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	246.973		
	Paddy	8		321.892	
	Forest	8			375.238
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	8.477		
	Pineapple	8		11.622	
	Forest	8			13.387
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	54.197		
	Paddy	8		68.937	
	Forest	8			80.172
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	32.195		
	Pineapple	8		45.876	
	Forest	8			57.252
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	29.791	
	Pineapple	8	34.000	
	Forest	8		51.125
	Sig.		.240	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	37.904		
	Pineapple	8		43.659	
	Forest	8			90.376
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	34.249		
	Pineapple	8		42.848	
	Forest	8			46.250
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix-C: Statistical analysis of the soil parameters (surface soil, 0-0.25 m) of monsoon season including ANOVA, Post Hoc test and Homogeneous subsets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	168.210	2	84.105	80.793	.000
	Within Groups	21.861	21	1.041		
	Total	190.071	23			
TC	Between Groups	160.978	2	80.489	35.789	.000
	Within Groups	47.228	21	2.249		
	Total	208.206	23			
PoxC	Between Groups	203879.590	2	101939.795	116.529	.000
	Within Groups	18370.894	21	874.804		
	Total	222250.484	23			
BD	Between Groups	.224	2	.112	142.951	.000
	Within Groups	.016	21	.001		
	Total	.241	23			
PD	Between Groups	.388	2	.194	42.025	.000
	Within Groups	.097	21	.005		
	Total	.485	23			
porosity	Between Groups	71.247	2	35.623	32.465	.000
	Within Groups	23.043	21	1.097		
	Total	94.290	23			
WHC	Between Groups	116.954	2	58.477	72.008	.000
	Within Groups	17.054	21	.812		
	Total	134.008	23			
pH	Between Groups	.814	2	.407	18.854	.000
	Within Groups	.453	21	.022		
	Total	1.267	23			
AvN	Between Groups	12551.188	2	6275.594	45.352	.000
	Within Groups	2905.904	21	138.376		
	Total	15457.092	23			
AvP2O5	Between Groups	443.823	2	221.911	16.564	.000
	Within Groups	281.338	21	13.397		
	Total	725.161	23			
AvK2O	Between Groups	30475.096	2	15237.548	96.489	.000
	Within Groups	3316.332	21	157.921		
	Total	33791.428	23			
Av S	Between Groups	631.612	2	315.806	26.857	.000
	Within Groups	246.932	21	11.759		
	Total	878.544	23			
Ex ca	Between Groups	1.632	2	.816	30.303	.000
	Within Groups	.565	21	.027		
	Total	2.197	23			
Ex.Mg	Between Groups	.916	2	.458	37.034	.000
	Within Groups	.260	21	.012		
	Total	1.175	23			
SMBC	Between Groups	222217.210	2	111108.605	40.588	.000

		Sum of Squares	df	Mean Square	F	Sig.
	Within Groups	57487.169	21	2737.484		
	Total	279704.380	23			
DHA	Between Groups	65.090	2	32.545	8.295	.002
	Within Groups	82.393	21	3.923		
	Total	147.483	23			
PHA	Between Groups	33251.654	2	16625.827	109.549	.000
	Within Groups	3187.101	21	151.767		
	Total	36438.755	23			
Glucosidase	Between Groups	6195.932	2	3097.966	105.002	.000
	Within Groups	619.581	21	29.504		
	Total	6815.513	23			
Bacterial popucfu	Between Groups	3531.148	2	1765.574	29.843	.000
	Within Groups	1242.403	21	59.162		
	Total	4773.551	23			
Respiration	Between Groups	26378.663	2	13189.332	2531.303	.000
	Within Groups	109.420	21	5.210		
	Total	26488.084	23			
Carbon Stock	Between Groups	725.078	2	362.539	58.946	.000
	Within Groups	129.158	21	6.150		
	Total	854.235	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
OC	LSD	Forest	Pineapple	2.526041666*	.51014371	.000	1.46513974	3.58694359
			Paddy	6.435416667*	.51014371	.000	5.37451474	7.49631859
		Pineapple	Forest	-2.526041666*	.51014371	.000	-3.58694359	-1.46513974
			Paddy	3.909375001*	.51014371	.000	2.84847307	4.97027692
		Paddy	Forest	-6.435416667*	.51014371	.000	-7.49631859	-5.37451474
			Pineapple	-3.909375001*	.51014371	.000	-4.97027692	-2.84847307
TC	LSD	Forest	Pineapple	2.630208332*	.74982564	.002	1.07086053	4.18955613
			Paddy	6.314583333*	.74982564	.000	4.75523553	7.87393113
		Pineapple	Forest	-2.630208332*	.74982564	.002	-4.18955613	-1.07086053
			Paddy	3.684375001*	.74982564	.000	2.12502719	5.24372280
		Paddy	Forest	-6.314583333*	.74982564	.000	-7.87393113	-4.75523553
			Pineapple	-3.684375001*	.74982564	.000	-5.24372280	-2.12502719
PoxC	LSD	Forest	Pineapple	89.294020320*	14.78854693	.000	58.53955387	120.0484877
			Paddy	224.222500050*	14.78854693	.000	193.46803304	254.9769669
		Pineapple	Forest	-89.294023320*	14.78854693	.000	-120.0484877	-58.5395538
			Paddy	134.928466730*	14.78854693	.000	104.1740122	165.6829461
		Paddy	Forest	-224.22250005*	14.78854693	.000	-254.9769669	-193.468033
			Pineapple	-134.92846673*	14.78854693	.000	-165.6829461	-104.174012
BD	LSD	Forest	Pineapple	-.081250000*	.01400998	.000	-.11038536	-.05211463
			Paddy	-.233333333*	.01400998	.000	-.26246869	-.20419796
		Pineapple	Forest	.081250000*	.01400998	.000	.05211463	.11038536
			Paddy	-.152083333*	.01400998	.000	-.18121869	-.12294796
		Paddy	Forest	.233333333*	.01400998	.000	.20419796	.26246869
			Pineapple	.152083333*	.01400998	.000	.12294796	.18121869
PD	LSD	Forest	Pineapple	-.006666667	.03396207	.846	-.07729467	.06396133
			Paddy	-.272916667*	.03396207	.000	-.34354467	-.20228866
		Pineapple	Forest	.006666667	.03396207	.846	-.06396133	.07729467
			Paddy	-.266250000*	.03396207	.000	-.33687800	-.19562199

		Paddy	Forest	.272916667*	.03396207	.000	.20228866	.3435446
			Pineapple	.266250000*	.03396207	.000	.19562199	.33687800
porosity	LSD	Forest	Pineapple	2.099818360*	.52375961	.001	1.01060029	3.18903580
			Paddy	4.220375719*	.52375961	.000	3.13115808	5.30959358
		Pineapple	Forest	-2.099818360*	.52375961	.001	-3.18903580	-1.01060029
			Paddy	2.120557359*	.52375961	.001	1.03134003	3.20977553
		Paddy	Forest	-4.220375719*	.52375961	.000	-5.30959358	-3.13115808
			Pineapple	-2.120557359*	.52375961	.001	-3.20977553	-1.03134003
WHC	LSD	Forest	Pineapple	3.449987086*	.45057970	.000	2.51295560	4.38701918
			Paddy	5.330843889*	.45057970	.000	4.39381189	6.26787547
		Pineapple	Forest	-3.449987086*	.45057970	.000	-4.38701918	-2.51295560
			Paddy	1.880856803*	.45057970	.000	.94382449	2.81788808
		Paddy	Forest	-5.330843889*	.45057970	.000	-6.26787547	-4.39381189
			Pineapple	-1.880856803*	.45057970	.000	-2.81788808	-.94382449
pH	LSD	Forest	Pineapple	.184583333*	.07345982	.020	.03181526	.33735140
			Paddy	-.264166667*	.07345982	.002	-.41693473	-.11139859
		Pineapple	Forest	-.184583333*	.07345982	.020	-.33735140	-.03181526
			Paddy	-.448750000*	.07345982	.000	-.60151806	-.29598193
		Paddy	Forest	.264166667*	.07345982	.002	.11139859	.41693473
			Pineapple	.448750000*	.07345982	.000	.29598193	.60151806
AvN	LSD	Forest	Pineapple	30.898750007*	5.8816740	.000	18.66713913	43.13036086
			Paddy	55.912916660*	5.8816740	.000	43.68130579	68.14452753
		Pineapple	Forest	-30.898750007*	5.88167409	.000	-43.13036086	-18.6671391
			Paddy	25.014166654*	5.88167409	.000	12.78255579	37.24577753
		Paddy	Forest	-55.912916660*	5.88167409	.000	-68.14452753	-43.6813057
			Pineapple	-25.014166654*	5.88167409	.000	-37.24577753	-12.7825557
AvP2O5	LSD	Forest	Pineapple	9.334166665*	1.83009919	.000	5.52826704	13.14006628
			Paddy	8.894583333*	1.83009919	.000	5.08868371	12.70048295
		Pineapple	Forest	-9.334166665*	1.83009919	.000	-13.14006628	-5.52826704
			Paddy	-.439583331	1.83009919	.813	-4.24548295	3.36631628
		Paddy	Forest	-8.894583333*	1.83009919	.000	-12.70048295	-5.08868371
			Pineapple	.439583331	1.83009919	.813	-3.36631628	4.24548295
AvK2O	LSD	Forest	Pineapple	-66.431250000*	6.28332264	.000	-79.49813475	-53.3643652
			Paddy	15.817499967*	6.28332264	.020	2.75061524	28.88438475
		Pineapple	Forest	66.431250000*	6.28332264	.000	53.36436524	79.49813475
			Paddy	82.248749970*	6.28332264	.000	69.18186524	95.31563475
		Paddy	Forest	-15.817499967*	6.28332264	.020	-28.88438475	-2.75061524
			Pineapple	-82.248749970*	6.28332264	.000	-95.31563475	-69.1818652
Av S	LSD	Forest	Pineapple	-7.953750003*	1.71454694	.000	-11.51934555	-4.38815444
			Paddy	4.448124997*	1.71454694	.017	.88252944	8.01372055
		Pineapple	Forest	7.953750003*	1.71454694	.000	4.38815444	11.51934555
			Paddy	12.401875000*	1.71454694	.000	8.83627944	15.96747055
		Paddy	Forest	-4.448124997*	1.71454694	.017	-8.01372055	-.88252944
			Pineapple	-12.401875000*	1.71454694	.000	-15.96747055	-8.83627944
Ex ca	LSD	Forest	Pineapple	.423333334*	.08204157	.000	.25271853	.59394812
			Paddy	.625833334*	.08204157	.000	.45521853	.79644812
		Pineapple	Forest	-.423333334*	.08204157	.000	-.59394812	-.25271853
			Paddy	.202500000*	.08204157	.022	.03188520	.37311479
		Paddy	Forest	-.625833334*	.08204157	.000	-.79644812	-.45521853
			Pineapple	-.202500000*	.08204157	.022	-.37311479	-.03188520
Ex.Mg	LSD	Forest	Pineapple	.287500000*	.05559859	.000	.17187639	.40312360
			Paddy	.475000000*	.05559859	.000	.35937639	.59062360
		Pineapple	Forest	-.287500000*	.05559859	.000	-.40312360	-.17187639
			Paddy	.187500000*	.05559859	.003	.07187639	.30312360
		Paddy	Forest	-.475000000*	.05559859	.000	-.59062360	-.35937639

