IMPACT OF AGRICULTURAL LAND USE SYSTEMS ON SOIL CARBON POOLS IN SOIL SERIES OF THIRUVANANTHAPURAM DISTRICT

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by

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(2014-11-243)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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EXTERNAL EXAMINER

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LIST OF ABBREVIATIONS

Pg	Petagrams
Gt	Gigatons
C	Carbon
CO_2	Carbon dioxide
SOC	Soil organic carbon
SIC	Soil inorganic carbon
AAOC	Aggregate associated organic carbon
HWSC	Hot water soluble carbon
LC	Labile carbon
POC	Particulate organic carbon
MC	Minaralizable carbon
DOC	Dissolved organic carbon
SOM	Soil organic matter
BD	Bulk density
WSA	Water stable aggregate
EC	Electrical conductivity
CEC	Cation exchange capacity
MBC	Microbial biomass carbon
mg kg^{-1}	Milligram per kilogram
%	Per cent
µg	Microgram
^{0}C	Degrees Celsius
CD	Critical difference
et al.	And others

g	Gram
hr.	Hour
kg^{-1}	Per kilogram
m	Metre
ml	Millilitre
Fig	Figure
$Mg\ m^{-3}$	Mega gram per meter cube
viz.	Namely

INTRODUCTION

1. INTRODUCTION

Soils are a major reservoir of carbon as an important sink. Atmospheric carbon is withheld for long period of time in the soil and it is often referred to as being sequestered. Carbon sequestration is an option to reduce the enrichment of atmospheric carbon dioxide concentration. Soil organic carbon (SOC) storage has been widely considered as a measure for mitigating global climate change through carbon sequestration in soil. There are many land uses and management practices that can lead to carbon sequestration in the soil.

Globally, the soil carbon pool is estimated at 2,500 Gt up to a 2-m depth (Anon, 2012). Out of this, the soil organic carbon pool comprises 1,550 Gt, while the soil inorganic carbon and elemental pools make up the remaining 950 Gt (Batjes, 1996). The soil carbon pool is more than 3 times the size of the atmospheric pool (760 Gt) and about 4.5 times the size of the biotic pool (560 Gt). The first estimation of organic carbon stock in Indian soils was 24.3 Pg based on 48 soil series taking into account of a few major soils. The present OC stock has been estimated as 63 Pg in the first 150 cm depth of soils (Bhattacharyya *et al.,* 2000). The SOC concentration in most cultivated soils is less than 5 g kg^{-1} compared with 15 to 20 g kg^{-1} in uncultivated soils (Lal, 2004). The build-up of each ton of soil organic matter removes 3.667 tons of CO_2 from the atmosphere (Bowen and Rovira, 1999).

Soil organic carbon is made up of a number of different pools that vary in their chemical composition and stage of decomposition. Land use and management can influence the proportion of different carbon pools present in a soil. SOC is divided in to four major pools: plant residues, particulate organic carbon, humus carbon and recalcitrant organic carbon. Several carbon fractions have been used as indicators of changes in SOC. Plant residues and particulate organic carbon are often referred to as ‘labile carbon’ because they cycle in the soil relatively quickly and available to plants and soil microorganism (Bell and Lawrence, 2009).

The labile C as a fraction of total carbon pool have greater effect on soil physical stability and more sensitive indicator than total C values of carbon dynamics in agricultural systems. On the other hand, the resistant or stable fraction of soil organic matter contributes mainly to nutrient holding capacity and soil colour. This fraction of organic matter decomposes very slowly and has less influence on soil fertility than the labile organic carbon fraction. Labile fraction of SOC can respond rapidly to changes in C supply and have therefore been suggested as early indicators of the land use effect on soil quality.

The SOC fractions, *viz.*, labile, hot water soluble and aggregate-associated carbon have been proposed as sensitive indicators of change in land use and management practices.

The study of inter-relationship of land use and land use changes with SOC dynamics is quite important in recommending sound land management practices to mitigate the impact of the climate change at the local and regional level. The interrelationship can be utilized to predict future scenarios of the carbon dynamics. However there is a scarcity of studies addressing long term land use change dynamics and its effect on soil C pool in ecosystem level.

Soil organic matter plays an important role in maintaining soil quality and ecosystem functionality. Land use and agricultural management practices influence the storage of soil organic carbon due to differences in cropping practices, tillage, irrigation, fertilization etc. Changing pattern of land use and land use management practices can have significant direct and indirect effects on soil organic pools, due to changes in plant species, primary productivity, litter quantity and quality. Management practices or technologies that increase carbon input to the soil and reduce carbon loss or both, lead to net carbon sequestration in soil. Depending on the land use system, soil can be a net sink or source of carbon dioxide. Suitable land use system can help in sequestering carbon in soil and reduce the green house effect. Estimating soil carbon pools will help to identify the carbon fractions which are dominant in different land uses and help to prioritize land use system for carbon sequestration in soil which has co-benefits of restoring soil fertility, improving crop productivity, reducing erosion and loss of nutrients.

Hence the present study on "Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district" was carried out with the following objectives.

1. To study the soil aggregation and organic carbon storage in different sized aggregates under various land use systems in soil series of Thiruvananthapuram district.
2. To study the influence of agricultural land uses on soil carbon pools and soil properties of major soil series of Thiruvananthapuram district.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The soil organic carbon (SOC) has been recognized as a key component of soil quality as is closely associated with a wide range of physical, chemical and biological properties of soil and also plays a critical role in soil processes and functioning. SOC maintenance in cropland is a major determinant of the productivity and long-term stability of agricultural systems. SOC storage (C sequestration in soils) has been widely considered as a promising measure for mitigating global climate change. Different SOC fraction, *viz.,* labile carbon, particulate organic carbon, hot water soluble carbon, aggregate associated carbon rather than total SOC, respond very rapidly to land use change and thus could be used as an important indicator of critical soil function. The research information pertaining to the fractionation of carbon pools with particular reference to soils under different land use systems are reviewed in this chapter.

2.1. SOIL CARBON POOLS AND DYNAMICS

SOC is considered as the largest global terrestrial carbon pool (Schlesinger, 2000) which can stock about 1500-2000 Pg of carbon in various organic forms to a depth of l m. Various land uses have different potential for carbon sequestration (Blanco *et al.,* 2007). The land use controls the carbon footprint in terrestrial systems (Smith, 2004).

The soil carbon (C) pool consists of organic and inorganic components. The soil organic C (SOC) pool is derived from the remains of C in plants and animals. The soil inorganic carbon (SIC) pool is derived from the parent material as primary carbonates of minerals such as calcite, dolomite and gypsum and from sequestration of atmospheric CO_2 as secondary carbonates. Soil organic carbon pool is estimated at 1550 Pg and soil inorganic C pool (SIC) estimated at 950 Pg (Batjes, 1996).

The SOC pool is more reactive, highly dynamic and a strong determinant of soil quality. Total organic carbon pool in soils of India is estimated at 9.55 Gt at 0.3 m depth and 30 Gt at 1.5 m depth (Bhattacharyya *et al*., 2009).

Depending on land use systems, soil can be a net sink or source of carbon dioxide. It is estimated that about 40-80 Pg of carbon can be sequestered in soils over next 50-100 years through sustainable land management (Bell, 2009). Different land uses have different potentials for carbon sequestration due to differential SOC and aggregation dynamics (Six *et al.,* 1998).

Grasslands are able to sequester about double the quantity of C in the soil in comparison to arable land (Cambardella and Elliot, 1992).

Sreekanth *et al.* (2013) reported that apart from native grassland sites, the conventional cropping site of cardamom is also found to offer innate capacity to store soil carbon at a considerable rate. An understanding of the effect of land use conversion and disturbance intensity in soil carbon storage is therefore needed in the sustainable management of grasslands.

The SOC fractions like labile, hot water soluble and aggregate-associated carbon have been proposed as sensitive indicator of change in land use and management practices (Cambardella and Elliott, 1992). The SOC fraction like hot water soluble carbon, dissolved organic carbon and particulate organic C are considered as more sensitive indicators of management induced changes than total SOC (Tan *et al.,* 2007). Labile fraction of SOC can respond rapidly to changes in C supply and such components have therefore been suggested as early indicators of the land use effect on soil quality (Jinob *et al.,* 2006).

Soil organic carbon (SOC) plays an important role in enhancing crop production (Stevenson and Cole, 1999) and mitigating greenhouse gas emissions

(Lal *et al.,* 1995).

Land use of agricultural systems is known to change the storage of soil organic carbon through variation in land use, cropping practices (intensity and types of crops), and other activities (Paustian *et al.,* 1997). Most changes in land use affect the amount of carbon held in vegetation and soil, thereby, either it releases carbon dioxide (a greenhouse gas) to, or removing it from the atmosphere (Houghton and Goodale, 2004).

Agroforestry systems sequester more carbon as compared to sole agricultural land use systems (Yadava *et al.,* 2010).

Changes in land use (plant species diversity and function) increased CO_2 levels, have the potential to modify the composition and turnover of soil C pools in the long term. Microbial communities from different environments will also affect the C balance in soil (Steenwerth 2003).

The microbial biomass is an essential component of organic matter turnover (Jenkinson, 1990). Microbial biomass decreased in agricultural soils due to lower organic matter addition (Doran, 2002). Soil microbial biomass C and potentially mineralizable C were considered as active fractions of SOC. These active fractions were important for supplying plant nutrients, residue decomposing and developing soil structure (Franzluebbers *et al.,* 2000). Systems with high organic matter inputs and available soil organic matter tend to have higher microbial biomass contents because they are preferred energy sources for microorganisms (Landgraf and Kosle, 2002).

The amount of C in the soil microbial biomass mostly accounts for 1-3% of the total soil organic C, and its turnover time is less than one year. Soil microbial biomass C comprises only 1 to 4% of organic carbon due to its fast turnover time (Li and Chen, 2004).

Srivastava and Singh (1991) found that microbial biomass C was highest in forest, compared to other vegetation types, and ranged from 250 μ g^{-1} in crop land soil to 609 μ g^{-1} in forest soil. Tree based systems can sequester substantial quantities of carbon in to biomass in a short period (Lal, 2004).

According to Chacko *et al.* (2014) soil carbon storage capacity indicates the C sequestration potential of the soils and maximum SOC sequestration was found under abandoned paddy cultivation followed by coconut plantation. The higher magnitudes of POC a subset of SOC was noted in the Coconut plantation site than that of abandoned and cultivated paddy sites. In paddy soil the organic amendments and rice residues (rice stubble and root) are the main C sources converted to soil C (Shao-xian *et al.,* 2012).

The greater soil organic C in agroforestry and fallow field may partly be attributed to enhanced C inputs to the soil because a large proportion of above and below-ground biomass from vegetation is annually added to the soil. (Wang *et al*., 2011).

Oyedele *et al*. (2010) observed that soil organic carbon were significantly higher under forest and tree crops in comparison to pasture, no tilled and tilled plots. Durodoluwa *et al.* (2005) noticed that soil organic carbon were significantly higher under tree crops in comparison to pasture, no tilled and tilled plots.

The sizes of soil labile and non-labile C pools and their contributions to the total soil C pool differed significantly among land use categories (Stecio *et al.,* 2007).

Shifts in plant community composition may affect SOC dynamics as a result of changes in the amount and chemical composition of plant residues returned to the soil which in turn influences the pool size and activity of the soil microbial biomass (Kasel and Bennett, 2007).

Ghani *et al.,* (1999) stated that the water soluble fraction is a sensitive indicator of labile organic matter. Water soluble organic carbon is considered as almost mobile and reactive soil carbon source which modulates a number of physical, chemical and biological processes in both aquatic and terrestrial environment. Shreshta *et al.* (2004) observed a large difference in $KMnO_4$ oxidizable organic carbon due to the effect of cultivation length and cropping system.

2.2 INFLUENCE OF AGRICULTURAL LAND USE ON SOIL PROPERTIES

Soil organic carbon has a great contribution to chemical, physical and biological properties of soil because it is a source of energy for the microbial biomass, participates in nutrient storage and cycling, plant available water, aggregate formation and stability, density and soil resilience, as well as influencing cation exchange capacity (Reeves, 1997).

2.2.1. Soil texture

Agoume and Birang (2009) reported that continuous cropping and intensive land use significantly affected clay content under ravenous land. The change in particle size distribution is attributed to extensive erosion which leads to translocation of clay from one place to another (Hillel, 1998).

The amount of clay content and the type of clay determines the aggregation. Increasing clay concentration is associated with increased SOC stabilization (Sollins *et al.,* 1996).

In any give environment, the amount of SOC increases as soil texture becomes finer (Tisdall and Oades, 1982). This is due to the ability of silt and clay sized particles to interact with organic matter to form micro and macro aggregates which protect SOC from biological mineralization.

The organic carbon contents in several particle size fractions from the surface horizons of two chernozemic soils showed that large proportion of organic carbon was associated with clay fraction and least for sand (Anderson and Domsch 1981). Clay particles and aggregates can reduce losses of organic carbon by physically protecting organic matter from decomposition. Particles of organic matter can become adsorbed to clay surfaces, coated with clay particles or buried inside small pores or aggregates (Kay and Angers, 1999). All these processes make it difficult for microorganisms to come in contact with organic matter. And therefore, the amount of soil organic carbon stored in soil tends to increase with increasing clay content.

2.2.2 Soil bulk density

Soil bulk density has been found to be negatively correlated to SOC (Shrestha et al. 2004). Bhattacharyya *et al*. (2007) reported that in black soils the bulk density decreases as the SOC content increases in first 30 cm depth of soil. Ahukaemere and Akpan (2012) reported an increased bulk density in cultivated soils and forest cover compared to other land uses and also reported that low soil organic matter was responsible for higher bulk density.

Gajri and Majumdar (2002) observed low bulk density in forest system due to no disturbance to soil which might have contributed to retention of organic matter. The organic matter content have favorable influence on both bulk density and maximum water holding capacity of soil due to enhancement of aggregation of soil particles (Ladd, 1996). High soil bulk density caused by soil compaction could lead to low aeration and root growth with subsequent low carbon accumulation (Smith and Doran, 1996).