			Pineapple	-.187500000*	.05559859	.003	-.30312360	-.07187639
SMBC	LSD	Forest	Pineapple	183.270833260*	26.16048664	.000	128.86712312	237.6745435
			Paddy	219.988749920*	26.16048664	.000	165.58503979	274.3924602
		Pineapple	Forest	-183.27083326*	26.16048664	.000	-237.6745435	-128.867123
			Paddy	36.717916670	26.16048664	.175	-17.68579354	91.12162687
		Paddy	Forest	-219.98874992*	26.16048664	.000	-274.3924602	-165.585039
			Pineapple	-36.717916670	26.16048664	.175	-91.12162687	17.68579354
DHA	LSD	Forest	Pineapple	3.298333332*	.99038741	.003	1.23870995	5.35795671
			Paddy	3.660416663*	.99038741	.001	1.60079328	5.72004004
		Pineapple	Forest	-3.298333332*	.99038741	.003	-5.35795671	-1.23870995
			Paddy	.362083331	.99038741	.718	-1.69754004	2.42170671
		Paddy	Forest	-3.660416663*	.99038741	.001	-5.72004004	-1.60079328
			Pineapple	-.362083331	.99038741	.718	-2.42170671	1.69754004
PHA	LSD	Forest	Pineapple	79.778750020*	6.15968211	.000	66.968989804	92.58851019
			Paddy	78.115000010*	6.15968211	.000	65.305239804	90.92476019
		Pineapple	Forest	-79.778750020*	6.15968211	.000	-92.58851019	-66.9689898
			Paddy	-1.663750007	6.15968211	.790	-14.47351019	11.14601019
		Paddy	Forest	-78.115000010*	6.15968211	.000	-90.92476019	-65.3052398
			Pineapple	1.663750007	6.15968211	.790	-11.14601019	14.47351019
Glucosidase	LSD	Forest	Pineapple	12.431249991*	2.71587331	.000	6.78328226	18.07921773
			Paddy	38.555000000*	2.71587331	.000	32.90703226	44.20296773
		Pineapple	Forest	-12.431249991*	2.71587331	.000	-18.07921773	-6.78328226
			Paddy	26.123750010*	2.71587331	.000	20.47578226	31.77171773
		Paddy	Forest	-38.555000000*	2.71587331	.000	-44.20296773	-32.9070322
			Pineapple	-26.123750010*	2.71587331	.000	-31.77171773	-20.4757822
Bacterial popucfu	LSD	Forest	Pineapple	13.416666679*	3.84584311	.002	5.41879808	21.41453525
			Paddy	29.666666670*	3.84584311	.000	21.66879808	37.66453525
		Pineapple	Forest	-13.416666679*	3.84584311	.002	-21.41453525	-5.41879808
			Paddy	16.249999993*	3.84584311	.000	8.25213141	24.24786858
		Paddy	Forest	-29.666666670*	3.84584311	.000	-37.66453525	-21.6687980
			Pineapple	-16.249999993*	3.84584311	.000	-24.24786858	-8.25213141
Respiration	LSD	Forest	Pineapple	46.870416640*	1.14132510	.000	44.49690117	49.24393216
			Paddy	80.866666650*	1.14132510	.000	78.49315117	83.24018216
		Pineapple	Forest	-46.870416640*	1.14132510	.000	-49.24393216	-44.4969011
			Paddy	33.996250000*	1.14132510	.000	31.62273450	36.36976549
		Paddy	Forest	-80.866666650*	1.14132510	.000	-83.24018216	-78.4931511
			Pineapple	-33.996250000*	1.14132510	.000	-36.36976549	-31.6227345
Carbon Stock	LSD	Forest	Pineapple	4.756364330*	1.23999631	.001	2.17765107	7.33507809
			Paddy	13.286196666*	1.23999631	.000	10.70748440	15.86491142
		Pineapple	Forest	-4.756364330*	1.23999631	.001	-7.33507809	-2.17765107
			Paddy	8.529833336*	1.23999631	.000	5.95111982	11.10854684
		Paddy	Forest	-13.286197666*	1.23999631	.000	-15.86491142	-10.7074844
			Pineapple	-8.529833336*	1.23999631	.000	-11.10854684	-5.95111982

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

			Subset for alpha = 0.05		
	Land Use	N	1	2	3
Duncan[a]	Paddy	8	10.674		
	Pineapple	8		14.584	
	Forest	8			17.110
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TOC

			Subset for alpha = 0.05		
	Land Use	N	1	2	3
Duncan[a]	Paddy	8	13.720		
	Pineapple	8		17.405	
	Forest	8			20.035
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	197.181		
	Pineapple	8		332.110	
	Forest	8			421.404
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.2133		
	Pineapple	8		1.2945	
	Paddy	8			1.4466
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

PD

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Forest	8	2.4008	
	Pineapple	8	2.4075	
	Paddy	8		2.6737
	Sig.		.846	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Porosity

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	45.215		
	Pineapple	8		47.335	
	Forest	8			49.435
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	38.618		
	Pineapple	8		40.499	
	Forest	8			43.949
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	4.383		
	Forest	8		4.568	
	Paddy	8			4.832
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	245.669		
	Pineapple	8		270.683	
	Forest	8			301.582
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	22.838	
	Paddy	8	23.278	
	Forest	8		32.172
	Sig.		.813	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	131.000		
	Forest	8		146.817	
	Pineapple	8			213.249
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	20.650		
	Forest	8		25.098	
	Pineapple	8			33.052
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex Ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.345		
	Pineapple	8		1.547	
	Forest	8			1.970
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	.5283		
	Pineapple	8		.7158	
	Forest	8			1.003
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	329.469	
	Pineapple	8	366.187	
	Forest	8		549.457
	Sig.		.175	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	13.755	
	Pineapple	8	14.117	
	Forest	8		17.416
	Sig.		.718	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	71.648	
	Paddy	8	73.312	
	Forest	8		151.427
	Sig.		.790	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	33.227		
	Pineapple	8		59.351	
	Forest	8			71.782
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	41.291		
	Pineapple	8		57.541	
	Forest	8			70.958
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	33.775		
	Pineapple	8		67.771	
	Forest	8			114.641
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	38.585		
	Pineapple	8		47.115	
	Forest	8			51.871
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix-D: Statistical analysis of the soil parameters (sub surface soil, 0.25- 0.50 m) of monsoon season including ANOVA, Post Hoc test and Homogeneous subset

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	98.398	2	49.199	48.703	.000
	Within Groups	21.214	21	1.010		
	Total	119.611	23			
TC	Between Groups	99.141	2	49.570	33.076	.000
	Within Groups	31.472	21	1.499		
	Total	130.613	23			
PoxC	Between Groups	159050.617	2	79525.309	167.223	.000
	Within Groups	9986.866	21	475.565		
	Total	169037.483	23			
BD	Between Groups	.249	2	.125	242.033	.000
	Within Groups	.011	21	.001		
	Total	.260	23			
PD	Between Groups	.287	2	.144	52.047	.000
	Within Groups	.058	21	.003		
	Total	.345	23			
porosity	Between Groups	61.384	2	30.692	24.456	.000
	Within Groups	26.355	21	1.255		
	Total	87.739	23			
WHC	Between Groups	120.693	2	60.347	71.201	.000
	Within Groups	17.799	21	.848		
	Total	138.492	23			
pH	Between Groups	.566	2	.283	16.002	.000
	Within Groups	.372	21	.018		
	Total	.938	23			
AvN	Between Groups	11519.060	2	5759.530	67.160	.000
	Within Groups	1800.923	21	85.758		
	Total	13319.983	23			
AvP_2O_5	Between Groups	332.791	2	166.396	16.589	.000
	Within Groups	210.642	21	10.031		
	Total	543.433	23			
AvK_2O	Between Groups	23256.090	2	11628.045	112.537	.000
	Within Groups	2169.856	21	103.326		
	Total	25425.946	23			
Av S	Between Groups	211.808	2	105.904	23.532	.000
	Within Groups	94.511	21	4.501		
	Total	306.318	23			
Ex ca	Between Groups	1.157	2	.578	33.609	.000
	Within Groups	.361	21	.017		
	Total	1.518	23			
Ex.Mg	Between Groups	.481	2	.240	23.091	.000
	Within Groups	.219	21	.010		
	Total	.699	23			
SMBC	Between Groups	139418.572	2	69709.286	21.537	.000
	Within Groups	67970.550	21	3236.693		
	Total	207389.123	23			

DHA	Between Groups	330.294	2	165.147	73.880	.000
	Within Groups	46.942	21	2.235		
	Total	377.236	23			
PHA	Between Groups	15872.911	2	7936.455	133.040	.000
	Within Groups	1252.751	21	59.655		
	Total	17125.662	23			
Glucosidase	Between Groups	5665.510	2	2832.755	84.523	.000
	Within Groups	703.804	21	33.514		
	Total	6369.314	23			
Bacterial popucfu	Between Groups	10246.361	2	5123.181	118.963	.000
	Within Groups	904.375	21	43.065		
	Total	11150.736	23			
Respiration	Between Groups	16094.628	2	8047.314	1987.626	.000
	Within Groups	85.023	21	4.049		
	Total	16179.651	23			
Carbon Stock	Between Groups	366.842	2	183.421	26.897	.000
	Within Groups	143.207	21	6.819		
	Total	510.050	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
OC	LSD	Forest	Pineapple	1.770208333*	.50253628	.002	.72512691	2.81528975
			Paddy	4.897500001*	.50253628	.000	3.85241857	5.94258142
		Pineapple	Forest	-1.770208333*	.50253628	.002	-2.81528975	-.72512691
			Paddy	3.127291668*	.50253628	.000	2.08221024	4.17237308
		Paddy	Forest	-4.897500001*	.50253628	.000	-5.94258142	-3.85241857
			Pineapple	-3.127291668*	.50253628	.000	-4.17237308	-2.08221024
TC	LSD	Forest	Pineapple	1.791041667*	.61210012	.008	.51810977	3.06397356
			Paddy	4.918333331*	.61210012	.000	3.64540143	6.19126522
		Pineapple	Forest	-1.791041667*	.61210012	.008	-3.06397356	-.51810977
			Paddy	3.127291665*	.61210012	.000	1.85435977	4.40022356
		Paddy	Forest	-4.918333331*	.61210012	.000	-6.19126522	-3.64540143
			Pineapple	-3.127291665*	.61210012	.000	-4.40022356	-1.85435977
PoxC	LSD	Forest	Pineapple	77.927916700*	10.90372672	.000	55.25237560	100.60345773
			Paddy	197.921250010*	10.90372672	.000	175.24570893	220.59679106
		Pineapple	Forest	-77.927916700*	10.90372672	.000	-100.60345773	-55.25237560
			Paddy	119.993333310*	10.90372672	.000	97.31779226	142.66887439
		Paddy	Forest	-197.921250010*	10.90372672	.000	-220.59679106	-175.24570893
			Pineapple	-119.993333310*	10.90372672	.000	-142.66887439	-97.31779226
BD	LSD	Forest	Pineapple	-.079583333*	.01134039	.000	-.10316697	-.05599969
			Paddy	-.244583333*	.01134039	.000	-.26816697	-.22099969
		Pineapple	Forest	.079583333*	.01134039	.000	.05599969	.10316697
			Paddy	-.165000000*	.01134039	.000	-.18858363	-.14141636
		Paddy	Forest	.244583333*	.01134039	.000	.22099969	.26816697
			Pineapple	.165000000*	.01134039	.000	.14141636	.18858363
PD	LSD	Forest	Pineapple	-.128750000*	.02626621	.000	-.18337358	-.07412641

			Paddy	-.267916667*	.02626621	.000	-.32254024	-.21329308
		Pineapple	Forest	.128750000*	.02626621	.000	.07412641	.18337358
			Paddy	-.139166667*	.02626621	.000	-.19379024	-.08454308
		Paddy	Forest	.267916667*	.02626621	.000	.21329308	.32254024
			Pineapple	.139166667*	.02626621	.000	.08454308	.19379024
porosity	LSD	Forest	Pineapple	1.617347858*	.56013400	.009	.45248512	2.78220996
			Paddy	3.898605891*	.56013400	.000	2.73374275	5.06346760
		Pineapple	Forest	-1.617347858*	.56013400	.009	-2.78220996	-.45248512
			Paddy	2.281257033*	.56013400	.001	1.11639521	3.44612006
		Paddy	Forest	-3.898605891*	.56013400	.000	-5.06346760	-2.73374275
			Pineapple	-2.281257033*	.56013400	.001	-3.44612006	-1.11639521
WHC	LSD	Forest	Pineapple	2.485469359*	.46031294	.000	1.52819611	3.44274244
			Paddy	5.485001677*	.46031294	.000	4.52772788	6.44227421
		Pineapple	Forest	-2.485469359*	.46031294	.000	-3.44274244	-1.52819611
			Paddy	2.999531318*	.46031294	.000	2.04225860	3.95680493
		Paddy	Forest	-5.485001677*	.46031294	.000	-6.44227421	-4.52772788
			Pineapple	-2.999531318*	.46031294	.000	-3.95680493	-2.04225860
pH	LSD	Forest	Pineapple	.203749999*	.06651247	.006	.06542974	.34207025
			Paddy	-.172083333*	.06651247	.017	-.31040358	-.03376307
		Pineapple	Forest	-.203749999*	.06651247	.006	-.34207025	-.06542974
			Paddy	-.375833333*	.06651247	.000	-.51415358	-.23751307
		Paddy	Forest	.172083333*	.06651247	.017	.03376307	.31040358
			Pineapple	.375833333*	.06651247	.000	.23751307	.51415358
AvN	LSD	Forest	Pineapple	29.310833335*	4.63028764	.000	19.68162304	38.94004362
			Paddy	53.584583400*	4.63028764	.000	43.95537304	63.21379362
		Pineapple	Forest	-29.310833335*	4.63028764	.000	-38.94004362	-19.68162304
			Paddy	24.273750064*	4.63028764	.000	14.64453970	33.90296029
		Paddy	Forest	-53.584583400*	4.63028764	.000	-63.21379362	-43.95537304
			Pineapple	-24.273750064*	4.63028764	.000	-33.90296029	-14.64453970
AvP2O5	LSD	Forest	Pineapple	7.846666664*	1.58355393	.000	4.55348598	11.13984734
			Paddy	7.950833332*	1.58355393	.000	4.65765265	11.24401401
		Pineapple	Forest	-7.846666664*	1.58355393	.000	-11.13984734	-4.55348598
			Paddy	.104166668	1.58355393	.948	-3.18901401	3.39734734
		Paddy	Forest	-7.950833332*	1.58355393	.000	-11.24401401	-4.65765265
			Pineapple	-.104166668	1.58355393	.948	-3.397347347	3.18901401
AvK2O	LSD	Forest	Pineapple	-59.864583314*	5.08248143	.000	-70.43418209	-49.29498457
			Paddy	10.966250016*	5.08248143	.043	.39665123	21.53584876
		Pineapple	Forest	59.864583314*	5.08248143	.000	49.29498457	70.43418209
			Paddy	70.830833330*	5.08248143	.000	60.26123457	81.40043209
		Paddy	Forest	-10.966250016*	5.08248143	.043	-21.53584876	-.39665123
			Pineapple	-70.830833330*	5.08248143	.000	-81.40043209	-60.26123457
Av S	LSD	Forest	Pineapple	-3.889791671*	1.06071931	.001	-6.09567824	-1.68390508
			Paddy	3.381083333*	1.06071931	.004	1.17519675	5.58696991
		Pineapple	Forest	3.889791671*	1.06071931	.001	1.68390508	6.09567824
			Paddy	7.270875004*	1.06071931	.000	5.06498841	9.47676158
		Paddy	Forest	-3.381083333*	1.06071931	.004	-5.58696991	-1.17519675
			Pineapple	-7.270875004*	1.06071931	.000	-9.47676158	-5.06498841
Ex ca	LSD	Forest	Pineapple	.298750000*	.06559745	.000	.16233262	.43516737
			Paddy	.536666667*	.06559745	.000	.40024929	.67308403

		Pineapple	Forest	-.298750000*	.06559745	.000	-.43516737	-.16233262
			Paddy	.237916667*	.06559745	.002	.10149929	.37433403
		Paddy	Forest	-.536666667*	.06559745	.000	-.67308403	-.40024929
			Pineapple	-.237916667*	.06559745	.002	-.37433403	-.10149929
Ex.Mg	LSD	Forest	Pineapple	.088750000	.05101143	.097	-.01733407	.19483407
			Paddy	.334583333*	.05101143	.000	.22849925	.44066740
		Pineapple	Forest	-.088750000	.05101143	.097	-.19483407	.01733407
			Paddy	.245833333*	.05101143	.000	.13974925	.35191740
		Paddy	Forest	-.334583333*	.05101143	.000	-.44066740	-.22849925
			Pineapple	-.245833333*	.05101143	.000	-.35191740	-.13974925
SMBC	LSD	Forest	Pineapple	105.750416640*	28.44597019	.001	46.59378322	164.90705010
			Paddy	186.117916670*	28.44597019	.000	126.96128322	245.27455010
		Pineapple	Forest	-105.750416640*	28.44597019	.001	-164.90705010	-46.59378322
			Paddy	80.367500040*	28.44597019	.010	21.21086656	139.52413343
		Paddy	Forest	-186.117916670*	28.44597019	.000	-245.27455010	-126.96128322
			Pineapple	-80.367500040*	28.44597019	.010	-139.52413343	-21.21086656
DHA	LSD	Forest	Pineapple	3.388750000*	.74755396	.000	1.83412641	4.94337358
			Paddy	8.996250000*	.74755396	.000	7.44162641	10.55087358
		Pineapple	Forest	-3.388750000*	.74755396	.000	-4.94337358	-1.83412641
			Paddy	5.607500000*	.74755396	.000	4.05287641	7.16212358
		Paddy	Forest	-8.996250000*	.74755396	.000	-10.55087358	-7.44162641
			Pineapple	-5.607500000*	.74755396	.000	-7.16212358	-4.05287641
PHA	LSD	Forest	Pineapple	52.349166670*	3.86182615	.000	44.31805952	60.38027381
			Paddy	56.519999996*	3.86182615	.000	48.48889285	64.55110714
		Pineapple	Forest	-52.349166670*	3.86182615	.000	-60.38027381	-44.31805952
			Paddy	4.170833327	3.86182615	.292	-3.86027381	12.20194047
		Paddy	Forest	-56.519999996*	3.86182615	.000	-64.55110714	-48.48889285
			Pineapple	-4.170833327	3.86182615	.292	-12.20194047	3.86027381
Glucosidase	LSD	Forest	Pineapple	13.266250007*	2.89458352	.000	7.24663401	19.28586598
			Paddy	37.133750006*	2.89458352	.000	31.11413401	43.15336598
		Pineapple	Forest	-13.266250007*	2.89458352	.000	-19.28586598	-7.24663401
			Paddy	23.867499996*	2.89458352	.000	17.84788401	29.88711598
		Paddy	Forest	-37.133750006*	2.89458352	.000	-43.15336598	-31.11413401
			Pineapple	-23.867499996*	2.89458352	.000	-29.88711598	-17.84788401
Bacterial popucfu	LSD	Forest	Pineapple	22.958333336*	3.28121456	.000	16.13467408	29.78199257
			Paddy	50.541666664*	3.28121456	.000	43.71800742	57.36532591
		Pineapple	Forest	-22.958333336*	3.28121456	.000	-29.78199257	-16.13467408
			Paddy	27.583333330*	3.28121456	.000	20.75967408	34.40699257
		Paddy	Forest	-50.541666664*	3.28121456	.000	-57.36532591	-43.71800742
			Pineapple	-27.583333330*	3.28121456	.000	-34.40699257	-20.75967408
Respiration	LSD	Forest	Pineapple	35.332916680*	1.00606982	.000	33.24067993	37.425153398
			Paddy	63.289166674*	1.00606982	.000	61.19692993	65.381403398
		Pineapple	Forest	-35.332916680*	1.00606982	.000	-37.42515339	-33.24067993
			Paddy	27.956250000*	1.00606982	.000	25.86401326	30.04848673
		Paddy	Forest	-63.289166674*	1.00606982	.000	-65.38140339	-61.19692993
			Pineapple	-27.956250000*	1.00606982	.000	-30.04848673	-25.86401326
Carbon Stock	LSD	Forest	Pineapple	2.995406995*	1.30569867	.032	.28005720	5.71075529
			Paddy	9.375114335*	1.30569867	.000	6.65976553	12.09046363