2.2.3 Soil pH

Carboxylic, phenolic and hydroxyl groups of organic matter increases H^+ ion concentration in soil solution, there by soil acidity increases (Rao, 1992).

The difference in soil pH among soils under different land use systems may be attributed to variation in rain fall, impact of parent material (granite & gneiss), topographic position, management practices and leaching of basic cation due to heavy rainfall (3000 mm) and high organic matter content. (Haynes and Naidu, 1998).

Large aggregates are formed in soils of high pH and high carbonate concentration (Boix- Fayos *et al.,* 2001).

2.2.4. Soil EC

Addition of various salts through continuous and excess application of fertilizer in the agricultural land increases EC of soil. (Nagaraj *et al.,* 2002). Movement of salts from higher region to paddy system existing in vallies results higher electrical conductivity (Rao, 1992).

Ananthkumar (2011) observed higher soil EC under mixed shade coffee compared to mono shade coffee due to decrease in the leaching loss of salts under lesser impact of rain drops on the surface of soil.

2.2.5 Water stable aggregates in soil

Land use system is one of the key factors influencing soil aggregates stability. This was attributed to positive impact of the vegetation on soil health due to addition of organic matter through leaf litter (Mohanty *et al*., 2012).

Forests improve soil aggregation in deeper layers by transferring organic C into deeper soil horizons by their root system compared to the grasslands having different root architecture which remain confined to the surface layer only (Blanco-Canqui and Lal, 2004). Homestead regions and teak plantation showed high proportion of microaggregates due to the disturbance-induced increase in macro-aggregate turnover as reported by Debasish *et al*. (2010). Perennial grasses are generally associated with high microbial biomass and carbohydrate production which stimulates micro-aggregation (Gale *et al*., 2000).

Soil aggregation is a process which is controlled by SOC and POC dynamics. (Bouajila and Tahar, 2010). Water stable aggregates and mean aggregate size are related with biochemical composition of plant residues like phenols, lignin, proteins, monosaccharide sugars, saccharides and phenols in the soil and phenolic acids such as vanillic acid in the residue (Martens, 2000). Water stable aggregates were significantly larger in the forest and pasture soils than in the cultivated soils (Six *et al.,* 2000). A close inter-relation exists between SOC concentration and aggregation Aggregate stability is significantly correlated with SOC due to the binding action of humic substances and other microbial by-products (Shepherd *et al.,* 2001).

Soils under native vegetation and forest were better structured than those under arable cropping. Perturbation of soil during cropping may have destroyed soil aggregates and adversely affected the structure of soils under arable cropping system. (Beare *et al.,* 1994).

Haghighi *et al.* (2010) observed a significant impact of land use on water stable aggregates. The quality of the structure, and of the soil itself, depends on the influence of many factors participating in aggregation, as for instance, of organic matter content, clay, iron and aluminum oxides and plant root activity.

Li and Mathew (2010) observed a good recovery of WSA and percentage of soil aggregation at the depth of 0 – 30 cm. According to Jinbo *et al. (*2007) agricultural land improved soil physical properties by increasing water stable aggregates.

2.2.6 Cation exchange capacity

Jyothi *et al*. (2009) reported that low organic carbon content of soil and the dominance of low activity clay are the reasons for low CEC under different land use systems. The CEC is often related to stable aggregates (Dimoyiannis et al., 1998). Aggregation is stimulated by the interaction of polycationic bridging in which the repulsive forces between negatively charged clay and or SOC are reduced (Tisdall, 1996).

Papini (2011) observed that the correlation coefficient of CEC is closely related to SOC content and in particular all SOC pools were positively related to CEC of soil. Correlation of SOC fractions to CEC suggest that soil organic matter contributed to increased soil CEC under Mediterranean bush in comparison with crop lands.

2.3. INFLUENCE OF AGRICULTURAL LAND USE ON SOIL CARBON POOLS

2.3.1. Soil organic carbon

Soil organic C (SOC) plays a crucial role in sustaining soil quality, crop production and environmental quality (Baver and Black, 1994) due to their effect on soil physical, chemical, and biological properties (Sainju and Kalisz, 1990). The type of land use system is an important factor that controls soil organic matter levels since it affects the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization in soils (Romkens, 1999). Changes of land use and management practices influence the amount and rate of SOC losses (Guggenberger *et al*., 1994).

2.3.2 Aggregate associated organic carbon

Aggregates greater than 250 µm in diameter are referred to as macroaggregates, while microaggregates are less than 250 µm in diameter (Elliott, 1986). Macroaggregates generally have higher levels of organic matter than microaggregates. Macroaggregate associated organic matter is more labile than that found in microaggregates (Bronick and Lal, 2005). Macroaggregates are enriched with C when compared to whole soil and this C was in the form of relatively labile plant fragments (Cambardella and Elliot, 1993).

Gupta *et al.* (2009) assessed SOC pool and aggregation under poplar-based agroforestry systems, and observed that the SOC pool to increase by 2.9-4.8 Mg ha^{-1} over 6 year period compared with the sole crop system. However, the increase in SOC pool may primarily occur in the labile C pool (Benbi *et al.* 2012).

In microaggregates interaction between clay and SOM renders the protection of organic substances from decomposition (Tisdall and Oades, 1982). The soil organic matter that binds micro-aggregates to form macro aggregates is a labile fraction and is highly sensitive to land use change and cultivation (Ashagrie *et al.,* 2005). Sodhi *et al.* (2009) also reported that macro-aggregates having higher carbon concentration than micro-aggregates.

The carbon associated with micro-aggregates is more strongly attracted by the soil particles (clay and silt). (Shrestha *et al.,* 2004).

2.3.3. Hot water soluble carbon

Hot water-soluble organic carbon (HWSOC) is the direct organic substrate for soil microorganisms (McGill *et al.,* 1981). WSOC is the most labile and mobile form of C. Concentrations of water-soluble and bio-available SOC have been reported to be high in agricultural soils (Boyer and Groffiman, 1996).

Agricultural soils might support greater rate of microbial activity than forest soils due to increased production of water soluble carbon. (Saviozzi *et al.,* 1994).

The HWSOC being a subset of SOC pool, relatively labile in nature (Ghani *et al.* 1999) were found to be a sensitive indicator of subtle change in land use and land management practices.

2.3.4. Particulate organic carbon

Particulate organic carbon (POC) is biologically available and a source of C and energy for soil microorganisms (Gregorich and Janzen, 1996). POC is an active fraction of SOC responds to soil management practice immediately (Bayer *et al.,* 2001). POC is considered as an intermediate fraction of SOC between active and slow fractions that change rapidly over time due to changes in land uses. Carbon present in particulate organic matter can accumulate rapidly under minimum soil disturbance and may even provide an early indicator of changes in SOC under different management practices (Cambardella and Elliott, 1992).

Greater inputs of labile C from root exudates accounted for the higher POC and MBC in agroforest and fallow field relative to grain cropping, where living roots were present and active for 3-6 months (Huang *et al.,* 2010).

The POC has been reported as an early indicator that is more sensitive to changes in soil organic carbon due to agricultural management (Carter, 2002). POC is an active fraction easily available for microbial biomass (Cambardella and Elliot, 1992).

2.3.5. Labile carbon

Light fraction organic carbon is characterized by the rapid mineralization due to the labile nature of its constituents and to the lack of protection by soil colloids (Turchenek and Oades 1979). Labile C fractions *i.e*., particulate organic carbon, hot-water extractable carbon, and permanganate oxidizable carbon respond more quickly to changes in management practices than SOC and are thus used as early and sensitive indicators of SOC changes (Haynes *et al.,* 2000). Changes in carbon stocks following land use change can be more pronounced in labile fractions (Turchenek and Oades, 1979).

2.3.6. Mineralizable carbon

Total carbon mineralized during 114 days of incubation in pine plantation soil ranged from 228 to 330 mg and 282 to 427 mg CO_2 C /g C under 20^0C and 25^0C, respectively (Zhang *et al.,* 2006).

Cote *et al*. (2000) studied C mineralization of forest topsoil by incubation at constant temperature 21°C for 282 d, and found that the C mineralization of the mineral topsoil ranged from 0.12 to 0.45 mg C/(g OC d). Reichstein *et al*. (2000) reported C mineralization of forest soils ranging from 0.6 mg C/(g OC d) at the beginning to 0.2 mg C/g OC d) at the end of incubation.

Leirs *et al*. (1999) reported C mineralization of Ah and OA horizons of acid forest soils by incubation for 10 days from 0.08 to 4.5 mg C/ g OC d, depending on the interaction of moisture and temperature conditions.

MATERIALS AND METHODS

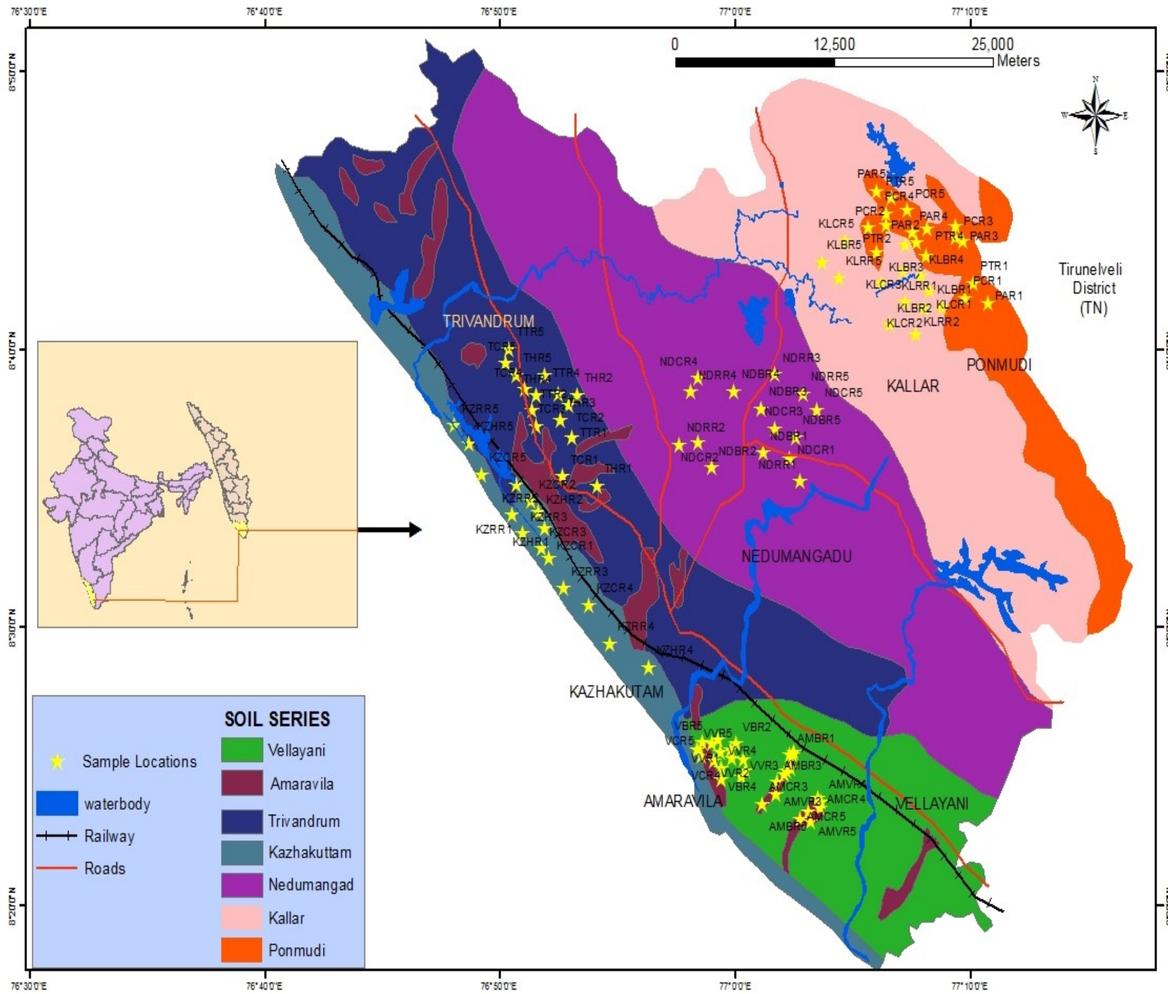
3. MATERIALS AND METHODS

Soil carbon is the largest terrestrial carbon pool, which plays a key role in the carbon cycle and thus it is important in global climate change. Measuring the quantity and the spatial distribution of carbon is essential for evaluating soil function and for understanding soil carbon sequestration process. Changes in carbon pools due to land use are important from the view point of soil fertility and influence on atmosphere CO_2 concentration and global warming. The methodology adopted for the present investigation on "Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district" is given in this chapter.

3.1 SELECTION OF STUDY AREA

To achieve the objective of the study on "Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district" seven soil series, *viz.,* Vellayani, Amaravila, Trivandrum, Kazhakuttam, Nedumangadu, Kallar, and Ponmudi from Thiruvanthapuram district of Kerala were selected, which is located between 8º 11' – 8º 52' N latitude and 76º 40' - 77º 17' E longitude. The elevation of the study area ranged from 4 to 1161 m above mean sea level. The annual average rainfall is 1529.6 mm. The annual average temperature is 27.65º C.

THIRUVANANTHAPURAM DISTRICT



Fig, 1. Sampling site

3.2 SELECTION OF AGRICULTURAL LND USE SYSTEM

Three agricultural land use systems were identified for each selected soil series in Thiruvanthapuram district as given below.

Sl. No.	Soil series	Agricultural land use systems
1.	Vellayani	Coconut based Banana based Vegetable based
2.	Amaravila	Coconut based Banana based Vegetable based
3.	Trivandrum	Coconut based Tapioca based Homestead based
4.	Kazhakuttam	Coconut based Rice based Homestead based
5.	Nedumangadu	Coconut based Rubber based Banana based
6.	Kallar	Coconut based Rubber based Banana based
7.	Ponmudi	Coconut based Tea based Arecanut based

Five spots were identified from each agriculture land use system under each soil series and surface soil sample were taken with the help of a spade at 0 – 15 cm. The 5 spots selected were considered as replications for each land use system.