	Pineapple	Forest	-2.995406295*	1.30569867	.032	-5.71075529	-.28005720
		Paddy	6.379708340*	1.30569867	.000	3.66435928	9.09505738
	Paddy	Forest	-9.375114535*	1.30569867	.000	-12.09046363	-6.65976553
		Pineapple	-6.379708340*	1.30569867	.000	-9.09505738	-3.66435928

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	9.82291		
	Pineapple	8		12.95020	
	Forest	8			14.72041
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TOC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	12.477		
	Pineapple	8		15.604	
	Forest	8			17.395
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	140.1854		
	Pineapple	8		260.1787	
	Forest	8			338.1066
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.26083		
	Pineapple	8		1.34041	
	Paddy	8			1.50541
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000

PD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	2.41666		
	Pineapple	8		2.54541	
	Paddy	8			2.68458
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

porosity

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	43.9055		
	Pineapple	8		46.1868	
	Forest	8			47.8041
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	37.117		
	Pineapple	8		40.116	
	Forest	8			42.602
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	4.57791		
	Forest	8		4.78166	
	Paddy	8			4.95374
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	232.811		
	Pineapple	8		257.08	
	Forest	8			286.39
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	20.28583	
	Pineapple	8	20.39000	
	Forest	8		28.23666
	Sig.		.948	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	119.905		
	Forest	8		130.871	
	Pineapple	8			190.736
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	14.8666		
	Forest	8		18.2477	
	Pineapple	8			22.1375
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.2408		
	Pineapple	8		1.4787	
	Forest	8			1.7775
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	.421666	
	Pineapple	8		.667500
	Forest	8		.756250
	Sig.		1.000	.097

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	233.168		
	Pineapple	8		313.535	
	Forest	8			419.286
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	6.6429		
	Pineapple	8		12.2504	
	Forest	8			15.6391
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	55.7179	
	Pineapple	8	59.8887	
	Forest	8		112.2379
	Sig.		.292	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	25.4766		
	Pineapple	8		49.3441	
	Forest	8			62.6104
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	13.5833		
	Pineapple	8		41.1666	
	Forest	8			64.1250
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	31.3679		
	Pineapple	8		59.3241	
	Forest	8			94.6570
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	36.9529		
	Pineapple	8		43.3326	
	Forest	8			46.3280
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix-E: Statistical analysis of the soil parameters (surface soil, 0-0.25 m) of post monsoon season including ANOVA, Post Hoc test and Homogeneous subsets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	174.343	2	87.172	148.687	.000
	Within Groups	12.312	21	.586		
	Total	186.655	23			
TC	Between Groups	202.517	2	101.259	53.701	.000
	Within Groups	39.597	21	1.886		
	Total	242.115	23			
PoxC	Between Groups	166663.822	2	83331.911	47.678	.000
	Within Groups	36704.108	21	1747.815		
	Total	203367.930	23			
BD	Between Groups	.123	2	.061	151.212	.000
	Within Groups	.009	21	.000		
	Total	.131	23			
PD	Between Groups	.244	2	.122	25.686	.000
	Within Groups	.100	21	.005		
	Total	.343	23			
porosity	Between Groups	112.903	2	56.452	50.252	.000
	Within Groups	23.591	21	1.123		
	Total	136.494	23			
WHC	Between Groups	128.538	2	64.269	85.698	.000
	Within Groups	15.749	21	.750		
	Total	144.287	23			
pH	Between Groups	.564	2	.282	13.668	.000
	Within Groups	.433	21	.021		
	Total	.998	23			
AvN	Between Groups	16363.237	2	8181.618	62.991	.000
	Within Groups	2727.609	21	129.886		
	Total	19090.845	23			
AvP2O5	Between Groups	454.281	2	227.140	15.095	.000
	Within Groups	316.003	21	15.048		
	Total	770.284	23			
AvK2O	Between Groups	31765.900	2	15882.950	106.671	.000
	Within Groups	3126.838	21	148.897		
	Total	34892.738	23			
Av S	Between Groups	593.932	2	296.966	14.441	.000
	Within Groups	431.832	21	20.563		
	Total	1025.764	23			
Ex ca	Between Groups	6.809	2	3.405	134.790	.000
	Within Groups	.530	21	.025		
	Total	7.340	23			
Ex.Mg	Between Groups	2.277	2	1.139	88.814	.000
	Within Groups	.269	21	.013		
	Total	2.546	23			
SMBC	Between Groups	201913.962	2	100956.981	103.645	.000
	Within Groups	20455.312	21	974.062		
	Total	222369.275	23			

		Sum of Squares	df	Mean Square	F	Sig.
DHA	Between Groups	52.670	2	26.335	10.002	.001
	Within Groups	55.293	21	2.633		
	Total	107.962	23			
PHA	Between Groups	2943.302	2	1471.651	18.035	.000
	Within Groups	1713.559	21	81.598		
	Total	4656.861	23			
Glucosidase	Between Groups	3861.912	2	1930.956	49.643	.000
	Within Groups	816.829	21	38.897		
	Total	4678.741	23			
Bacterial popucfu	Between Groups	5675.194	2	2837.597	149.167	.000
	Within Groups	399.483	21	19.023		
	Total	6074.678	23			
Respiration	Between Groups	21143.671	2	10571.835	1320.548	.000
	Within Groups	168.118	21	8.006		
	Total	21311.789	23			
Carbon Stock	Between Groups	812.860	2	406.430	127.104	.000
	Within Groups	67.150	21	3.198		
	Total	880.010	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
OC	LSD	Forest	Pineapple	3.074166661*	.38284277	.000	2.27800152	3.87033180
			Paddy	6.596874997*	.38284277	.000	5.80070985	7.39304014
		Pineapple	Forest	-3.074166661*	.38284277	.000	-3.87033180	-2.27800152
			Paddy	3.522708336*	.38284277	.000	2.72654319	4.31887347
		Paddy	Forest	-6.596874997*	.38284277	.000	-7.39304014	-5.80070985
			Pineapple	-3.522708336*	.38284277	.000	-4.31887347	-2.72654319
TC	LSD	Forest	Pineapple	3.333958335*	.68658286	.000	1.90613110	4.76178556
			Paddy	7.110833337*	.68658286	.000	5.68300610	8.53866056
		Pineapple	Forest	-3.333958335*	.68658286	.000	-4.76178556	-1.90613110
			Paddy	3.776875002*	.68658286	.000	2.34904777	5.20470222
		Paddy	Forest	-7.110833337*	.68658286	.000	-8.53866056	-5.68300610
			Pineapple	-3.776875002*	.68658286	.000	-5.20470222	-2.34904777
PoxC	LSD	Forest	Pineapple	121.548296730*	20.90343663	.000	78.07721542	165.01936790
			Paddy	202.791666740*	20.90343663	.000	159.32059042	246.26274290
		Pineapple	Forest	-121.548296730*	20.90343663	.000	-165.01936790	-78.07721542
			Paddy	81.243375010*	20.90343663	.001	37.77229876	124.71445123
		Paddy	Forest	-202.791666740*	20.90343663	.000	-246.26274290	-159.32059042
			Pineapple	-81.243375010*	20.90343663	.001	-124.71445123	-37.77229876
BD	LSD	Forest	Pineapple	-.037916667*	.01007412	.001	-.05886696	-.01696636
			Paddy	-.167083333*	.01007412	.000	-.18803363	-.14613303
		Pineapple	Forest	.037916667*	.01007412	.001	.01696636	.05886696
			Paddy	-.129166667*	.01007412	.000	-.15011696	-.10821636
		Paddy	Forest	.167083333*	.01007412	.000	.14613303	.18803363
			Pineapple	.129166667*	.01007412	.000	.10821636	.15011696
PD	LSD	Forest	Pineapple	.151250000*	.03444164	.000	.07962467	.22287532
			Paddy	-.093333333*	.03444164	.013	-.16495865	-.02170801
		Pineapple	Forest	-.151250000*	.03444164	.000	-.22287532	-.07962467
			Paddy	-.244583333*	.03444164	.000	-.31620865	-.17295801
		Paddy	Forest	.093333333*	.03444164	.013	.02170801	.16495865