3.3 SOIL SAMPLE COLLECTION

In order to study the soil carbon storage at different soil carbon pools and their distribution as different size aggregates under different agricultural land use, seven soil series, *viz.,* Vellayani, Amaravila, Trivandrum, Kazhakuttam, Nedumangadu, Kallar, and Ponmudi from Thiruvananthapuram district were selected. In each soil series three agricultural land use systems were identified. In each of the selected land use systems of each soil series the soil samples were collected from surface depth (0-15 cm) in different locations selected randomly and pooled to get one composite sample. Soil core samples were also collected for the analysis of bulk density. The air dried soil samples were passed through a set of 5 and 8 mm sieves and the soil fraction retained on the 8 mm was used for analysis of aggregates size distribution. The soil fraction that passed through 2 mm size sieve was used for determing soil properties and carbon pools. The samples were air dried, ground stored and used for characterizing carbon fractions and other physico-chemical properties of soil.

3.4 SOIL ANALYSIS

3.4.1 Soil texture

Soil texture was determined by Bouyoucos hydrometer method (Bouyoucos, 1962).

3.4.2 Bulk density

For the determination of bulk density soil sample was collected by soil core sampler from field. Soil mass was determined by subtracting amount of moisture from fresh weight, and volume was calculated from core dimension. Bulk density was determined by dividing the soil mass by the volume and expressed as Mg m^{-3} (Black, 1965).

3.4.3 Water stable aggregate size distribution

Aggregate size distribution was determined by wet sieving method as described by Yoder (1936).

3.4.4 Soil pH

The soil pH was determined in 1:2.5 soil-water suspensions using digital pH meter (Jackson, 1967).

3.6.2 Soil electrical conductivity

The electrical conductivity of soil was measured in 1:2.5 soil water suspension using a conductivity bridge and results were expressed in terms of dSm^{-1} at 25^0 C (Jackson, 1973).

3.4.6 Cation exchange capacity of soil

CEC was determined by using 1N ammonium acetate method by Jackson (1967).

3.5 SOIL CARBON POOLS

3.5.1 Soil organic carbon

Soil organic carbon was determined by Walkley and Black's (1934) rapid titration method.

3.5.2 Aggregate associated organic carbon

Oven dried (50^0 C) soil aggregates of different size fractions were ground with a wooden pestle and mortar to <0.25 mm size and aggregate associated C was determined by Walkley and Black's (1934) rapid titration method.

3.5.3 Hot water soluble carbon

Ten g soil sample was taken in a centrifuge tube and 20 ml distilled water was added, heated, shaken it for 1 hour, centrifuged for 20 minutes at 9000-10000 rpm and filtered the aliquot in a beaker. Ten ml of aliquot was taken in 250 ml conical flask and 2 ml 0.2 N $K_2Cr_2O_7$ was added and then 10 ml of con. H_2SO_4 and 5ml ortho-phosphoric acid were added and kept the conical flask on water bath at 100^0C for 30 minutes and titrated the contents in flask with 0.01 N FAS. A blank was also done simultaneously (McGill *et al.,* 1986).

3.5.4 Labile carbon

Three g of air dried soil (<2 mm) sample was taken in a 50 ml centrifuge tube and to that 30 ml of 20 mM $KMnO_4$ was added. A blank was done without taking soil. The content was shaken for 15 minutes and centrifuged for 5 minutes at 2000 rpm and transferred 2 ml aliquot of supernatant solution into 50 ml volumetric flask and read the absorbance at 560-565 nm and determined the concentration of $KMnO_4$ from standard calibration curve and calculated the labile carbon (Blair *et al*., 1995).

3.5.5 Particulate organic carbon

Particulate organic carbon (POC) was determined by the method as described by Camberdella and Elliott (1992) and Hassink (1995). Fifty gram soil sample was dispersed in 150 ml of 0.5 per cent sodium hexametaphosphate solution by shaking for 15 h on a reciprocal shaker. The dispersed soil sample was passed through 250 and 53 µm sieves. After rinsing several times with water, the material that was retained on the sieves was collected and very fine fraction which was collected in beakers were dried at 50°C overnight. The POC fraction of >250 µm size (coarse fraction) was separated from sand by sieving. The coarse fraction (250µm), fine fraction (53-250 µm) and very fine fraction (<53 µm) POC were ground and analysed for total carbon by Walkley and Black's (1934) rapid titration method.

3.5.6 Mineralizable carbon

Mineralizable carbon was determined by CO_2 evoluation method in aerobic condition (Ladd, 1996). The CO_2 measurement was made on 1^{st}, 5^{th}, 10^{th} day and 15^{th} of incubation.

3.6. STATISTICAL ANALYSIS

All the data generated were analyzed statistically for analysis of variance for completely randomized design (CRD) by standard procedures using statistical analysis software (SAS) package.

RESULTS

4. RESULTS

The results of the investigation on "Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district" are presented in this chapter under the following headings:

- Effect of agricultural land use systems on soil properties
  - Soil texture
  - Soil bulk density
  - Soil pH
  - Soil electrical conductivity
  - Cation exchange capacity of soil
  - Water stable aggregate size distrubution in soil

- Influence of agricultural land use systems on soil carbon pools
  - Soil organic carbon
  - Aggregate associated organic carbon
  - Hot water soluble carbon
  - Labile carbon
  - Particulate organic carbon
  - Mineralizable carbon

4.1 EFFECT OF AGRICULTURAL LAND USE SYSTEMS ON SOIL PROPERTIES.

4.1.1 Soil texture

The data on soil textural fractions of different soil series under different agricultural land uses are given in table 1. The data revealed that the soils of Vellayani series contain more of sand (65.23 to 69.52%) compared to silt (15.43 to 18.52 %) and clay (14.48 to 16.19 %) under various land uses and the soil texture is sandy loam. The soil texture of Amaravila series varied from sandy loam to loam. It also contains more sand fraction (52.18 to 66.43%) followed by silt (18.24 to 29.75%) and less clay content (15.33 to 19.33%).

Soils of Trivandrum series had sand fraction ranged from 49.33 to 79.72 %, silt 10.85 to 26.85% and clay 13.92 to 25.76% under different land use systems. Textural class varied from sandy clay loam to sandy loam. In Kazhakuttam soil series, the sand content varied from 46.43 to 83.63 %, silt content varied from 8.19 to 27.86 % and clay content from 8.19 to 25.70 % under different land use systems. In Nedumangadu soil series, sand fraction (28.26 to 45.43%) was higher than silt (26.65 to 30.14) and clay (28.05 to 41.46 %). The texture of soil is sandy clay loam to clay under different land uses. The soils of Kallar and Ponmudi series where coconut, rubber and banana were cultivated, the soil texture varied from loamy sand to sandy loam. The sand content of Kallar soil series ranged from 58.32 to 83.09 %, followed by silt content 8.67 to 21.81 % and clay content 8.24 to 19.87 %. In Ponmudi soil series, sand fraction was more (70.32 to 77.14 %) compared to silt (14.66 to 18.54 %) and clay (8.20 to 13.31 %) under different land uses.

Table 1. Soil texture of different soil series under different agricultural land use systems.

Soil series	Soil textural fractions	Agricultural land use systems		
		Coconut	Banana	Vegetable
Vellayani	Sand (%)	69.52	67.33	65.23
	Silt (%)	15.67	15.43	18.52
	Clay (%)	14.48	15.33	16.19
	Textural Name	Sandy loam	Sandy loam	Sandy loam
Amaravila	Sand (%)	66.43	57.95	52.18
	Silt (%)	18.24	22.72	29.76
	Clay (%)	15.33	19.33	18.19
	Textural Name	Sandy loam	Sandy loam	Sandy Loam
		Coconut	Tapioca	Homestead
Trivandrum	Sand (%)	79.72	49.33	49.38
	Silt (%)	10.85	24.85	26.85
	Clay (%)	13.92	25.76	22.76
	Textural Name	Loamy sand	Sandy clay loam	Sandy clay loam
		Coconut	Rice	Homestead
Kazhakuttam	Sand (%)	70.05	46.43	83.63
	Silt (%)	14.85	27.86	8.19
	Clay (%)	12.67	25.70	8.19
	Textural Name	Sandy loam	Sandy clay loam	Loamy sand

		Coconut	Rubber	Banana
Nedumangadu	Sand (%)	45.43	41.46	28.26
	Silt (%)	26.65	30.14	27.14
	Clay (%)	29.90	28.05	41.46
	Textural Name	Sandy clay loam	Sandy clay loam	clay
Kallar	Sand (%)	83.09	58.32	63.23
	Silt (%)	8.67	21.81	21.15
	Clay (%)	8.24	19.87	15.63
	Textural Name	Loamy sand	Sandy loam	Sandy loam
		Coconut	Tea	Arecanut
Ponmudi	Sand (%)	77.14	70.92	70.32
	Silt (%)	14.66	15.43	18.54
	Clay (%)	8.20	13.31	12.14
	Textural Name	Loamy sand	Sandy loam	Sandy loam

4.1.2 Soil bulk density

The bulk density of soils of various soil series in Thiruvananthapuram district were significantly influenced by different agricultural land use systems as presented in table 2. In Vellayani soil series the bulk density ranged from 1.10 to 1.28 Mg m^{-3}, where the highest value was recoded in vegetable and banana and the lowest in coconut land use system. The bulk density of Amaravila soil series varied between 1.25 and 1.42 Mg m^{-3} with significantly higher value recorded in coconut compared to banana and vegetable.

In Trivandrum soil series the bulk density ranged from 1.36 to 1.52 Mg m^{-3}, where the highest value was recoded in coconut and homestead and the lowest in tapioca. The bulk density of soils of Kazhakuttam series ranged from 1.28 to 1.59 Mg m^{-3} with significantly higher value recorded in rice compared to coconut and homestead. In Kallar and Nedumangadu soil series the bulk density varied from 1.15 to 1.41 Mg m^{-3} and 1.16 to 1.55 Mg m^{-3}, respectively. In both series, the highest bulk density was recorded in rubber, which was significantly different from coconut and banana. The soil bulk density of Ponmudi series ranged from 1.11 to 1.40 Mg m^{-3}, where the highest value was recorded in coconut which was on par with arecanut (1.26 Mg m^{-3}) and the lowest value was recorded with tea (1.11 Mg m^{-3}).

Table 2. Effect of agricultural land use systems on bulk density of soil, Mg m^{-3}

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	1.10	1.28	1.28	0.14
Amaravila	1.42	1.27	1.25	0.11
	Coconut	Tapioca	Homestead	
Trivandrum	1.52	1.36	1.49	0.12
	Coconut	Rice	Homestead	
Kazhakuttam	1.30	1.59	1.28	0.12
	Coconut	Rubber	Banana	
Nedumangadu	1.15	1.41	1.22	0.10
Kallar	1.20	1.55	1.16	0.28
	Coconut	Tea	Arecanut	
Ponmudi	1.40	1.11	1.26	0.17

4.1.3 Soil pH

The soil pH of different soil series of Thiruvananthapuram district under various agricultural land uses given in table 3 revealed that the soil pH of Vellayani series ranged from 4.72 to 4.94 and Amaravila series ranged from 4.56 to 5.74. In both series, the highest pH was recorded in coconut which was on par with vegetable and the lowest was recorded in banana.

Table 3. Effect of agricultural land use systems on pH of soil

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	4.94	4.72	4.80	0.15
Amaravila	5.74	4.56	4.93	0.91
	Coconut	Tapioca	Homestead	
Trivandrum	5.32	5.77	5.07	0.44
	Coconut	Rice	Homestead	
Kazhakuttam	5.28	4.29	5.28	0.55
	Coconut	Rubber	Banana	
Nedumangadu	5.35	5.18	5.74	0.22
Kallar	5.74	5.22	5.13	0.27
	Coconut	Tea	Arecanut	
Ponmudi	4.77	4.77	4.85	NS

In Trivandrum soil series the pH value ranged from 5.07 to 5.77, where the highest pH was recorded in tapioca (5.77) which was on par with coconut (5.32) and the lowest in the case of homestead (5.07). The soil pH observed in Kazhakuttam series varied from 4.29 to 5.28 with the highest value recorded in coconut and homestead (5.28) land use systems and the lowest in of rice (4.29). In Nadumangadu series pH of soil ranged from 5.18 to 5.74, where significantly higher pH was recorded in banana (5.74) land use system compared to coconut (5.35) and rubber (5.18) and latter two were on par. The soil pH of Kallar series ranged from 5.13 to 5.74, with the highest pH value recorded in coconut (5.74) land use system followed by banana (5.13) and rubber (5.22). The soil pH of Ponmudi series varied from 4.77 to 4.85 in different land use systems like coconut (4.77), tea (4.77) and arecanut (4.85) which did not show any significant difference.

4.1.4 Electrical conductivity of soil

The results of soil electrical conductivity under different land use systems in various soil series are presented in table 4. A significant difference was observed between EC values of different land use systems in all the soil series

The EC of soils of Vellayani series ranged from 0.04 to 0.09 dS m^{-1} with the highest value recorded in coconut land use system followed by banana and vegetable and latter two were on par.

In Amaravila series, EC value ranged from 0.02 to 0.08 dS m^{-1}. Significantly higher EC was recorded in vegetable (0.08) land use system than banana (0.04) and coconut (0.02) and latter two were on par. The EC of Trivandrum soil series ranged from 0.03 to 0.05 dS m^{-1}. The highest EC was recorded in tapioca land use system which was on par with homestead and the lowest was recoded in coconut.

In Kazhakuttam series, soil EC was influenced by different land use systems and it ranged from 0.02 to 0.13 dS m^{-1}. The highest EC was recorded in rice land use system compared to homestead and coconut and latter two were on par. The EC of soils of Nadumangadu series varied from 0.04 to 0.09 dS m^{-1}, where the highest EC was recorded in coconut land use system compared to rubber (0.05 dS m^{-1}) and banana (0.04 dS m^{-1}) and latter two were on par. The soil EC value observed in Kallar series ranged from 0.04 to 0.08 dS m^{-1}. The highest EC was recorded in banana land use system followed by rubber (0.04 dS m^{-1}) and coconut (0.04 dS m^{-1}). The soil EC of Ponmudi soil series ranged from 0.03 to 0.05 dS m^{-1}. The highest EC was recorded in coconut land use system which was on par with arecanut which in turn on par with tea.

Table 4. Effect of agricultural land use systems on EC of soil, dS m^{-1}

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	0.09	0.05	0.04	0.01
Amaravila	0.02	0.04	0.08	0.03
	Coconut	Tapioca	Homestead	
Trivandrum	0.03	0.05	0.04	0.01
	Coconut	Rice	Homestead	
Kazhakuttam	0.03	0.13	0.02	0.02
	Coconut	Rubber	Banana	
Nedumangadu	0.09	0.05	0.04	0.02
Kallar	0.04	0.04	0.08	0.01
	Coconut	Tea	Arecanut	
Ponmudi	0.05	0.03	0.04	0.01

4.1.5 Cation exchange capacity of soil

The results of cation exchange capacity of soil shown in table 5, revealed a significant influence of different agricultural land use systems on CEC in all the soil series of Thiruvananthapuram district.

In Vellyani and Amaravila soil series, the CEC varied from 4.95 to 6.88 and 5.38 to 6.54 c mol (p^+) kg^{-1}soil, respectively. In both series the highest CEC was observed in vegetable land use system which was on par with banana and the lowest in coconut system.

Table 5. Effect of agricultural land use systems on CEC of soil, c mol (p^+) kg^{-1}

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	4.95	6.69	6.88	0.90
Amaravila	5.38	5.60	6.54	0.86
	Coconut	Tapioca	Homestead	
Trivandrum	3.88	5.31	4.99	0.62
	Coconut	Rice	Homestead	
Kazhakuttam	3.65	5.21	4.76	1.15
	Coconut	Rubber	Banana	
Nedumangadu	4.93	6.53	4.58	1.58
Kallar	5.05	5.94	5.03	0.77
	Coconut	Tea	Arecanut	
Ponmudi	4.89	6.11	4.31	1.33

A significant difference was observed between different agricultural land use systems with respect to CEC of soils of Trivandrum series and values were ranged from 3.88 to 4.99 c mol (p^+) kg^{-1} soil. The soil CEC of Kazhakuttam soil series varied between 3.65 to 5.21 c mol (p^+) kg^{-1} soil. In Nedumangadu and Kallar soil series, the highest CEC was recorded in rubber land use which was followed by coconut and the lowest in banana. The CEC of Ponmudi soil series ranged from 4.32 to 6.11 c mol (p^+) kg^{-1}. The highest CEC was recorded in tea land use system which was on par with coconut and the lowest was recoded in arecanut.

4.1.6 Water stable aggregates in soil

The distribution of aggregates in different size classes (8-5, 5-2, 2-1, 1-0.5, 0.5-0.25, 0.25-0.1) are presented in tables 6 - 12. The effect of different agricultural land use systems on the extent of different sized water stable aggregates were found to be significant.

In Vellayani soil series, total water stable aggregate (TWSA) distribution varied from 73.42 to 81.14 %, where significantly higher value was observed in coconut (81.14%) compared to banana and vegetable. Among the aggregates, 0.25-0.5 mm size fraction constituted the greatest proportion followed by 0.1 to 0.25 mm size fraction. Total water stable aggregates in Amaravila soil series (Table 7) ranged from 62.09 to 78.16 %, where significantly higher value was observed in coconut compared to banana and vegetable. With respect to different size fractions, 0.1 to 0.25 mm fraction was more, followed by 0.25 to 0.5 mm and 1 to 2 mm fractions.

In Trivandrum soil series, total water stable aggregates varied between 49.50 and 72.30 %, where significantly higher value was observed in tapioca followed by coconut and the lowest value was observed in homestead (49.50 %). Among the different size fractions, 0.1 to 0.25 mm was found to be the highest, which was followed by 0.25 - 0.5 mm size and the lowest was 5-8 mm size fraction. With respect to Kazhakuttam series, the total water stable aggregate varied between 58.44 and 76.26 % where significantly higher value was observed in rice (76.26%) compared to coconut (67.58%) and homestead (58.44 %) When the different size fractions are compared, the 0.25-0.5 mm size fraction was more in coconut and homestead land uses, followed by 0.1-0.25 mm fraction and least was 2-5 mm size fraction. In rice land use system, 2-5 mm size fraction was more followed by 1-2 and 0.1-0.25 mm size and the least was 5-8 mm size fraction.

Table 6. Aggregate size distribution in relation to different agricultural land uses in Vellayani soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	13.19	11.33	10.41	15.54	30.69	11.26	81.16
Banana	13.49	8.15	11.53	16.34	23.91	25.00	73.42
Vegetable	10.24	4.14	15.40	18.65	26.49	22.99	74.95
CD (0.05)	1.58	2.78	3.00	1.09	2.54	7.60	4.50

Table 7. Aggregate size distribution in relation to different agricultural land uses in Amaravila soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	23.4	10.90	22.61 3	8.95	12.26	20.42	78.16
Banana	6.450	10.38	14.47	12.31	22.75	27.35	66.39
Vegetable	11.58	4.55	17.04	13.53	15.39	26.81	62.09
CD (0.05)	3.46	1.03	2.29	2.64	4.31	0.85	8.93

Table 8. Aggregate size distribution in relation to different agricultural land uses in Trivandrum soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	3.92	10.05	14.61	12.05	16.69	28.48	57.32
Tapioca	1.90	1.96	14.49	15.47	37.82	27.87	72.30
Homestead	3.70	3.70	12.72	14.39	14.99	40.40	49.50
CD (0.05)	0.11	5.12	0.71	2.49	6.99	2.41	7.32

In Nadumangadu soil series, total water stable aggregates varied between 63.02 and 95.08 %, where significantly higher value was observed in rubber compared to coconut and banana. Among the different size fraction, 5-8 mm fraction was higher in coconut, 1-2 mm size in rubber and 0.1 - 0.25 mm size in banana. The data on total water stable aggregates in Kallar soil series (Table 11) varied between 45.94 and 88.48 %, where significantly higher value was observed in rubber compared to coconut and banana. In coconut and banana land use systems, 0.1- 0.25 mm size fraction was found to be high, where as in rubber 5-8 mm size fraction was found to be high. In Ponmudi soil series (Table 12) total water stable aggregates varied between 46.36 and 90.41%, where significantly higher value was observed in tea compared to arecanut and coconut. With respect to different size fractions 5-8 mm size was more in tea, 0.1 to 0.25 mm size was more in coconut and 1-2 mm size was more in arecanut.

The distribution of 5-8 mm aggregate size in Vellayani series varied between 13.19 to 10.24 % where the highest value was observed in vegetable, followed by banana and the lowest recorded in coconut. Aggregates of 2-5 mm size ranged between 4.14 and 11.33 % where higher value was observed in coconut followed by banana and the lowest value recorded in vegetable. Aggregate size (1-2 mm) varied between 10.41 and 15.40 %, where higher value was observed in vegetable compared to banana and coconut and latter two were on par. Aggregate size of 0.5-1 mm ranged between 15.54 and 18.65 %, where higher value was observed in vegetable compared to coconut and banana. Aggregate size of 0.25-0.5 mm ranged between 23.91 and 30.69 %, where higher value was observed in coconut (30.69 %) compared to vegetable (26.49 %) and banana (23.91 %). Aggregate size of 0.1-0.25 mm varied between 11.26 and 25.00 %, with higher value observed in banana compared to coconut and vegetable.

Table 9. Aggregate size distribution in relation to different agricultural land uses in Kazhakuttam soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	0.00	1.39	2.03	18.36	45.80	29.03	67.58
Rice	5.27	28.74	26.45	9.30	6.50	13.36	76.26
Homestead	0.00	0.79	2.27	16.56	38.82	35.07	58.44
CD (0.05)	0.02	2.08	1.55	6.73	18.24	3.19	3.90

Table 10. Aggregate size distribution in relation to different agricultural land uses in Nedumangadu soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	22.05	10.96	18.30	11.95	13.88	20.36	75.14
Rubber	23.05	24.33	32.12	9.99	5.53	4.28	95.08
Banana	4.63	13.29	18.48	13.39	13.23	29.32	63.02
CD (0.05)	2.41	1.10	1.755	1.02	2.52	5.50	6.76

In Amaravila soil series the distribution of (5-8 mm) aggregate size varied between 6.45 to 23.4 % with the highest value observed in coconut compared to vegetable and banana. Aggregates of 2-5 mm size ranged between 4.55 and 10.38 % where the highest value was recorded in banana (10.38 %), followed by coconut (10.90 %) and the lowest value was observed in vegetable (4.14 %). With respect to aggregates of 1-2 mm size the highest value was observed in coconut followed by vegetable and the lowest in banana. Aggregate size of 0.5-1 mm ranged between 8.95 and 13.53 % where higher value was observed in banana compared to vegetable and coconut. Aggregate size of 0.25-0.5 mm ranged between 12.26 and 22.75 % with significantly higher value observed in banana (22.75 %) compared to vegetable (15.39 %) and coconut (12.26 %). Aggregate size of 0.1-0.25 mm varied between 20.42 and 26.81 % where the highest value was observed in banana followed by vegetable and the lowest recorded in coconut.

The distribution of (5-8 mm) aggregate size in Trivandrum soil series varied between 1.90 and 3.70 %, with the highest value recorded in coconut followed by homestead and the lowest value was observed in tapioca. Aggregate size fractions of 2-5 mm and 1-2 mm sizes were found to be high in coconut land use system whereas 0.5-1 mm and 0.25-0.5 mm size fractions were found to be high in the case of tapioca and 0.1-0.25 mm size fraction was found to be high in homestead which were significantly different from other land use systems.

In Kazhakuttam soil series the distribution of aggregate size fractions revealed that 5-8 mm was significantly higher in rice (5.27 %). With respect to 2-5 mm and 1-2 mm size fractions significantly higher values of 28.74 % and 26.45 % respectively were observed in rice. In the case of 0.5-1mm and 0.25-0.5 mm sizes higher values of 18.36 % and 45.80 % respectively were noticed in coconut which was on par with homestead system. The distribution of aggregate size fraction of 0.1-0.25 mm varied between 13.36 and 35.07 %.

Table 11. Aggregate size distribution in relation to different agricultural land uses in Kallar soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	8.06	4.39	11.38	12.93	16.49	45.04	53.25
Rubber	29.36	11.35	22.77	13.38	11.62	10.41	88.48
Banana	5.49	7.41	12.61	10.61	9.82	37.11	45.94
CD (0.05)	2.30	1.32	1.51	1.09	1.12	3.49	7.82

Table 12. Aggregate size distribution in relation to different agricultural land uses in Ponmudi soil series

Agricultural land use systems	Aggregate size distribution (%)						Total WSA (%)
	5-8 mm	2-5 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	0.1-0.25 mm	
Coconut	3.21	6.41	13.48	12.88	10.37	33.81	46.36
Tea	21.77	21.64	19.33	17.29	10.50	8.60	90.41
Arecanut	18.76	13.86	20.81	16.55	14.86	13.13	84.84
CD (0.05)	2.16	1.16	1.11	1.00	1.16	7.77	8.33

The distribution of aggregate size fractions in Nedumangadu series revealed that, among the different agricultural land use systems rubber registered the highest values of 23.05 %, 24.33 %, 32.12 % for 5-8 mm, 2-5 mm and 1-2 mm size fractions respectively, banana recorded the higher values of 13.39 % and 29.32 % in the case of 0.5-1 mm and 0.1-0.25 mm size fractions respectively and coconut recorded the highest value of 13.8 % for 0.25-0.5 mm size fraction which were significantly different from rest of the land uses.

In Kallar soil series, the results on the distribution of various aggregate size fractions showed that, among the different agricultural land use systems, rubber registered significantly higher values of 29.36 %, 11.35 %, 22.77 % and 13.38 %, for 5-8 mm, 2-5 mm, 1-2 mm and 0.5-1 mm sizes respectively. In the case of 0.25- 0.5 mm and 0.1-0.25 mm size fraction the highest values (16.49 % and 45.04 %) were registered in coconut system, which were significantly different from rest of the land use systems.

With respect to the distribution of different aggregate size fractions in Ponmudi series, 5-8 mm, 2-5 mm and 0.5-1 mm sizes were found to be high in tea. Arecanut registered the higher values of 20.81 % and 14.86 %, respectively for 1-2 mm and 0.25-0.5 mm size fractions and coconut recorded the highest value of 33.81 % for 0.1-0.25 mm size fraction, which were significantly different from rest of the treatments.

4.2. INFLUENCE OF AGRICULTURAL LAND USE SYSTEMS ON SOIL CARBON POOLS.

4.2.1 Soil Organic Carbon

The results of soil organic carbon (SOC) under different land use systems in various soil series are presented in table 13.

The soil organic carbon content in Vellayani series ranged from 6.16 to 8.73 g kg^{-1}, with the highest value recorded in vegetable (8.73 g kg^{-1}) land use system which was on par with banana (7.56 g kg^{-1}) and the lowest value was recorded in coconut (6.16 g kg^{-1}). In Amaravila series, soil organic carbon status varied from 6.50 g kg^{-1} in banana to 7.96 g kg^{-1} in coconut. The soil organic carbon concentration in Nadumangadu series ranged from 6.53 to 9.37 g kg^{-1}. The highest SOC was recorded in rubber land use system which was significantly different from banana and coconut land use system.

Table 13. Soil organic carbon in relation to different agricultural land use systems, g kg^{-1}

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	6.16	7.56	8.73	1.30
Amaravila	7.96	6.50	6.56	1.06
	Coconut	Rubber	Banana	
Nedumangadu	6.53	9.37	7.80	1.52
Kallar	3.33	9.93	6.33	2.58
	Coconut	Tapioca	Homestead	
Trivandrum	6.53	6.83	7.30	NS
	Coconut	Rice	Homestead	
Kazhakuttam	2.96	9.96	4.36	2.43
	Coconut	Tea	Arecanut	
Ponmudi	10.33	11.67	10.13	1.08

In Kallar series, soil organic carbon content varied from 3.33 to 9.93 g kg^{-1}. When the different agricultural land uses were compared, the highest SOC was observed in rubber followed by banana and the lowest was recorded in coconut, which were significantly different from one another. With respect to the soil organic carbon content in Trivandrum series, the values ranged from 6.53 to 7.30 g kg^{-1} in different land use systems like coconut, tapioca and homestead, which did not show any significant difference. In Kazhakuttam series, soil organic carbon content varied from 2.96 to 9.96 g kg^{-1}. The highest value of SOC was recorded in rice which was significantly different from homestead and coconut. The soil organic carbon in Ponmudi soil series varied from 10.33 to 11.67 g kg^{-1}, and the highest SOC content was recorded in tea land use system followed by coconut and arecanut latter two were on par

4.2.2 Aggregate associated organic carbon.

The soil organic carbon was determined in macro (2-5, 1-2, 0.5-1, 0.25-0.5 mm) and microaggregates (0.25-0.1mm) and the results of aggregate associated organic carbon (AAOC) at various soil series under different land use systems are presented in tables 14 to 20.