			Pineapple	.244583333*	.03444164	.000	.17295801	.31620865
porosity	LSD	Forest	Pineapple	4.369958429*	.52994338	.000	3.26788085	5.47203603
			Paddy	4.801644093*	.52994338	.000	3.69956697	5.90372215
		Pineapple	Forest	-4.369958429*	.52994338	.000	-5.47203603	-3.26788085
			Paddy	.431686164	.52994338	.424	-.67039147	1.53376370
		Paddy	Forest	-4.801644093*	.52994338	.000	-5.90372215	-3.69956697
			Pineapple	-.431686164	.52994338	.424	-1.53376370	.67039147
WHC	LSD	Forest	Pineapple	4.415574600*	.43299758	.000	3.51510630	5.31604187
			Paddy	5.286395861*	.43299758	.000	4.38592812	6.18686368
		Pineapple	Forest	-4.415574600*	.43299758	.000	-5.31604187	-3.51510630
			Paddy	.870821861	.43299758	.057	-.02964596	1.77128959
		Paddy	Forest	-5.286395861*	.43299758	.000	-6.18686368	-4.38592812
			Pineapple	-.870821861	.43299758	.057	-1.77128959	.02964596
pH	LSD	Forest	Pineapple	.169166668*	.07183811	.028	.01977113	.31856219
			Paddy	-.205833333*	.07183811	.009	-.35522886	-.05643780
		Pineapple	Forest	-.169166668*	.07183811	.028	-.31856219	-.01977113
			Paddy	-.375000001*	.07183811	.000	-.52439553	-.22560446
		Paddy	Forest	.205833333*	.07183811	.009	.05643780	.35522886
			Pineapple	.375000001*	.07183811	.000	.22560446	.52439553
AvN	LSD	Forest	Pineapple	40.765416680*	5.69837986	.000	28.91498700	52.61584632
			Paddy	63.064583300*	5.69837986	.000	51.21415367	74.91501299
		Pineapple	Forest	-40.765416680*	5.69837986	.000	-52.61584632	-28.91498700
			Paddy	22.299166622*	5.69837986	.001	10.44873700	34.14959632
		Paddy	Forest	-63.064583300*	5.69837986	.000	-74.91501299	-51.21415367
			Pineapple	-22.299166622*	5.69837986	.001	-34.14959632	-10.44873700
AvP2O5	LSD	Forest	Pineapple	9.974583328*	1.93957359	.000	5.94101923	14.00814743
			Paddy	8.236666661*	1.93957359	.000	4.20310256	12.27023076
		Pineapple	Forest	-9.974583328*	1.93957359	.000	-14.00814743	-5.94101923
			Paddy	-1.737916667	1.93957359	.380	-5.77148076	2.29564743
		Paddy	Forest	-8.236666661*	1.93957359	.000	-12.27023076	-4.20310256
			Pineapple	1.737916667	1.93957359	.380	-2.29564743	5.77148076
AvK2O	LSD	Forest	Pineapple	-63.269999980*	6.10116873	.000	-75.95807497	-50.58192502
			Paddy	22.713750005*	6.10116873	.001	10.02567502	35.40182497
		Pineapple	Forest	63.269999980*	6.10116873	.000	50.58192502	75.95807497
			Paddy	85.983749990*	6.10116873	.000	73.29567502	98.67182497
		Paddy	Forest	-22.713750005*	6.10116873	.001	-35.40182497	-10.02567502
			Pineapple	-85.983749990*	6.10116873	.000	-98.67182497	-73.29567502
Av S	LSD	Forest	Pineapple	-5.990312502*	2.26734535	.015	-10.70551529	-1.27510970
			Paddy	6.194479160*	2.26734535	.012	1.47927637	10.90968195
		Pineapple	Forest	5.990312502*	2.26734535	.015	1.27510970	10.70551529
			Paddy	12.184791662*	2.26734535	.000	7.46958887	16.89999445
		Paddy	Forest	-6.194479160*	2.26734535	.012	-10.90968195	-1.47927637
			Pineapple	-12.184791662*	2.26734535	.000	-16.89999445	-7.46958887
Ex ca	LSD	Forest	Pineapple	1.003750000*	.07946518	.000	.83849310	1.16900689
			Paddy	1.223750000*	.07946518	.000	1.05849310	1.38900689
		Pineapple	Forest	-1.003750000*	.07946518	.000	-1.16900689	-.83849310
			Paddy	.220000000*	.07946518	.012	.05474310	.38525689
		Paddy	Forest	-1.223750000*	.07946518	.000	-1.38900689	-1.05849310
			Pineapple	-.220000000*	.07946518	.012	-.38525689	-.05474310
Ex.Mg	LSD	Forest	Pineapple	.535833333*	.05661032	.000	.41810571	.65356094
			Paddy	.727916666*	.05661032	.000	.61018905	.84564428
		Pineapple	Forest	-.535833333*	.05661032	.000	-.65356094	-.41810571
			Paddy	.192083333*	.05661032	.003	.07435571	.30981094
		Paddy	Forest	-.727916666*	.05661032	.000	-.84564428	-.61018905
			Pineapple	-.192083333*	.05661032	.003	-.30981094	-.07435571

SMBC	LSD	Forest	Pineapple	108.762499960*	15.60498714	.000	76.31015268	141.21484731
			Paddy	224.636666660*	15.60498714	.000	192.18431934	257.08901398
		Pineapple	Forest	-108.762499960*	15.60498714	.000	-141.21484731	-76.31015268
			Paddy	115.874166700*	15.60498714	.000	83.42181934	148.32651398
		Paddy	Forest	-224.636666660*	15.60498714	.000	-257.08901398	-192.18431934
			Pineapple	-115.874166700*	15.60498714	.000	-148.32651398	-83.42181934
DHA	LSD	Forest	Pineapple	3.294166666*	.81132472	.001	1.60692452	4.98140880
			Paddy	2.965000000*	.81132472	.001	1.27775785	4.65224214
		Pineapple	Forest	-3.294166666*	.81132472	.001	-4.98140880	-1.60692452
			Paddy	-.329166666	.81132472	.689	-2.01640880	1.35807547
		Paddy	Forest	-2.965000000*	.81132472	.001	-4.65224214	-1.27775785
			Pineapple	.329166666	.81132472	.689	-1.35807547	2.01640880
PHA	LSD	Forest	Pineapple	27.021249995*	4.51658155	.000	17.62850447	36.41399552
			Paddy	15.574166670*	4.51658155	.002	6.18142114	24.96691219
		Pineapple	Forest	-27.021249995*	4.51658155	.000	-36.41399552	-17.62850447
			Paddy	-11.447083325*	4.51658155	.019	-20.83982885	-2.05433780
		Paddy	Forest	-15.574166670*	4.51658155	.002	-24.96691219	-6.18142114
			Pineapple	11.447083325*	4.51658155	.019	2.05433780	20.83982885
Glucosidase	LSD	Forest	Pineapple	12.146250002*	3.11835797	.001	5.66126958	18.63123041
			Paddy	30.841250006*	3.11835797	.000	24.35626958	37.32623041
		Pineapple	Forest	-12.146250002*	3.11835797	.001	-18.63123041	-5.66126958
			Paddy	18.695000004*	3.11835797	.000	12.21001958	25.17998041
		Paddy	Forest	-30.841250006*	3.11835797	.000	-37.32623041	-24.35626958
			Pineapple	-18.695000004*	3.11835797	.000	-25.17998041	-12.21001958
Bacterial popucfu	LSD	Forest	Pineapple	18.708333330*	2.18076863	.000	14.17317668	23.24348998
			Paddy	37.666666664*	2.18076863	.000	33.13151001	42.20182331
		Pineapple	Forest	-18.708333330*	2.18076863	.000	-23.24348998	-14.17317668
			Paddy	18.958333336*	2.18076863	.000	14.42317668	23.49348998
		Paddy	Forest	-37.666666664*	2.18076863	.000	-42.20182331	-33.13151001
			Pineapple	-18.958333336*	2.18076863	.000	-23.49348998	-14.42317668
Respiration	LSD	Forest	Pineapple	58.496666680*	1.41471218	.000	55.55461162	61.43872171
			Paddy	66.638750020*	1.41471218	.000	63.69669495	69.58080504
		Pineapple	Forest	-58.496666680*	1.41471218	.000	-61.43872171	-55.55461162
			Paddy	8.142083336*	1.41471218	.000	5.20002828	11.08413837
		Paddy	Forest	-66.638750020*	1.41471218	.000	-69.58080504	-63.69669495
			Pineapple	-8.142083336*	1.41471218	.000	-11.08413837	-5.20002828
Carbon Stock	LSD	Forest	Pineapple	7.539916656*	.89409548	.000	5.68054331	9.39929002
			Paddy	14.247239532*	.89409548	.000	12.38786622	16.10661293
		Pineapple	Forest	-7.539916656*	.89409548	.000	-9.39929002	-5.68054331
			Paddy	6.707322976*	.89409548	.000	4.84794956	8.56669627
		Paddy	Forest	-14.247239532*	.89409548	.000	-16.10661293	-12.38786622
			Pineapple	-6.707322976*	.89409548	.000	-8.56669627	-4.84794956

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	12.089		
	Pineapple	8		15.612	
	Forest	8			18.686
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TOC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	15.556		
	Pineapple	8		19.333	
	Forest	8			22.667
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	340.666		
	Pineapple	8		421.909	
	Forest	8			543.457
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.170		
	Pineapple	8		1.208	
	Paddy	8			1.337
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

PD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	2.338		
	Forest	8		2.490	
	Paddy	8			2.583
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Porosity