In Vellayani series, vegetable land use recorded the highest aggregate associated carbon concentration when compared to coconut and banana (Table 14). Macro aggregates were richer in carbon content compared to micro aggregates. In coconut, aggregate associated carbon concentration was the highest in 2-5 mm size fraction followed by 1-2 mm size fraction. In the case of banana, the highest carbon was recorded in 0.5-1mm size fraction followed by 1-2 mm size fraction and in vegetable, the highest value was observed in 1-2 mm size fraction. The lowest aggregate associated carbon was recorded in 0.1-0.25 mm size fraction in all the agricultural land uses of Vellayani soil series. Micro aggregates had lower carbon as compared to macro aggregates and it ranged between 506 to 1120 mg kg^{-1}. The highest value was recorded in vegetable which was significantly different from banana and coconut. The macro aggregates size 2-5mm size fraction had carbon concentration ranged from 872 to 1463 mg kg^{-1}, 1-2 mm size fraction registered 835 to 1657 mg kg^{-1}, 0.5-1 mm size fraction contained 749 to 1550 mg kg^{-1} and 0.25-0.5 mm size fraction had 780 to 1520 mg kg^{-1} of aggregate associated carbon.

Table 14. Effect of agricultural land use systems on aggregate associated organic carbon at Vellayani soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	872	835	749	780	506
Banana	932	1260	1287	1153	792
Vegetable	1463	1657	1550	1520	1120
CD (0.05)	108	381	474	405	200

With respect to the distribution of AAOC in Amaravila soil series, among the different agricultural land uses, vegetable recorded higher concentration of carbon compared to banana and coconut (Table 15). The macro aggregates were richer in carbon concentration which ranged from 437 to 1287 mg kg^{-1}, whereas micro aggregates of 0.1 to 0.25 mm size fraction had lower carbon content ranged between 543 to 843 mg kg^{-1}. In coconut land use, the higher carbon concentration was observed in 0.25-0.5 mm size fraction, where as in banana higher carbon was observed in 0.5-1 mm size and in vegetable the higher carbon value was registered in 1-2 mm size. With respect to aggregate associated carbon in macro aggregates, significantly higher values were observed in vegetable for 2-5 mm (903mg kg^{-1}), 1-2 mm (1400 mg kg^{-1}) and 0.5-1mm (1287 mg kg^{-1}) size fractions and for 0.25-0.5 mm size, higher value was recorded in coconut (1263 mg kg^{-1}) which was on par with vegetable (1243 mg kg^{-1}). In micro aggregate (0.25-0.1 mm size) significantly higher carbon value was registered in vegetable (843 mg kg^{-1}) followed by coconut (633 mg kg^{-1}) which was on par with banana (543 mg kg^{-1}).

Table 15. Effect of agricultural land use systems on aggregate organic associated carbon at Amaravila soil series, mg kg^{-1}

Agricultural land use	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	510	933	1123	1263	633
Banana	437	617	547	477	543
Vegetable	903	1400	1287	1243	843
CD (0.05)	318	408	457	448	128

In Trivandrum series, under homestead, the aggregate associated carbon concentration was more compared to coconut and tapioca (Table 16). The aggregates associated carbon in 0.5-1 mm, 0.25-0.5 mm and 0.1-0.25 mm size fractions were higher in coconut compared to tapioca and homestead. In coconut, aggregate associated carbon concentration was the highest in 0.1-0.25 mm size fraction followed by 0.25-0.5 mm size fraction. In the case of tapioca, the highest carbon was recorded in 2-5 mm size fraction followed by 0.1-0.25 mm size fraction and in homestead, the highest value was observed in 2-5 mm size fraction. Micro aggregates (0.1-0.25 mm) had carbon ranged between 433 to 520 mg kg^{-1}, which was higher in coconut followed by tapioca and homestead. The macro aggregate of size 2-5 mm had carbon concentration ranged from 213 to 667 mg kg^{-1}, higher value was recorded in homestead followed by tapioca and coconut. In 0.5-1mm size fraction the higher value was observed in coconut (397 mg kg^{-1}) followed by homestead and the lowest in tapioca (147 mg kg^{-1}) and 0.25-0.5 mm size fraction had 277 to 400 mg kg^{-1} of aggregate associated carbon and significant difference was observed among various land uses with respect to AAOC.

Table 16. Effect of agricultural land use system on aggregate associated organic carbon at Trivandrum soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	213	307	397	400	520
Tapioca	547	280	147	277	433
Homestead	667	457	323	340	357
CD (0.05)	113	116	128	044	101

With respect to the distribution of AAOC in Kazhakuttam soil series, among the different agricultural land uses rice recorded significantly higher concentrations (Table 17) of carbon compared to coconut and homestead. The micro aggregates are richer in carbon concentration which ranged from 163 to 1725 mg kg $^{-1}$ where higher value in rice followed by coconut and lower in homestead. In rice land use the higher carbon concentration was observed in 0.1-0.25 mm size fraction, where as in coconut higher carbon was observed in 1-2 mm size and in homestead the higher carbon value was registered in 1-2 mm size. With respect to macro aggregates significantly higher value of carbon was observed in rice for 0.5-1 mm (1519 mg kg^{-1}), 1-2 mm (1106 mg kg^{-1}) and 2-5 mm (1176 mg kg^{-1}) size fraction respectively, which were significantly different from coconut and homestead, latter two were found to be on par.

The distribution of aggregate associated organic carbon in Nedumangadu soil series (Table 18) under different agricultural land uses reveled that, rubber had higher concentration of carbon compared to banana and coconut in all the size fractions. The macro aggregates had carbon concentration ranged from 532 to 1132 mg kg^{-1} whereas micro aggregates had carbon content ranged between 732 to 1093 mg kg^{-1}. In rubber land use, the higher carbon concentration was observed in 0.25-

0.5 mm whereas in banana, higher carbon was observed in 0.5-1 mm size and in coconut, the higher carbon value was registered in 0.25-0.5 mm size. With respect to macro aggregates significantly higher carbon value was observed in rubber for 0.25-0.5 mm and 0.5-1 mm size fractions which were significantly higher than coconut and banana. In micro aggregate (0.25-0.1mm size) significantly higher carbon value was registered in rubber (1193 mg kg^{-1}) followed by banana (866 mg kg^{-1}) which was on par with coconut (732 mg kg^{-1}).

In Kallar series (Table 19) also rubber land use recorded the highest aggregate associated carbon concentration in all size fractions compared to coconut and banana. Micro aggregates were richer in carbon content (1364 mg kg^{-1}) compared to macroaggregates (315 to 1207 mg kg^{-1}). In coconut land use aggregate associated carbon concentration was the highest in 2-5 mm size fraction. In the case of rubber, the highest carbon was recorded in 0.1-0.25 mm size fraction followed by 0.25-0.5 mm size fraction and in banana the highest value was observed in 0.1-0.25 mm size fraction. In micro aggregates (0.1-0.25 mm size) carbon content ranged between 324 to 1364 mg kg^{-1}, higher value observed in rubber which was significantly different from banana and coconut. The macro aggregates of 1-2 mm size fraction had 641 to 880 mg kg^{-1}, 2-5 mm size fraction had carbon concentration ranged from 577 to 844 mg kg^{-1}, 0.5-1 mm size fraction contained 395 to 899 mg kg^{-1} and 0.25-0.5 mm size fraction had 467 to 1207 mg kg^{-1} of aggregate associated carbon.

With respect to the distribution of AAOC in Ponmudi soil series (Table 20), among the different agricultural land uses, arecanut recorded higher concentration of carbon compared to tea and coconut. The micro aggregates (0.1 to 0.25 mm) are richer in carbon concentration which ranged from 1095 to 1370 mg kg^{-1} whereas macro aggregates of 2 to 5 mm size fraction had lower carbon content ranged between 809 to 1183 mg kg^{-1}. In coconut land use the higher carbon concentration was observed in 1-2 mm size fraction, where as in tea higher carbon was observed in 0.25-0.5 mm size and in arecanut the higher carbon value was registered in 0.1-0.25 mm size. With respect to micro aggregates of 0.25-0.1 mm size fraction, significantly higher carbon value was registered in arecanut (1370 mg kg^{-1}) followed by tea (1189 mg kg^{-1}) and the lowest in coconut (1095 mg kg^{-1}). With respect to macro aggregates of 2-5 mm size and 0.5-1 mm size fraction, higher AAOC was recorded in arecanut which was significantly different from tea and coconut. The aggregate size fraction of 1-2 mm and 0.25-0.5 mm had higher concentration of AAOC in arecanut which was on par with coconut and the lowest in coconut land use system.

Table 17. Effect of agricultural land use system on aggregate associated organic carbon at Kazhakuttam soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	195	293	123	150	193
Rice	1176	1106	1519	1510	1725
Homestead	210	213	146	163	163
CD (0.05)	193	183	101	157	150

Table 18. Effect of agricultural land use system on aggregate associated organic carbon at Nedumangadu soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	532	634	801	839	732
Rubber	741	896	1093	1132	1093
Banana	549	828	1050	895	866
CD (0.05)	114	163	181	230	224

Table 19. Effect of agricultural land use systems on aggregate associated organic carbon at Kallar soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	646	641	395	467	324
Rubber	844	880	899	1207	1364
Banana	577	746	462	589	875
CD (0.05)	164	161	167	363	292

Table 20. Effect of agricultural land use systems on aggregate associated organic carbon at Ponmudi soil series, mg kg^{-1}

Agricultural land uses	Aggregate associated organic carbon mg kg^{-1}				
	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	0.1-0.25mm
Coconut	903	1128	954	973	1095
Tea	809	936	1043	1216	1189
Arecanut	1183	1202	1236	1344	1370
CD (0.05)	171	168	138	179	141

4.2.3 Hot water soluble carbon

The data on hot water soluble carbon (HWSC) under different land use systems in various soil series are presented in table 21. Different agricultural land use systems significantly influenced the HWSC concentration in soil.

In Vellayani soil series, hot water soluble carbon varied from 29.90 to 46.25 mg kg^{-1}. The HWSC was significantly highest in vegetable land use system followed by coconut and banana, latter two were on par. The hot water soluble carbon in Amaravila soil series ranged from 31.62 to 42.69 mg kg^{-1} in different land use systems like coconut, banana and vegetable, which did not show any significant difference. Nadumangadu soil series contained HWSC concentration between 20.66 and 27.40 mg kg^{-1} and significantly the highest value was observed in rubber land use system which was on par with coconut and the lowest was recoded in banana. In Kallar soil series among the land uses, rubber (56.71mg kg^{-1}) possessed significantly higher HWSC than banana (44.58 mg kg^{-1}) and coconut (18.14 mg kg^{-1}) which were significantly different from each other.

Table 21. Effect of agricultural land use systems on hot water soluble carbon, mg kg^{-1}

Soil series	Hot water soluble carbon			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	35.70	29.90	46.25	7.53
Amaravila	31.62	41.93	42.69	NS
	Coconut	Rubber	Banana	
Nedumangadu	22.48	27.40	20.66	5.14
Kallar	18.14	56.71	44.58	9.97
	Coconut	Tapioca	Homestead	
Trivandrum	45.51	20.16	21.07	6.90
	Coconut	Rice	Homestead	
Kazhakuttam	36.48	76.45	32.20	6.15
	Coconut	Tea	Arecanut	
Ponmudi	51.69	57.60	50.85	4.75

In Trivandrum soil series hot water soluble carbon was the highest in coconut land use system (45.5 mg kg^{-1}) compared to homestead (21.07) and tapioca (20.16). The hot water soluble carbon content of Kazhakuttam series varied from 32.20 to 76.45 mg kg^{-1} with the highest value in rice land use system compared to coconut (36.48 mg kg^{-1}) and homestead (32.20 mg kg^{-1}). In Ponmudi soil series, significantly higher HWSC was obtained in tea land use which was followed by coconut (51.69 mg kg^{-1}) and arecanut (50.85 mg kg^{-1}) and latter two were found to be on par.

4.2.4 Labile Carbon

The labile carbon (LC) concentration in soil was ranged from 909 to 2541 mg kg^{-1} (Table 22) under different agricultural land use systems in different soil series of Thiruvananthapuram district.

In Vellayani soil series, a significant difference was observed between different land uses with respect to LC concentration, which varied from 1093 to 1997 mg kg^{-1}. The highest value was recorded in vegetable followed by banana and the lowest in coconut. Labile carbon content in Amaravila soil series ranged from 1827 to 2541 mg kg^{-1} with the highest value observed in vegetable followed by coconut and banana. Nedumangadu soil series recorded labile carbon concentration of 1195 to 2211 mg kg^{-1} with the highest value observed in rubber compared to banana and coconut. A significant difference was noticed between the various agricultural land use systems.

In Kallar soil series, among the land uses, significantly higher labile carbon was observed in rubber (1349 mg kg^{-1}) followed by coconut (1068 mg kg^{-1}) and the lowest was recorded in banana (948 $mgkg^{-1}$). Labile carbon concentration in Trivandrum soil series ranged from 1828 to 2516 mg kg^{-1} where the highest value was observed in coconut followed by homestead and tapioca. In Kazhakuttam soil series, among the different land uses rice (2187mg kg^{-1}) recorded significantly higher

LC when compared to coconut (948 mg kg^{-1}) and homestead (1142 mg kg^{-1}). The soil labile carbon in Ponmudi soil series ranged from 909 to 1241 mg kg^{-1}, where the highest value was observed in tea (1241 mg kg^{-1}) which was significantly different from arecanut (1015 mg kg^{-1}) and coconut (909 mg kg^{-1}) land use systems.

Table 22. Effect of agricultural land use systems on labile carbon, mg kg^{-1}

Soil series	Labile carbon			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	1093	1699	1997	265
Amaravila	2541	1827	2346	523
	Coconut	Rubber	Banana	
Nedumangadu	1195	2211	1627	334
Kallar	1068	1349	948	119
	Coconut	Tapioca	Homestead	
Trivandrum	2516	1828	2052	440
	Coconut	Rice	Homestead	
Kazhakuttam	948	2187	1142	532
	Coconut	Tea	Arecanut	
Ponmudi	909	1241	1015	192

4.2.5 Particulate organic carbon

The effect of different land use systems on particulate organic carbon (POC) concentration in various soil series are given in tables 23 to 29.

In Vellayani soil series, total particulate organic carbon ranged from 2044 to 2747 mg kg^{-1} (Table 23). Its concentration was the highest in vegetable land use followed by banana and was minimum in coconut. Particulate organic carbon was further fractioned in to vary fine (<53 μm), fine (53-250 μm) and coarse (>250 μm) fractions. Among the land uses, vegetable influenced very fine (<53 μm) and fine (53-250 μm) fractions of POC significantly and recorded the highest values of 1423 and 860 mg kg^{-1}, respectively. The coarse (>250 μm) fraction of POC was the highest in coconut land use (607 mg kg^{-1}) which was found to be significantly different from banana and vegetable.

Total particulate organic carbon in Amaravila soil series is given in table 24. Carbon concentration ranged from 2187 to 2347 mg kg^{-1}. The highest value was found in vegetable followed by coconut and the lowest value was recorded in banana. Among the land uses, vegetable had the highest coarse fraction (>250μm) and carbon content of 633 mg kg^{-1}which was followed by banana and coconut. Very fine (<53μm) fraction of POC was also significantly higher in coconut (1060 mg kg^{-1}) followed by vegetable and banana. Fine (<53-250 μm) fraction of POC content was higher in coconut (840 mg kg^{-1}) land use than banana and coconut.

In Trivandrum soil series, total particulate organic carbon included in table 25 revealed that the carbon concentration varied between 1130 to 1280 mg kg^{-1}, where higher value was observed in homestead, followed by coconut and lower value was recorded in tapioca. Homestead recorded the highest value of 217 and 163 mg kg^{-1} respectively for >250 μm and 53-250 μm POC compared to tapioca and coconut, however for the different land uses the values were on par. In the case of very fine (<53 μm) POC, coconut recorded the highest value of 953 mg kg^{-1}, which was on par with other land use systems viz., tapioca (870 mg kg^{-1}) and homestead (900 mg kg^{-1}).

Table 23. Effect of agricultural land use systems on particulate organic carbon at Vellayani soil series, mg kg^{-1}

Agricultural land uses	Particulate organic carbon mg kg^{-1}			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	607	527	910	2044
Banana	520	723	990	2233
Vegetable	463	860	1423	2747
CD (0.05)	80	243	240	409

Table 24. Effect of agricultural land use systems on particulate organic carbon at Amaravila soil series, mg kg^{-1}

Agricultural land uses	Particulate organic carbon (mg kg^{-1})			Tot mg kg^{-1} al POC
	>250µm	53-250µm	<53µm	
Coconut	417	840	930	2187
Banana	333	367	880	1580
Vegetable	633	653	1060	2347
CD (0.05)	218	180	114	894

Table 25. Effect of agricultural land use systems on particulate organic carbon at Trivandrum soil series, mg kg^{-1}

Agricultural land uses	Particulate organic carbon (mg kg^{-1})			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	153	140	953	1247
Tapioca	113	147	870	1130
Homestead	217	163	900	1280
CD (0.05)	64	15	61	74

With respect to the total and fractioned particulate organic carbon concentration in Kazhakuttam soil series (Table 26), among the different land uses the highest concentration was observed in rice in all the cases, which was significantly different from rest of the land uses, *viz.*, coconut and homestead. Total POC ranged from 1201 to 3310 mg kg^{-1} in different land uses. In coarse fraction (>250 µm) , rice recorded the highest POC of 996 mg kg^{-1} which was significantly different from homestead (366 mg kg^{-1}) and coconut (103 mg kg^{-1}). In fine fraction (53-250 µm) also rice attained higher value (1073 mg kg^{-1}) followed by homestead (210 mg kg^{-1}) and the lowest in coconut (126 mg kg^{-1}). Rice land possessed higher value of POC (1240 mg kg^{-1}) in very fine fraction (<53 µm), which was significantly different from coconut (971 mg kg^{-1}) and homestead (906 mg kg $^{-1}$).

Table 26. Effect of agricultural land use systems on particulate organic carbon at Kazhakuttam soil series, mg kg^{-1}

Agricultural land use	Particulate organic carbon mg kg^{-1}			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	103	126	971	1201
Rice	996	1073	1240	3310
Homestead	366	210	906	1483
CD (0.05)	156	150	159	539

The data shown in tables 27 and 28 revealed that in Nedumangadu and Kallar soil series, the total and different fraction of POC were significantly influenced by different agricultural land use systems. Among the land uses, rubber recorded significantly higher total and fractioned POC compared to coconut and banana. In Nedumangadu series the total POC ranged from 2463 to 3692 mg kg $^{-1}$ and in Kallar series it ranged from 1738 to 3980 mg kg $^{-1}$. The particulate organic carbon in coarse fraction (>250 µm) ranged from 470 to 915 mg kg^{-1} and 435 to 1247 mg kg^{-1}, fine fraction (53-250 µm) ranged from 556 to 1068 mg kg^{-1} and 443 to 1287 mg kg^{-1} and the very fine fraction (<53 µm) ranged from 1260 to 1708 mg kg^{-1} and 860 to 1647 mg kg^{-1} in Nedumangadu and Kallar series, respectively. While comparing the different fractions, higher concentration of POC was observed in very fine fraction (<53 µm), followed by fine fraction (<53-250 µm) and lower concentration in coarse fraction (>250 µm) irrespective of agricultural land uses in all soil series.

Table 27. Effect of agricultural land use systems on particulate organic carbon at Nadumangadu soil series, mg kg^{-1}

Agricultural land use	Particulate organic carbon mg kg^{-1}			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	470	733	1260	2463
Rubber	915	1068	1708	3692
Banana	567	556	1375	2498
CD (0.05)	320	221	339	595

Table 28. Effect of agricultural land use systems on particulate organic carbon at Kallar soil series, mg kg^{-1}

Agricultural land use	Particulate organic carbon mg kg^{-1}			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	435	443	860	1738
Rubber	1247	1287	1647	3980
Banana	505	512	1133	2150
CD (0.05)	357	439	356	600

With respect to the total POC in Ponmudi series presented in table 29, the highest concentration of 3360 mg kg^{-1} was registered in tea, which was significantly different from coconut (2975 mg kg^{-1}) and arecanut (2903 mg kg^{-1}), latter two were on par. The POC in coarse fraction (>250 µm) did not show any significant variation among the land uses. In very fine (<53 µm) and fine (<53-250 µm) fractions, the POC concentration was the highest in tea (1792 and 1013 mg kg^{-1}, respectively) compared to coconut and arecanut.

Table 29. Effect of agricultural land use systems on particulate organic carbon at Ponmudi soil series, mg kg^{-1}

Agricultural land uses	Particulate organic carbon mg kg^{-1}			Total POC mg kg^{-1}
	>250µm	53-250µm	<53µm	
Coconut	552	778	1645	2975
Tea	555	1013	1792	3360
Arecanut	522	733	1648	2903
CD (0.05)	NS	105	094	226

4.2.6 Mineralizable carbon

The results of cumulative amount of carbon mineralized in 15 days of incubation are given in table 30.

The mineralizeble carbon values ranged between 2.86 and 5.55 mg kg^{-1} of soil in Vellayni soil series. The highest amount of carbon was mineralized in banana (5.55 mg kg^{-1}) followed by vegetable (5.20 mg kg^{-1}) and both were on par and the lowest in coconut (4.44 mg kg^{-1}). In Amaravila soil series, mineralizeble carbon was the highest in coconut (5.48 mg kg^{-1}) which was on par with banana (5.42 mg kg^{-1}) and the lowest in vegetable (4.80 mg kg^{-1}).

The mineralizable carbon concentration recorded in Nedumangadu and Kallar soil series were from 3.91 to 5.44 mg kg $^{-1}$ and 2.86 to 4.04 mg kg^{-1}, respectively in both the series. The highest concentration was recorded by rubber, which was followed by banana and the lowest was recorded with coconut land use system. In Kazhakuttam series, the highest concentration of mineralizable carbon was noticed in rice (6.39 mg kg^{-1}) which was significantly different from homestead (5.62 mg kg^{-1}) and coconut (5.40 mg kg^{-1}). A significant difference was observed between different land use systems with regard to the mineralizable carbon content of Trivandrum soil series and the value ranged between 5.42 and 5.84 mg kg^{-1}. In Ponmudi soil series, the mineralizable carbon content was found to be high in arecanut (4.83 mg kg^{-1}) which was on par with tea (4.73 mg kg^{-1}) and low in coconut (3.39 mg kg^{-1}).

Table 30. Effect of agricultural land use systems on mineralizable carbon, mg kg^{-1}

Soil series	Agricultural land use systems			CD (0.05)
	Coconut	Banana	Vegetable	
Vellayani	4.44	5.55	5.20	0.45
Amaravila	5.48	5.42	4.80	0.42
	Coconut	Rubber	Banana	
Nedumangadu	3.91	5.44	5.12	1.07
Kallar	2.86	4.04	3.48	0.39
	Coconut	Rice	Homestead	
Kazhakuttam	5.40	6.39	5.62	0.74
	Coconut	Tapioca	Homestead	
Trivandrum	5.62	5.84	5.42	0.14
	Coconut	Tea	Arecanut	
Ponmudi	3.39	4.73	4.83	1.07

DISCUSSION

5. DISCUSSION

To assess the impact of agricultural land use systems on soil carbon pools of major soil series of Thiruvananthapuram district, studies were carried out on physical and chemical properties and soil carbon pools of seven soil series namely Vellayani, Amaravila, Trivandrum, Kazhakuttam, Nedumangadu, Kallar and Ponmudi under three agricultural land use systems in each series and the results obtained were discussed in this chapter.

5.1. EFFECT OF AGRICULTURAL LAND USE SYSTEMS ON SOIL PROPERTIES

5.1.1. Soil texture

Soil texture in most of the soil series varied from sandy loam to sandy clay loam. In Vellayani and Amaravila series sand content was more in coconut land use whereas silt and clay were more in vegetable land use. In Trivandrum series higher sand was noticed in coconut, silt in tapioca and clay in homestead. The rice land use system recorded the highest silt and clay content, whereas coconut recorded the highest sand content in Kazhakuttam series. In Nedumangadu and Kallar series the highest sand content was recorded in coconut land use whereas highest silt and clay contents were recorded in rubber. In Ponmudi series coconut land use registered the highest sand content, arecanut registered highest silt content and tea registered the highest clay content. Soils having more of fine fractions like silt and clay retain more organic matter and exchangeable cation. Clay and organic molecules interact in a complex manner and form organo-clay complex in the soil as reported by Wu *et al.* (1991). The silt and clay were found to be positively correlated with CEC and soil carbon pools like SOC HWSC, LC, POC and MC, whereas sand was negatively correlated with above parameters in most of the soils. Similar results were also observed by Singh *et al.* (2011) and Shrestha *et al.* (2007) suggesting that mineralogy and possibly other factors play a role in SOC stabilization process. In any given environment, the amount of SOC increases as soil texture becomes finer, this might be due to the ability of silt and clay sized particles to interact with organic matter to form macro and micro aggregates which protect SOC from biological mineralization as reported by Tisdall and Oades (1982).

5.1.2. Soil bulk density

The bulk density of soil was significantly influenced by different land use systems in all the soil series. The highest bulk density was noticed in rice land use. Ahukaemere and Akpan (2012) also reported similar results of an increased bulk density in cultivated soils compared to other land uses. This might be due to the influence of organic matter content on bulk density of soil which enhanced the aggregation of soil particles as reported by Ladd (1996). The lowest was recorded in coconut land use system. The low bulk density was attributed to no disturbance to soil which might have contributed to retention of organic matter as stated by Gajri and Majuimder (2002).

5.1.3. Soil pH

The pH of the soil in the study area varied from slightly acidic to moderately acidic, as these soils are basically derived from granite and also situated in high rainfall region. In Vellayani, Amaravila, Kazhakuttam and Kallar series the highest pH was observed in coconut land use, whereas the lowest pH was observed in banana land use. In Trivandrum, Nedumangadu and Ponmudi series, the highest pH was noticed in tapioca, banana and aracanut land uses. whereas lowest pH was noticed in homestead, rubber and tea land uses, respectively. The difference in pH among soils under different land use systems may be attributed to the variation in rhizosphere activity and rate of decomposition of organic matter that produces organic acids as reported by Ananthkumar (2011) and also attributed to the variation in rainfall, impact of parent material, topographic position, management practices, leaching of basic cations and high organic matter content as suggested by Haynes and Naidu (1998). A negative correlation was observed between pH and SOC. The acidic behavior of humic substances may be to some extent responsible for this relation as already reported by Johnson (2002).