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	48.162	
	Pineapple	8	48.593	
	Forest	8		52.963
	Sig.		.424	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	41.984	
	Pineapple	8	42.855	
	Forest	8		47.271
	Sig.		.057	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	4.529		
	Forest	8		4.698	
	Paddy	8			4.904
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	262.269		
	Pineapple	8		284.568	
	Forest	8			325.334
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	23.888	
	Paddy	8	25.626	
	Forest	8		33.862
	Sig.		.380	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	134.915		
	Forest	8		157.629	
	Pineapple	8			220.899
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	30.013		
	Forest	8		36.207	
	Pineapple	8			42.197
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.372		
	Pineapple	8		1.592	
	Forest	8			2.595
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	.5850		
	Pineapple	8		.7770	
	Forest	8			1.3129
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	136.922		
	Pineapple	8		252.797	
	Forest	8			361.559
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	11.087	
	Paddy	8	11.416	
	Forest	8		14.381
	Sig.		.689	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Pineapple	8	55.772		
	Paddy	8		67.219	
	Forest	8			82.793
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	30.753		
	Pineapple	8		49.448	
	Forest	8			61.595
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	21.208		
	Pineapple	8		40.166	
	Forest	8			58.875
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	31.177		
	Pineapple	8		39.319	
	Forest	8			97.815
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	40.428		
	Pineapple	8		47.135	
	Forest	8			54.675
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix-F: Statistical analysis of the soil parameters (sub surface soil, 0.25- 0.50 m) of post monsoon season including ANOVA, Post Hoc test and Homogeneous subsets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OC	Between Groups	149.881	2	74.941	98.169	.000
	Within Groups	16.031	21	.763		
	Total	165.912	23			
TC	Between Groups	170.094	2	85.047	55.920	.000
	Within Groups	31.938	21	1.521		
	Total	202.032	23			
PoxC	Between Groups	119289.724	2	59644.862	90.191	.000
	Within Groups	13887.709	21	661.319		
	Total	133177.433	23			
BD	Between Groups	.128	2	.064	137.666	.000
	Within Groups	.010	21	.000		
	Total	.138	23			
PD	Between Groups	.254	2	.127	32.551	.000
	Within Groups	.082	21	.004		
	Total	.335	23			
porosity	Between Groups	29.354	2	14.677	18.551	.000
	Within Groups	16.614	21	.791		
	Total	45.968	23			
WHC	Between Groups	73.406	2	36.703	53.283	.000
	Within Groups	14.466	21	.689		
	Total	87.872	23			
pH	Between Groups	.381	2	.190	17.797	.000
	Within Groups	.225	21	.011		
	Total	.605	23			
AvN	Between Groups	15827.136	2	7913.568	80.359	.000
	Within Groups	2068.020	21	98.477		
	Total	17895.156	23			
AvP2O5	Between Groups	443.286	2	221.643	23.723	.000
	Within Groups	196.202	21	9.343		
	Total	639.489	23			
AvK2O	Between Groups	23217.996	2	11608.998	94.847	.000
	Within Groups	2570.343	21	122.397		
	Total	25788.339	23			
Av S	Between Groups	278.525	2	139.262	11.770	.000
	Within Groups	248.475	21	11.832		
	Total	527.000	23			
Ex ca	Between Groups	5.592	2	2.796	134.809	.000
	Within Groups	.436	21	.021		
	Total	6.027	23			
Ex.Mg	Between Groups	2.338	2	1.169	151.575	.000
	Within Groups	.162	21	.008		
	Total	2.500	23			
SMBC	Between Groups	165254.242	2	82627.121	124.275	.000
	Within Groups	13962.290	21	664.871		
	Total	179216.532	23			

DHA	Between Groups	172.886	2	86.443	55.886	.000
	Within Groups	32.483	21	1.547		
	Total	205.369	23			
PHA	Between Groups	1840.834	2	920.417	18.616	.000
	Within Groups	1038.289	21	49.442		
	Total	2879.123	23			
Glucosidase	Between Groups	3866.246	2	1933.123	62.170	.000
	Within Groups	652.978	21	31.094		
	Total	4519.224	23			
Bacterial popucfu	Between Groups	4000.172	2	2000.086	129.347	.000
	Within Groups	324.721	21	15.463		
	Total	4324.894	23			
Respiration	Between Groups	15553.391	2	7776.696	1134.003	.000
	Within Groups	144.013	21	6.858		
	Total	15697.404	23			
Carbon Stock	Between Groups	751.909	2	375.955	82.739	.000
	Within Groups	95.421	21	4.544		
	Total	847.330	23			

Post Hoc Tests

Multiple Comparisons

Dependent Variable		(I) Land Use	(J) Land Use	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
OC	LSD	Forest	Pineapple	2.852083335*	.43685941	.000	1.94358444	3.76058221
			Paddy	6.116666667*	.43685941	.000	5.20816778	7.02516555
		Pineapple	Forest	-2.852083335*	.43685941	.000	-3.76058221	-1.94358444
			Paddy	3.264583333*	.43685941	.000	2.35608444	4.17308221
		Paddy	Forest	-6.116666667*	.43685941	.000	-7.02516555	-5.20816778
			Pineapple	-3.264583333*	.43685941	.000	-4.17308221	-2.35608444
TC	LSD	Forest	Pineapple	3.432499997*	.61661928	.000	2.15016999	4.71483000
			Paddy	6.517916665*	.61661928	.000	5.23558666	7.80024667
		Pineapple	Forest	-3.432499997*	.61661928	.000	-4.71483000	-2.15016999
			Paddy	3.085416667*	.61661928	.000	1.80308666	4.36774667
		Paddy	Forest	-6.517916665*	.61661928	.000	-7.80024667	-5.23558666
			Pineapple	-3.085416667*	.61661928	.000	-4.36774667	-1.80308666
PoxC	LSD	Forest	Pineapple	105.669583320*	12.85806618	.000	78.92977087	132.40939579
			Paddy	171.123749970*	12.85806618	.000	144.38393754	197.86356245
		Pineapple	Forest	-105.669583320*	12.85806618	.000	-132.40939579	-78.92977087
			Paddy	65.454166650*	12.85806618	.000	38.71435420	92.19397912
		Paddy	Forest	-171.123749970*	12.85806618	.000	-197.86356245	-144.38393754
			Pineapple	-65.454166650*	12.85806618	.000	-92.19397912	-38.71435420
BD	LSD	Forest	Pineapple	-.052083333*	.01077517	.000	-.07449154	-.02967512
			Paddy	-.174166667*	.01077517	.000	-.19657487	-.15175845
		Pineapple	Forest	.052083333*	.01077517	.000	.02967512	.07449154
			Paddy	-.122083334*	.01077517	.000	-.14449154	-.09967512
		Paddy	Forest	.174166667*	.01077517	.000	.15175845	.19657487
			Pineapple	.122083334*	.01077517	.000	.09967512	.14449154
PD	LSD	Forest	Pineapple	-.008333334	.03120353	.792	-.07322464	.05655797
			Paddy	-.222083334*	.03120353	.000	-.28697464	-.15719202
		Pineapple	Forest	.008333334	.03120353	.792	-.05655797	.07322464
			Paddy	-.213750000*	.03120353	.000	-.27864130	-.14885869
		Paddy	Forest	.222083334*	.03120353	.000	.15719202	.28697464

			Pineapple	.213750000*	.03120353	.000	.14885869	.27864130
porosity	LSD	Forest	Pineapple	2.257595321*	.44473655	.000	1.33271513	3.18247571
			Paddy	2.425433059*	.44473655	.000	1.50055367	3.35031425
		Pineapple	Forest	-2.257595321*	.44473655	.000	-3.18247571	-1.33271513
			Paddy	.167838537	.44473655	.710	-.75704175	1.09271883
		Paddy	Forest	-2.425433059*	.44473655	.000	-3.35031425	-1.50055367
			Pineapple	-.167838537	.44473655	.710	-1.09271883	.75704175
WHC	LSD	Forest	Pineapple	3.395410852*	.41498045	.000	2.53241113	4.25840932
			Paddy	3.959807501*	.41498045	.000	3.09680868	4.82280687
		Pineapple	Forest	-3.395410852*	.41498045	.000	-4.25840932	-2.53241113
			Paddy	.564397549	.41498045	.188	-.29860154	1.42739664
		Paddy	Forest	-3.959807501*	.41498045	.000	-4.82280687	-3.09680868
			Pineapple	-.564397549	.41498045	.188	-1.42739664	.29860154
pH	LSD	Forest	Pineapple	.214583333*	.05169833	.000	.10707075	.32209591
			Paddy	-.084583333	.05169833	.117	-.19209591	.02292924
		Pineapple	Forest	-.214583333*	.05169833	.000	-.32209591	-.10707075
			Paddy	-.299166665*	.05169833	.000	-.40667924	-.19165408
		Paddy	Forest	.084583333	.05169833	.117	-.02292924	.19209591
			Pineapple	.299166665*	.05169833	.000	.19165408	.40667924
AvN	LSD	Forest	Pineapple	36.217083335*	4.96178292	.000	25.89849087	46.53567579
			Paddy	62.648750010*	4.96178292	.000	52.33015753	72.96734246
		Pineapple	Forest	-36.217083335*	4.96178292	.000	-46.53567579	-25.89849087
			Paddy	26.431666672*	4.96178292	.000	16.11307420	36.75025912
		Paddy	Forest	-62.648750010*	4.96178292	.000	-72.96734246	-52.33015753
			Pineapple	-26.431666672*	4.96178292	.000	-36.75025912	-16.11307420
AvP2O5	LSD	Forest	Pineapple	9.698333334*	1.52831380	.000	6.52003079	12.87663587
			Paddy	8.395000003*	1.52831380	.000	5.21669746	11.57330253
		Pineapple	Forest	-9.698333334*	1.52831380	.000	-12.87663587	-6.52003079
			Paddy	-1.303333331	1.52831380	.403	-4.481635871	1.87496920
		Paddy	Forest	-8.395000003*	1.52831380	.000	-11.57330253	-5.21669746
			Pineapple	1.303333331	1.52831380	.403	-1.87496920	4.48163587
AvK2O	LSD	Forest	Pineapple	-57.444166690*	5.53166553	.000	-68.94789489	-45.94043843
			Paddy	14.619583324*	5.53166553	.015	3.11585510	26.12331156
		Pineapple	Forest	57.444166690*	5.53166553	.000	45.94043843	68.94789489
			Paddy	72.063750010*	5.53166553	.000	60.56002176	83.56747823
		Paddy	Forest	-14.619583324*	5.53166553	.015	-26.12331156	-3.11585510
			Pineapple	-72.063750010*	5.53166553	.000	-83.56747823	-60.56002176
Av S	LSD	Forest	Pineapple	-4.146979164*	1.71989567	.025	-7.72369803	-.57026030
			Paddy	4.197499998*	1.71989567	.024	.62078113	7.77421886
		Pineapple	Forest	4.146979164*	1.71989567	.025	.57026030	7.72369803
			Paddy	8.344479162*	1.71989567	.000	4.76776030	11.92119803
		Paddy	Forest	-4.197499998*	1.71989567	.024	-7.77421886	-.62078113
			Pineapple	-8.344479162*	1.71989567	.000	-11.92119803	-4.76776030
Ex ca	LSD	Forest	Pineapple	.880416667*	.07200460	.000	.73067489	1.03015844
			Paddy	1.123625000*	.07200460	.000	.97388322	1.27336677
		Pineapple	Forest	-.880416667*	.07200460	.000	-1.03015844	-.73067489
			Paddy	.243208333*	.07200460	.003	.09346655	.39295010
		Paddy	Forest	-1.123625000*	.07200460	.000	-1.27336677	-.97388322
			Pineapple	-.243208333*	.07200460	.003	-.39295010	-.09346655
Ex.Mg	LSD	Forest	Pineapple	.487916667*	.04391305	.000	.39659446	.57923886
			Paddy	.753750000*	.04391305	.000	.66242780	.84507219
		Pineapple	Forest	-.487916667*	.04391305	.000	-.57923886	-.39659446
			Paddy	.265833333*	.04391305	.000	.17451113	.35715553
		Paddy	Forest	-.753750000*	.04391305	.000	-.84507219	-.66242780
			Pineapple	-.265833333*	.04391305	.000	-.35715553	-.17451113