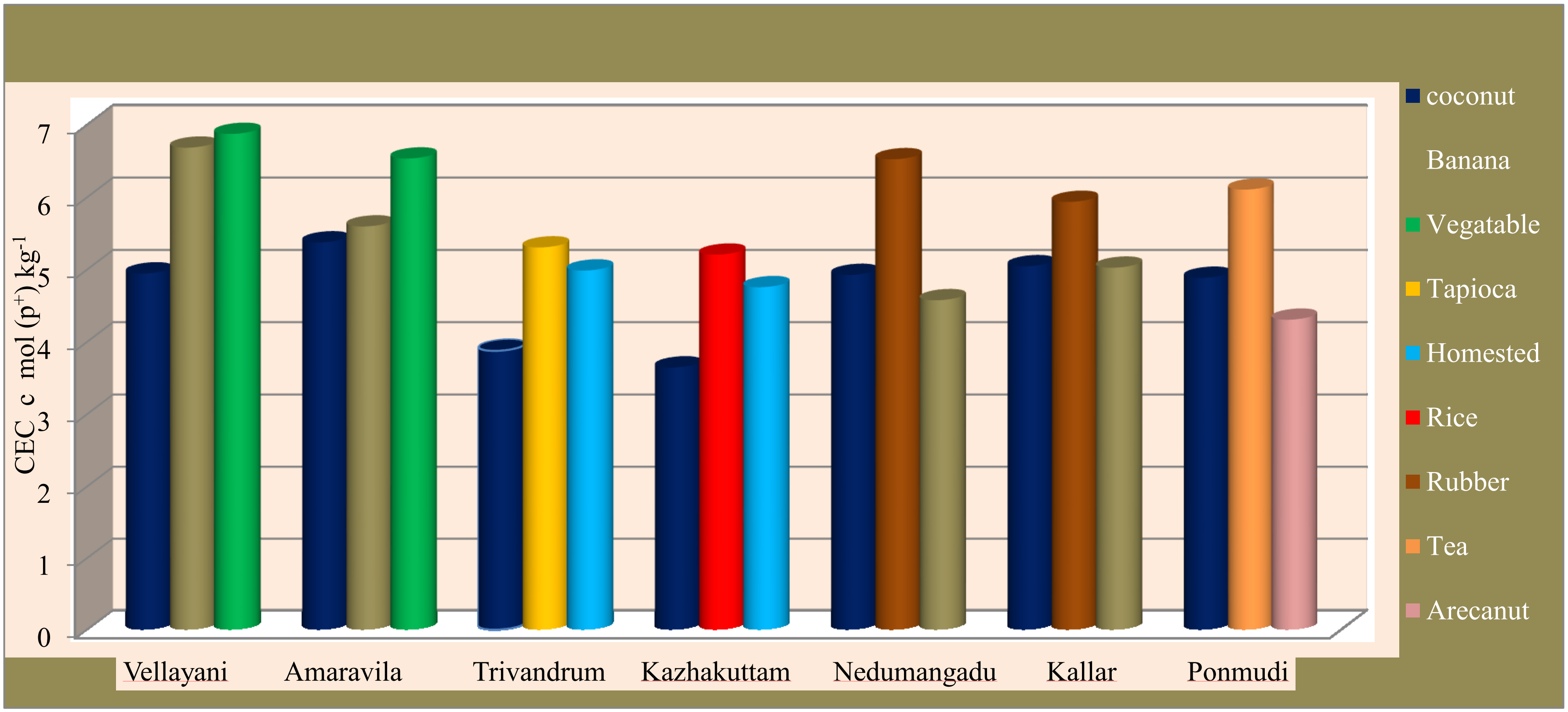
5.1.4. Soil EC

With respect to electrical conductivity of soil significant difference was observed between various land uses in all the soil series. Electrical conductivity showed a range with minimum value of 0.02 dS m^{-1} in the coconut land use of Amaravila series to a maximum of 0.13 ds m^{-1} in the rice land use of Kazhakuttam series. The highest EC was observed in rice land use probably because of addition of various salts through fertilizers. These results are in line with the finding of Nagaraj *et al.* (2002). The low EC indicated that soluble salts were leached out of soil due to high rainfall as reported by Ananthkumar (2011).

5.1.5. Soil CEC

The CEC of soil under different land use systems of various soil series ranged from 3.65 to 6.88 c mol (p^{+}) kg^{-1} soil (Fig. 2). The agricultural land use systems *viz.*, vegetable (Vellayani and Amaravila series), Tapioca (Trivandrum series), rice (Kazhakuttam series), rubber (Nedumangadu and Kallar series) and tea (Ponmudi series) possessed higher CEC compared to other land uses in the respective soil series. The highest CEC in these land uses is due to the regular addition of organic carbon through organic manures and crop residues and also due

Fig. 2. Effect of agricultural land use systems on CEC of various soil series.

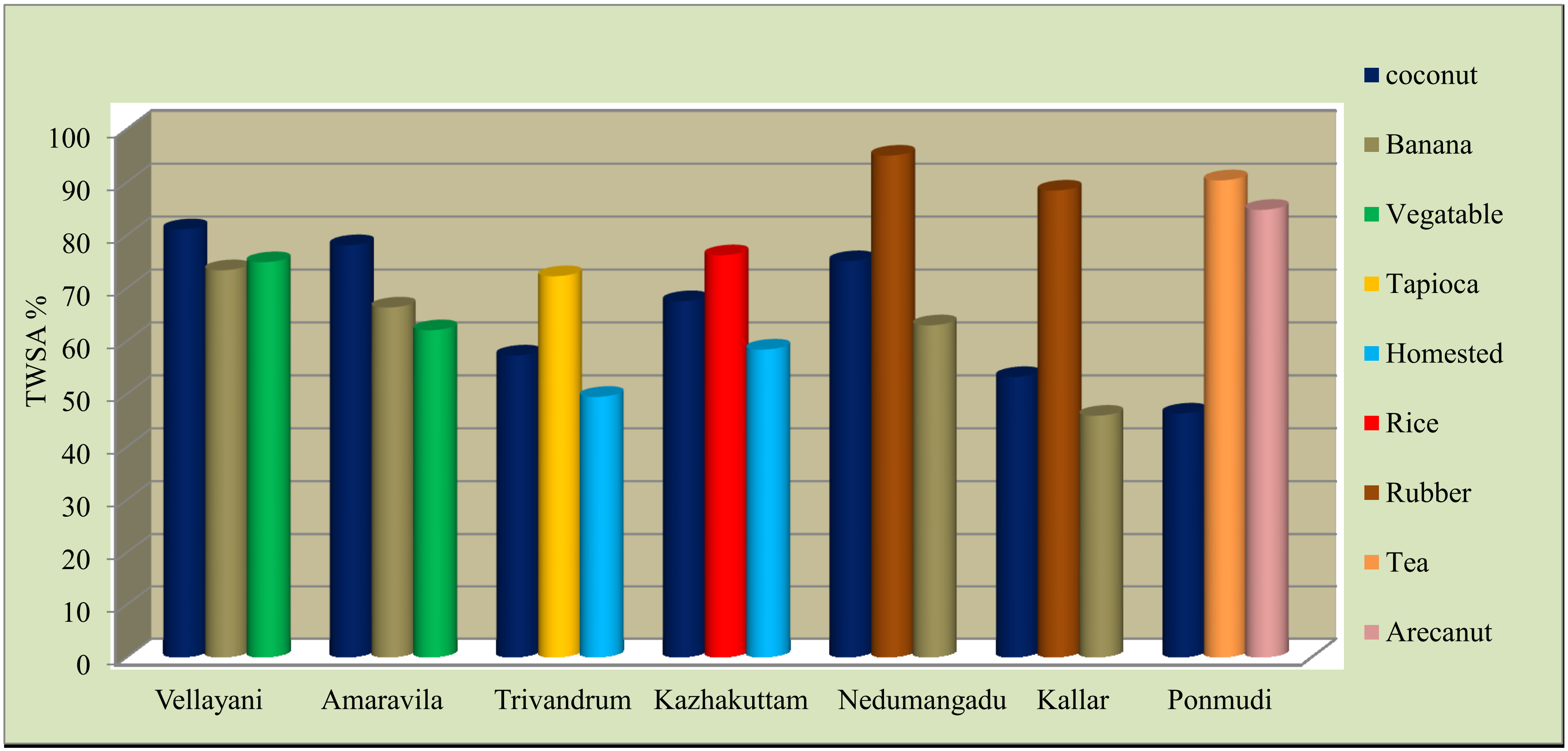


to high clay content as already reported by Jyothi et al. (2009). The CEC of soil was positively related with silt and clay content and also with all soil organic carbon pools namely SOC, HWSC, POC, AAOC and MC. Correlation of SOC fraction to CEC suggested that soil organic matter contributed to increased CEC under different agricultural land uses and these were in line with the findings of Papini (2011).

5.1.6. Water stable aggregates in soil

The effect of land uses on the extent of different sized water stable aggregates was more pronounced in both macro (0.25 to 2mm) and micro (0.1- 0.25mm) aggregates (Fig. 3). The agricultural land uses *viz.,* coconut (Vellayani and Amaravila series), tapioca (Trivandrum series), rice (Kazhakuttam series), rubber (Nedumangadu and Kallar series) and tea (Ponmudi series) recorded the highest total water stable aggregate percentage. Among the aggregates, macro aggregates constituted greater proportion compared to micro aggregates in all the soil series. With respect to micro aggregates of 0.1- 0.25 mm size, banana (Vellayani and Amaravila series), homestead (Trivandrum and Kazhakuttam series), banana (Nedumangadu series), coconut (Kazhakuttam and Ponmudi series) land uses recorded the highest percentage. Among the different size fractions 0.1 to 0.25 mm size registered highest percentage in Amaravila, Trivandrum, Ponmudi and Kallar series, whereas 0.25- 0.5 mm size registered highest percentage in Vellayani and Kazhakuttam series and 1-2 mm registered highest percentage in Nedumangadu series compared to other fractions. The distribution of total water stable aggregates in macro and micro aggregate classes indicates the land disturbance intensity. Greater proportion of macro aggregates in different land use systems like coconut, tea and rubber may be attributed to the binding effect of organic matter and also absence of soil disturbances as earlier reported by Debasish *et al.* (2010). The existence of litter and humus in the soil might have contributed towards the higher proportion of micro

Fig. 3. Effect of agricultural land use systems on TWSA under various soil series.



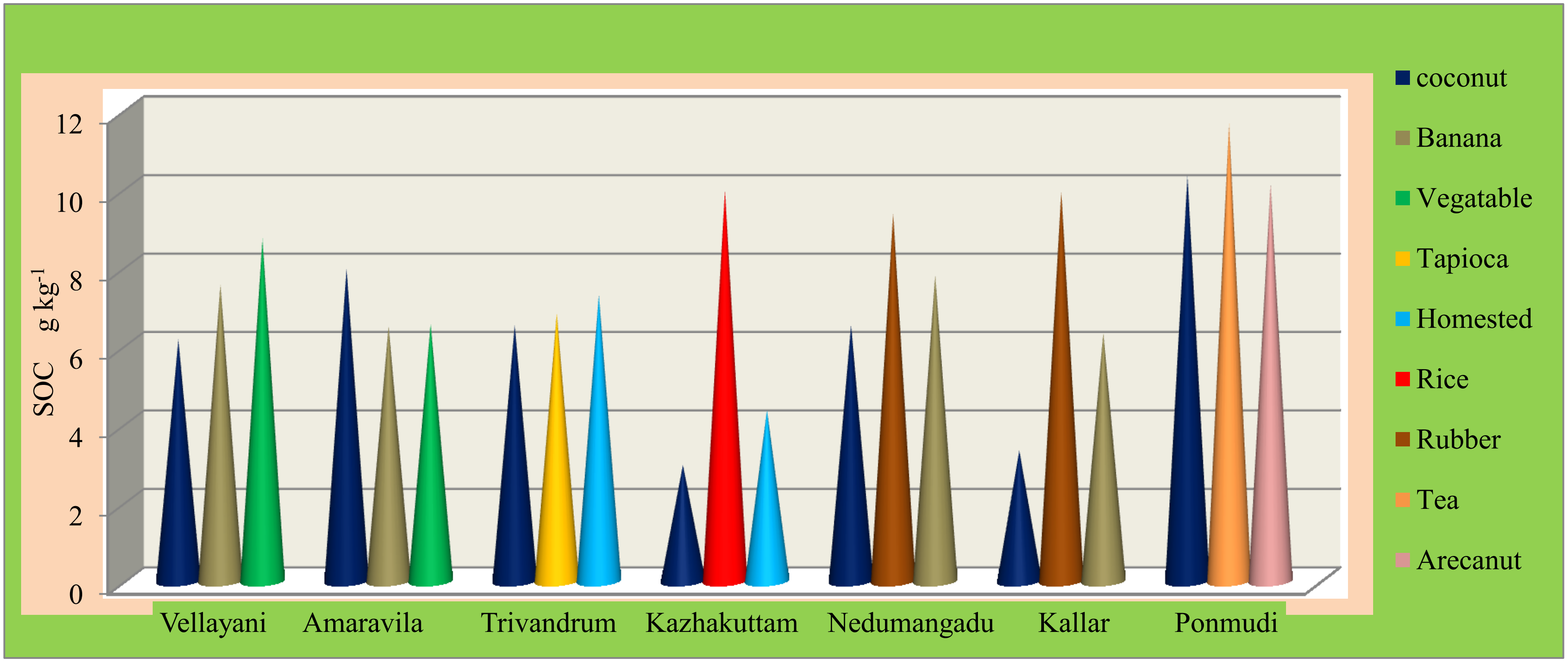
aggregates in different land use systems like vegetable and banana, which also represents the disturbance induced turnover of macro aggregates. More the roots in soil greater is the amount of water stable aggregates as the roots when decompose, the fragments act as a central nucleon of water stable aggregates (Oades, 1984). Total water stable aggregates showed a positive correlation with soil organic carbon pools in all soil series except Vellayani and Trivandrum series. Similar results were also reported by Hati *et al.* (2007).

5.2 EFFECT OF AGRICULTURAL LAND USE SYSTEM ON SOIL CARBON POOLS

5.2.1. Soil organic carbon

Soil organic carbon (SOC) content in various soil series under different land use systems varied from 2.96 to 11.67 g kg^{-1} (Fig. 4). The land uses, *viz.,* vegetable in Vellayani series, coconut in Amaravila series, rubber in Nedumangadu and Kallar series, homestead in Trivandrum series, rice in Kazhakuttam series and tea in Ponmudi series significantly contributed to SOC addition compared to other land uses in the respective soil series. This may be attributed to input of C through litter fall and greater root biomass and to the chemical stabilization of organic carbon in soil matrix (Percival *et al.*, 2000). The lowest organic carbon noticed in coconut land use system of Kazhakuttam and Kallar series could be due to low organic matter input coupled by reduced physical protection of SOC as a result of oxidation of soil organic matter. This was in agreement with the findings of John et al. (2005). SOC was positively and significantly correlated with soil carbon pools like LC, AAOC, POC and MC. A close relationship was also observed between SOC and silt and clay content whereas negative relation was observed between SOC fraction and BD. Xia *et al.* (2010) has also observed positive correlation among different SOC pools.