SMBC	LSD	Forest	Pineapple	128.074583300*	12.89254604	.000	101.26306609	154.88610057
			Paddy	200.722499970*	12.89254604	.000	173.91098275	227.53401724
		Pineapple	Forest	-128.074583300*	12.89254604	.000	-154.88610057	-101.26306609
			Paddy	72.647916670*	12.89254604	.000	45.83639942	99.45943390
		Paddy	Forest	-200.722499970*	12.89254604	.000	-227.53401724	-173.91098275
			Pineapple	-72.647916670*	12.89254604	.000	-99.45943390	-45.83639942
DHA	LSD	Forest	Pineapple	1.504166666*	.62184986	.025	.21095907	2.79737425
			Paddy	6.294583333*	.62184986	.000	5.00137574	7.58779092
		Pineapple	Forest	-1.504166666*	.62184986	.025	-2.79737425	-.21095907
			Paddy	4.790416666*	.62184986	.000	3.49720907	6.08362425
		Paddy	Forest	-6.294583333*	.62184986	.000	-7.58779092	-5.00137574
			Pineapple	-4.790416666*	.62184986	.000	-6.08362425	-3.49720907
PHA	LSD	Forest	Pineapple	21.118333340*	3.51576152	.000	13.80690699	28.42975967
			Paddy	13.825416662*	3.51576152	.001	6.513990329	21.13684300
		Pineapple	Forest	-21.118333340*	3.51576152	.000	-28.42975967	-13.80690699
			Paddy	-7.292916677	3.51576152	.051	-14.60434300	.01850967
		Paddy	Forest	-13.825416662*	3.51576152	.001	-21.13684300	-6.51399032
			Pineapple	7.292916677	3.51576152	.051	-.01850967	14.60434300
Glucosid ase	LSD	Forest	Pineapple	11.354166664*	2.78810852	.001	5.55597757	17.15235575
			Paddy	30.741666664*	2.78810852	.000	24.94347757	36.53985575
		Pineapple	Forest	-11.354166664*	2.78810852	.001	-17.15235575	-5.55597757
			Paddy	19.387500000*	2.78810852	.000	13.58931090	25.18568909
		Paddy	Forest	-30.741666664*	2.78810852	.000	-36.53985575	-24.94347757
			Pineapple	-19.387500000*	2.78810852	.000	-25.18568909	-13.58931090
Bacterial popucfu	LSD	Forest	Pineapple	10.583333340*	1.96614633	.000	6.49450819	14.67215847
			Paddy	31.099166672*	1.96614633	.000	27.01034152	35.18799180
		Pineapple	Forest	-10.58333340*	1.96614633	.000	-14.67215847	-6.49450819
			Paddy	20.515833333*	1.96614633	.000	16.42700819	24.60465847
		Paddy	Forest	-31.099166672*	1.96614633	.000	-35.18799180	-27.01034152
			Pineapple	-20.515833333*	1.96614633	.000	-24.60465847	-16.42700819
Respirati on	LSD	Forest	Pineapple	49.817499995*	1.30936426	.000	47.09452793	52.54047206
			Paddy	57.388333320*	1.30936426	.000	54.66536127	60.11130539
		Pineapple	Forest	-49.817499995*	1.30936426	.000	-52.54047206	-47.09452793
			Paddy	7.570833329*	1.30936426	.000	4.84786127	10.29380539
		Paddy	Forest	-57.388333320*	1.30936426	.000	-60.11130539	-54.66536127
			Pineapple	-7.570833329*	1.30936426	.000	-10.29380539	-4.847861272
Carbon Stock	LSD	Forest	Pineapple	6.779843798*	1.06581441	.000	4.563361335	8.99632616
			Paddy	13.710208327*	1.06581441	.000	11.49372591	15.92669074
		Pineapple	Forest	-6.779843798*	1.06581441	.000	-8.996326164	-4.563361335
			Paddy	6.930364329*	1.06581441	.000	4.713882168	9.14684699
		Paddy	Forest	-13.710208327*	1.06581441	.000	-15.92669074	-11.49372591
			Pineapple	-6.930364329*	1.06581441	.000	-9.146846998	-4.71388216

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

OC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	10.670		
	Pineapple	8		13.935	
	Forest	8			16.787
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

TOC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	14.154		
	Pineapple	8		17.239	
	Forest	8			20.672
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PoxC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	262.990		
	Pineapple	8		328.445	
	Forest	8			434.114
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

BD

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Forest	8	1.199		
	Pineapple	8		1.251	
	Paddy	8			1.373
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PD

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Forest	8	2.40833	
	Pineapple	8	2.41666	
	Paddy	8		2.63041
	Sig.		.792	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Porosity

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	47.73954	
	Pineapple	8	47.90738	
	Forest	8		50.16498
	Sig.		.710	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

WHC

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Paddy	8	41.27978	
	Pineapple	8	41.84418	
	Forest	8		45.23959
	Sig.		.188	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

pH

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	4.727	
	Forest	8		4.941
	Paddy	8		5.026
	Sig.		1.000	.117

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvN

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	241.872		
	Pineapple	8		268.304	
	Forest	8			304.521
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvP_2O_5

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	21.219	
	Paddy	8	22.522	
	Forest	8		30.917
	Sig.		.403	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

AvK_2O

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	125.910		
	Forest	8		140.530	
	Pineapple	8			197.974
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Av S

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	23.712		
	Forest	8		27.910	
	Pineapple	8			32.057
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex ca

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	1.277		
	Pineapple	8		1.520	
	Forest	8			2.400
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Ex.Mg

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	.4658		
	Pineapple	8		.7316	
	Forest	8			1.219
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

SMBC

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	130.231		
	Pineapple	8		202.879	
	Forest	8			330.954
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

DHA

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	5.650		
	Pineapple	8		10.441	
	Forest	8			11.945
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

PHA

	Land Use	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Pineapple	8	44.991	
	Paddy	8	52.284	
	Forest	8		66.110
	Sig.		.051	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Glucosidase

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	22.425		
	Pineapple	8		41.812	
	Forest	8			53.167
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Bacterial popucfu

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	7.442		
	Pineapple	8		27.958	
	Forest	8			38.541
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Respiration

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	25.757		
	Pineapple	8		33.328	
	Forest	8			83.145
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Carbon Stock

	Land Use	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Paddy	8	36.612		
	Pineapple	8		43.542	
	Forest	8			50.322
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.000.

Appendix-G: Geo-coordinates of sampling sites

Name of villages	**Land use system/ sites**	**Latitude**	**Longitude**	**Elevation**	**Latitude in decimal degrees**	**Longitude in decimal degrees**
Bungsung	Forest 1	$25^{0}44^{/}15.84^{//}$N	$93^{0}50^{/}19.14^{//}$E	409m	25.73773°N	93.83865°E
	Forest 2	$25^{0}44^{/}15.96^{//}$N	$93^{0}50^{/}18.90^{//}$E	406m	25.73777°N	93.83858° E
	Forest 3	$25^{0}44^{/}16.86^{//}$N	$93^{0}50^{/}19.44^{//}$E	411m	25.73802°N	93.83873° E
	Pineapple 1	$25^{0}44^{/}15.36^{//}$N	$93^{0}50^{/}24.48^{//}$E	401m	25.7376°N	93.84013° E
	Pineapple 2	$25^{0}44^{/}15.06^{//}$N	$93^{0}50^{/}24.06^{//}$E	404m	25.73752° N	93.84002° E
	Pineapple 3	$25^{0}44^{/}14.04^{//}$N	$93^{0}50^{/}25.08^{//}$E	403m	25.73723° N	93.8403° E
	Paddy 1	$25^{0}44^{/}36.96^{//}$N	$93^{0}50^{/}33.43^{//}$E	350m	25.7436° N	93.84262° E
	Paddy 2	$25^{0}44^{/}38.58^{//}$N	$93^{0}50^{/}36.45^{//}$E	352m	25.74405° N	93.84346° E
	Paddy 3	$25^{0}44^{/}36.48^{//}$N	$93^{0}50^{/}36.36^{//}$E	353m	25.74347° N	93.84343° E
Jharnapani	Forest 1	$25^{0}45^{/}27.56^{//}$N	$93^{0}50^{/}40.58^{//}$E	342m	25.75766° N	93.84461° E
	Forest 2	$25^{0}45^{/}23.44^{//}$N	$93^{0}50^{/}47.19^{//}$E	351m	25.75651° N	93.84644° E
	Forest 3	$25^{0}45^{/}20.46^{//}$N	$93^{0}50^{/}49.55^{//}$E	359m	25.75568° N	93.8471° E
	Pineapple 1	$25^{0}45^{/}29.58^{//}$N	$93^{0}50^{/}31.58^{//}$E	320m	25.75822° N	93.84211° E
	Pineapple 2	$25^{0}45^{/}33.41^{//}$N	$93^{0}50^{/}27.45^{//}$E	313m	25.75928° N	93.84096° E
	Pineapple 3	$25^{0}45^{/}39.55^{//}$N	$93^{0}50^{/}34.28^{//}$E	311m	25.76099° N	93.84286° E
	Paddy 1	$25^{0}45^{/}26.11^{//}$N	$93^{0}50^{/}23.28^{//}$E	282m	25.75725° N	93.8398° E
	Paddy 2	$25^{0}45^{/}23.46^{//}$N	$93^{0}50^{/}38.25^{//}$E	289m	25.75652° N	93.84396° E
	Paddy 3	$25^{0}45^{/}22.21^{//}$N	$93^{0}50^{/}33.45^{//}$E	290m	25.75617° N	93.84263° E
Khaibung	Forest 1	$25^{0}44^{/}11.94^{//}$N	$93^{0}50^{/}45.0^{//}$E	397m	25.73665° N	93.84583° E
	Forest 2	$25^{0}44^{/}12.06^{//}$N	$93^{0}50^{/}44.64^{//}$E	401m	25.73668° N	93.84573° E
	Forest 3	$25^{0}44^{/}12.78^{//}$N	$93^{0}50^{/}44.34^{//}$E	398m	25.73688° N	93.84565° E
	Pineapple 1	$25^{0}44^{/}13.86^{//}$N	$93^{0}50^{/}45.78^{//}$E	395m	25.73718° N	93.84605° E
	Pineapple 2	$25^{0}44^{/}12.66^{//}$N	$93^{0}50^{/}45.24^{//}$E	392m	25.73685° N	93.8459° E
	Pineapple 3	$25^{0}44^{/}11.70^{//}$N	$93^{0}50^{/}45.0^{//}$E	396m	25.73658° N	93.84583° E
	Paddy 1	$25^{0}42^{/}18.06^{//}$N	$93^{0}51^{/}0.84^{//}$E	357m	25.70502° N	93.85023° E
	Paddy 2	$25^{0}42^{/}17.76^{//}$N	$93^{0}51^{/}0.78^{//}$E	356m	25.70493° N	93.85022° E
	Paddy 3	$25^{0}42^{/}17.46^{//}$N	$93^{0}51^{/}2.34^{//}$E	354m	25.70485° N	93.85065° E
Kukidolong	Forest 1	$25^{0}45^{/}33.34^{//}$N	$93^{0}50^{/}25.42^{//}$E	379m	25.75926° N	93.84039° E
	Forest 2	$25^{0}45^{/}39.21^{//}$N	$93^{0}50^{/}35.18^{//}$E	372m	25.76089° N	93.84311° E
	Forest 3	$25^{0}45^{/}31.13^{//}$N	$93^{0}50^{/}33.23^{//}$E	381m	25.75865° N	93.84256° E
	Pineapple 1	$25^{0}45^{/}34.54^{//}$N	$93^{0}50^{/}25.22^{//}$E	312m	25.75959° N	93.84034° E

	Pineapple 2	$25^{0}45^{/}33.45^{//}$N	$93^{0}50^{/}24.41^{//}$E	306m	25.75929° N	93.84011° E
	Pineapple 3	$25^{0}45^{/}44.14^{//}$N	$93^{0}50^{/}29.20^{//}$E	319m	25.76226° N	93.84144° E
	Paddy 1	$25^{0}45^{/}36.58^{//}$N	$93^{0}49^{/}59.24^{//}$E	264m	25.76016° N	93.83312° E
	Paddy 2	$25^{0}45^{/}34.22^{//}$N	$93^{0}49^{/}57.29^{//}$E	260m	25.75951° N	93.83258° E
	Paddy 3	$25^{0}45^{/}31.33^{//}$N	$93^{0}49^{/}55.43^{//}$E	268m	25.7587° N	93.83206° E
Kupuhe	Forest 1	$25^{0}45^{/}19.21^{//}$N	$93^{0}49^{/}57.12^{//}$E	352m	25.75534° N	93.83253° E
	Forest 2	$25^{0}45^{/}21.44^{//}$N	$93^{0}49^{/}49.32^{//}$E	368m	25.75596° N	93.83037° E
	Forest 3	$25^{0}45^{/}25.11^{//}$N	$93^{0}49^{/}47.10^{//}$E	363m	25.75698° N	93.82975° E
	Pineapple 1	$25^{0}45^{/}18.17^{//}$N	$93^{0}49^{/}55.11^{//}$E	285m	25.75505° N	93.83198° E
	Pineapple 2	$25^{0}45^{/}16.06^{//}$N	$93^{0}49^{/}58.48^{//}$E	297m	25.75446° N	93.83291° E
	Pineapple 3	$25^{0}45^{/}22.36^{//}$N	$93^{0}49^{/}48.27^{//}$E	288m	25.75621° N	93.83008° E
	Paddy 1	$25^{0}45^{/}40.60^{//}$N	$93^{0}49^{/}29.30^{//}$E	253m	25.76128° N	93.82481° E
	Paddy 2	$25^{0}45^{/}51.20^{//}$N	$93^{0}49^{/}29.06^{//}$E	250m	25.76422° N	93.82474° E
	Paddy 3	$25^{0}45^{/}41.29^{//}$N	$93^{0}49^{/}25.19^{//}$E	255m	25.76147° N	93.82366° E
Maova	Forest 1	$25^{0}44^{/}11.94^{//}$N	$93^{0}50^{/}$ $55.0^{//}$E	404m	25.73665° N	93.84861° E
	Forest 2	$25^{0}44^{/}11.26^{//}$N	$93^{0}50^{/}$ $54.44^{//}$E	410m	25.73646° N	93.84846° E
	Forest 3	$25^{0}44^{/}12.68^{//}$N	$93^{0}50^{/}$ $44.30^{//}$E	411m	25.73686° N	93.84564° E
	Pineapple 1	$25^{0}44^{/}19.66^{//}$N	$93^{0}50^{/}$ $35.56^{//}$E	395m	25.73879° N	93.84321° E
	Pineapple 2	$25^{0}44^{/}12.56^{//}$N	$93^{0}50^{/}$ $41.22^{//}$E	394m	25.73682° N	93.84478° E
	Pineapple 3	$25^{0}44^{/}13.71^{//}$N	$93^{0}50^{/}$ $35.0^{//}$E	399m	25.73714° N	93.84306° E
	Paddy 1	$25^{0}41^{/}36.96^{//}$N	$93^{0}51^{/}$ $35.34^{//}$E	355m	25.6936° N	93.85982° E
	Paddy 2	$25^{0}41^{/}38.58^{//}$N	$93^{0}51^{/}$ $36.60^{//}$E	356m	25.69405° N	93.86017° E
	Paddy 3	$25^{0}41^{/}36.48^{//}$N	$93^{0}51^{/}$ $36.36^{//}$E	353m	25.69347° N	93.8601° E
Medziphema	Forest 1	$25^{0}45^{/}48.58^{//}$N	$93^{0}52^{/}45.16^{//}$E	416m	25.76349° N	93.87921° E
	Forest 2	$25^{0}45^{/}56.12^{//}$N	$93^{0}52^{/}39.24^{//}$E	433m	25.76559° N	93.87757° E
	Forest 3	$25^{0}45^{/}50.22^{//}$N	$93^{0}52^{/}49.42^{//}$E	426m	25.76395° N	93.88039° E
	Pineapple 1	$25^{0}45^{/}48.55^{//}$N	$93^{0}52^{/}44.13^{//}$E	403m	25.76349° N	93.87893° E
	Pineapple 2	$25^{0}45^{/}46.37^{//}$N	$93^{0}52^{/}41.55^{//}$E	409m	25.76288° N	93.87821° E
	Pineapple 3	$25^{0}45^{/}52.35^{//}$N	$93^{0}52^{/}39.11^{//}$E	416m	25.76454° N	93.87753° E
	Paddy 1	$25^{0}45^{/}42.36^{//}$N	$93^{0}52^{/}39.47^{//}$E	354m	25.76177° N	93.87763° E
	Paddy 2	$25^{0}45^{/}40.49^{//}$N	$93^{0}52^{/}38.52^{//}$E	359m	25.76125° N	93.87737° E
	Paddy 3	$25^{0}45^{/}49.23^{//}$N	$93^{0}52^{/}33.32^{//}$E	350m	25.76368° N	93.87592° E
Molvom	Forest 1	$25^{0}44^{/}16.14^{//}$N	$93^{0}50^{/}$ $18.60^{//}$E	412m	25.73782° N	93.8385° E
	Forest 2	$25^{0}44^{/}16.32^{//}$N	$93^{0}50^{/}$ $18.72^{//}$E	402m	25.73787° N	93.83853° E
	Forest 3	$25^{0}44^{/}16.80^{//}$N	$93^{0}50^{/}$ $19.74^{//}$E	401m	25.7380° N	93.83882° E

	Pineapple 1	25^{0}44$^{/}$16.20$^{//}$N	93^{0}50$^{/}$ 24.42$^{//}$E	402m	25.73783° N	93.84012° E
	Pineapple 2	25^{0}44$^{/}$17.16$^{//}$N	93^{0}50$^{/}$ 24.66$^{//}$E	401m	25.7381° N	93.84018° E
	Pineapple 3	25^{0}44$^{/}$17.40$^{//}$N	93^{0}50$^{/}$ 23.04$^{//}$E	409m	25.73817° N	93.83973° E
	Paddy 1	25^{0}44$^{/}$22.36$^{//}$N	93^{0}50$^{/}$29.44$^{//}$E	351m	25.73954° N	93.84151° E
	Paddy 2	25^{0}44$^{/}$20.29$^{//}$N	93^{0}50$^{/}$28.52$^{//}$E	349m	25.73897° N	93.84126° E
	Paddy 3	25^{0}44$^{/}$29.32$^{//}$N	93^{0}50$^{/}$33.31$^{//}$E	353m	25.74148° N	93.84259° E