Fig. 4. Effect of agricultural land use systems on soil organic carbon content of various soil series.



5.2.2 Aggregate associated organic carbon

Soil carbon determined in macro aggregates (2-5 mm, 1-2 mm, 0.5-1 mm, and 0.25- 0.5 mm) and micro aggregates (0.1-0.25 mm) are presented in Fig 5, 6 & 7. Macro aggregates were richer in carbon content compared to micro aggregates. In Vellayani and Amaravila series vegetable land use recorded the highest aggregates associated organic carbon (AAOC) compared to coconut and banana in all the size fractions. In Trivandrum series homestead registered the highest carbon content in 2-5 mm and 1-2 mm size fractions whereas coconut registered the highest carbon in 0.5-1mm, 0.25-0.5 mm and 0.1-0.25 mm fractions. In Kazhakuttam series, rice land use recorded the maximum AAOC in all the size fractions. In Nedumangadu and Kallar series rubber land use recorded the highest AAOC and the lowest was with coconut. In Ponmudi series arecanut recorded the highest AAOC in different size fractions which was followed by tea and the lowest was recorded in coconut.

A positive relation was observed between AAOC and water stable aggregates distribution. Micro aggregates (0.1-0.25 mm) were positively correlated with AAOC whereas macro aggregates (2-5 mm) had negative correlation with AAOC. Chaney and Swift (1984) found highly significant correlation between aggregate stability and soil organic matter. The highest amount of SOC observed from the root density in the surface soils resulted in the higher stability of aggregates under different agricultural land use system as reported by Eynard *et al.* (2005). In cultivated soils most of the organic inputs are from roots and crop residues. These organic sources increased carbon accumulation in different sized aggregates and the effect was more pronounced on macro aggregates than micro aggregates. This may be because of binding together of micro aggregates due to decomposition of organic matter and the physical protection provided by the macro aggregates as reported by Camberdella and Elliot (1994). The amount of organic matter in an aggregate size fraction depends on the intra-aggregate particulate organic matter. This fraction was more in

Fig. 5. Effect of agricultural land use system on aggregate associated organic carbon under Vellayani and Amaravila soil series.

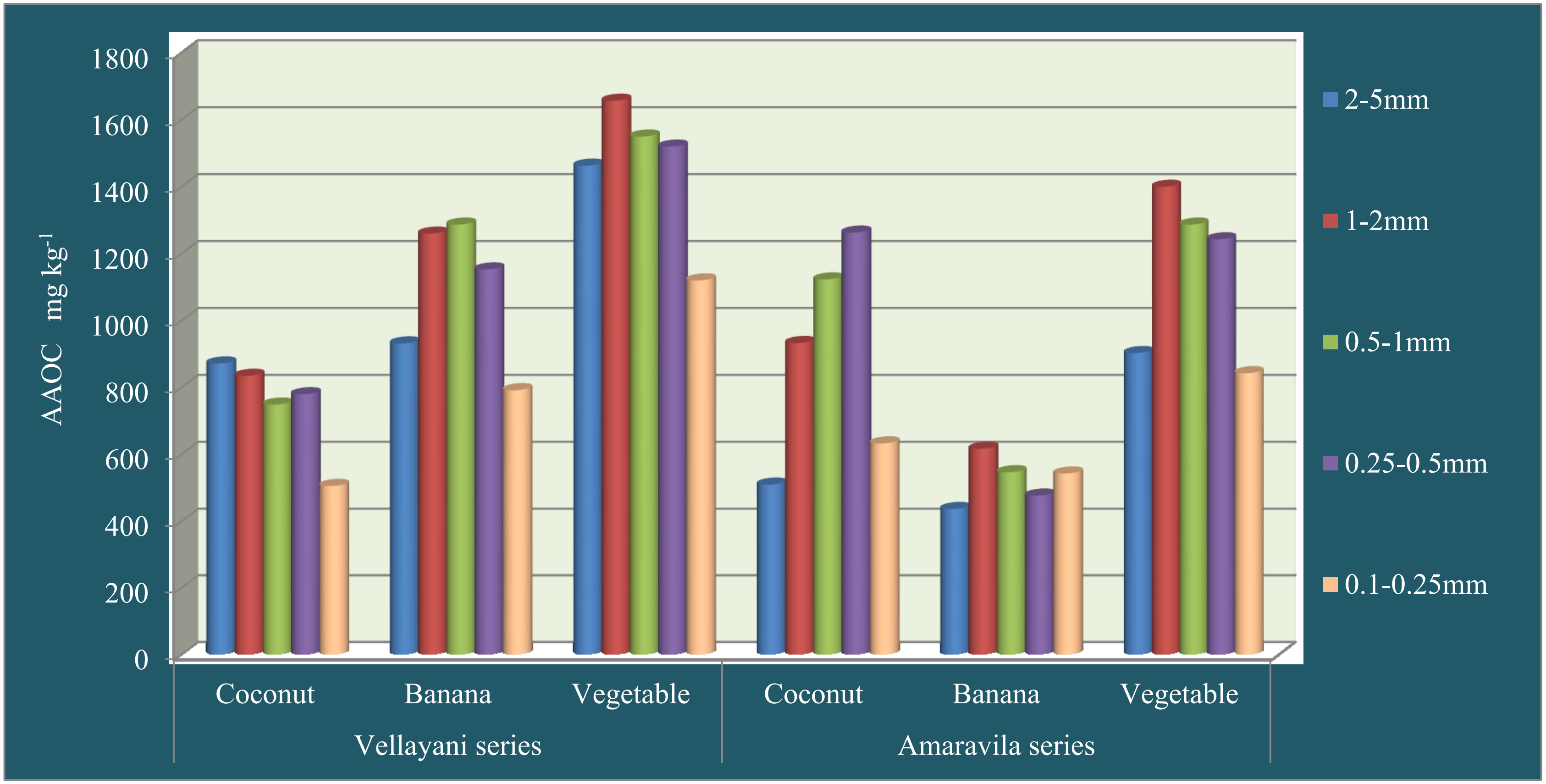


Fig. 6. Effect of agricultural land use system on aggregated associated carbon under Trivandrum and Kazhakuttam soil series.

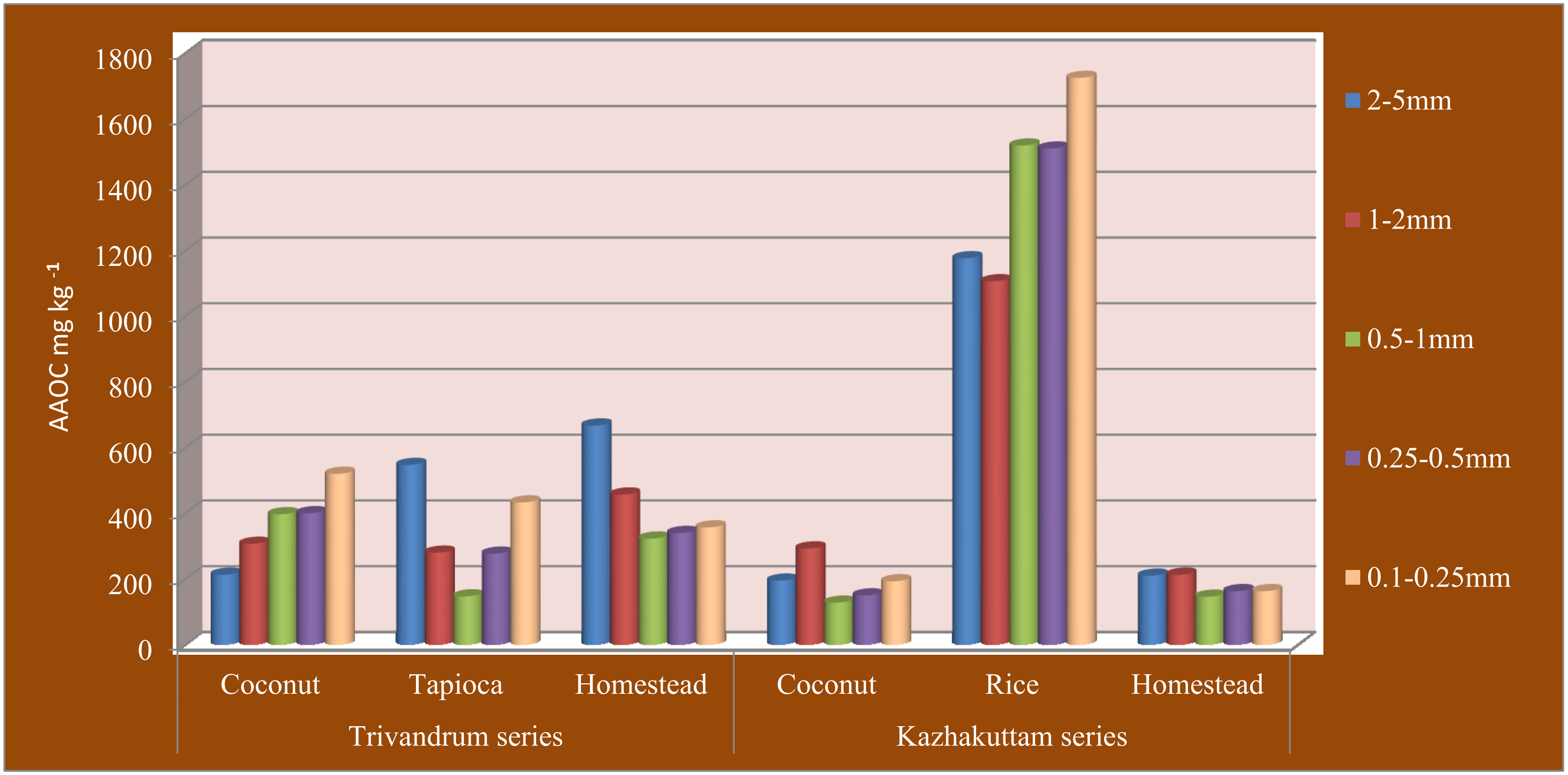
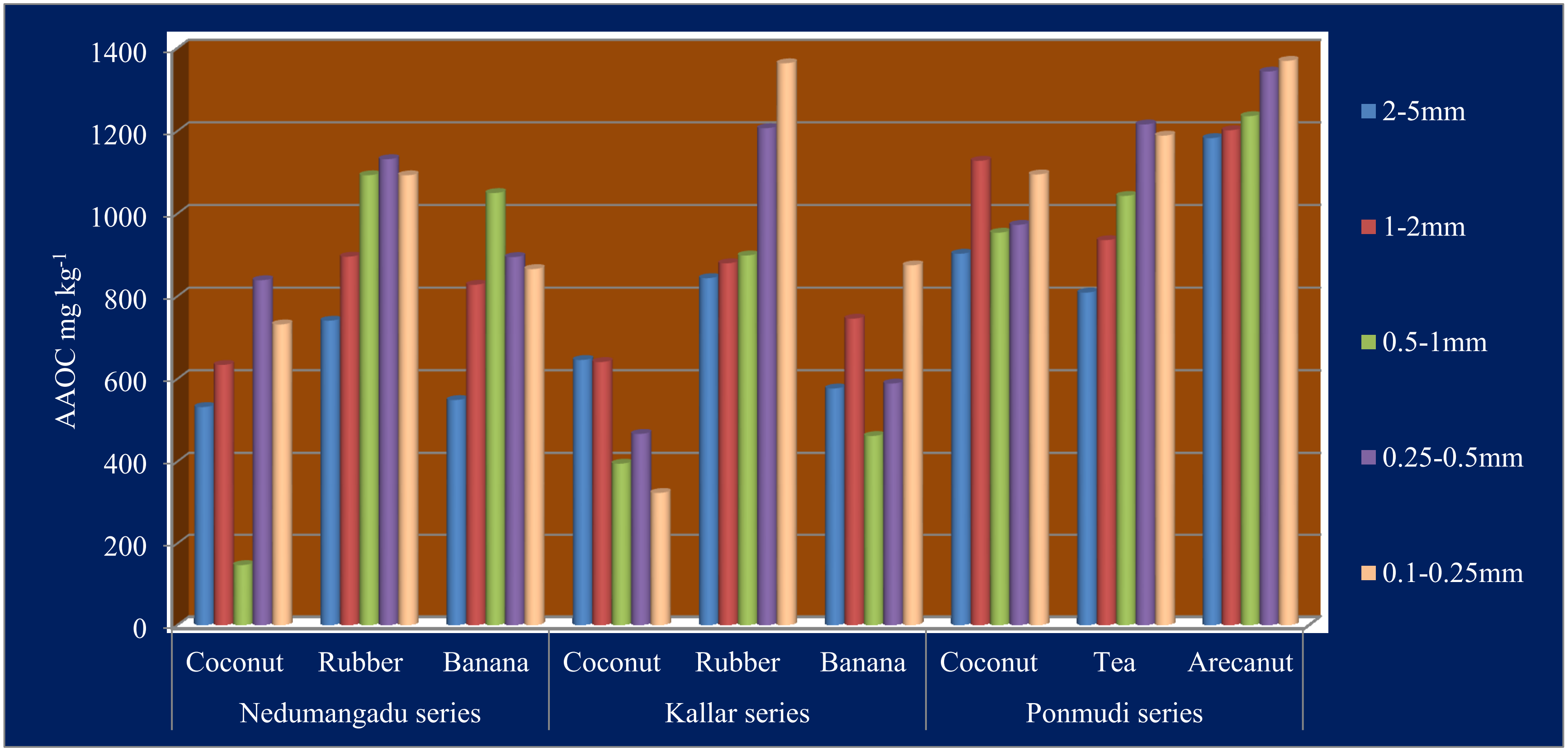


Fig. 7. Effect of agricultural land use system on aggregated associated carbon Nedumangadu, Kallar and Ponmudi soil series.

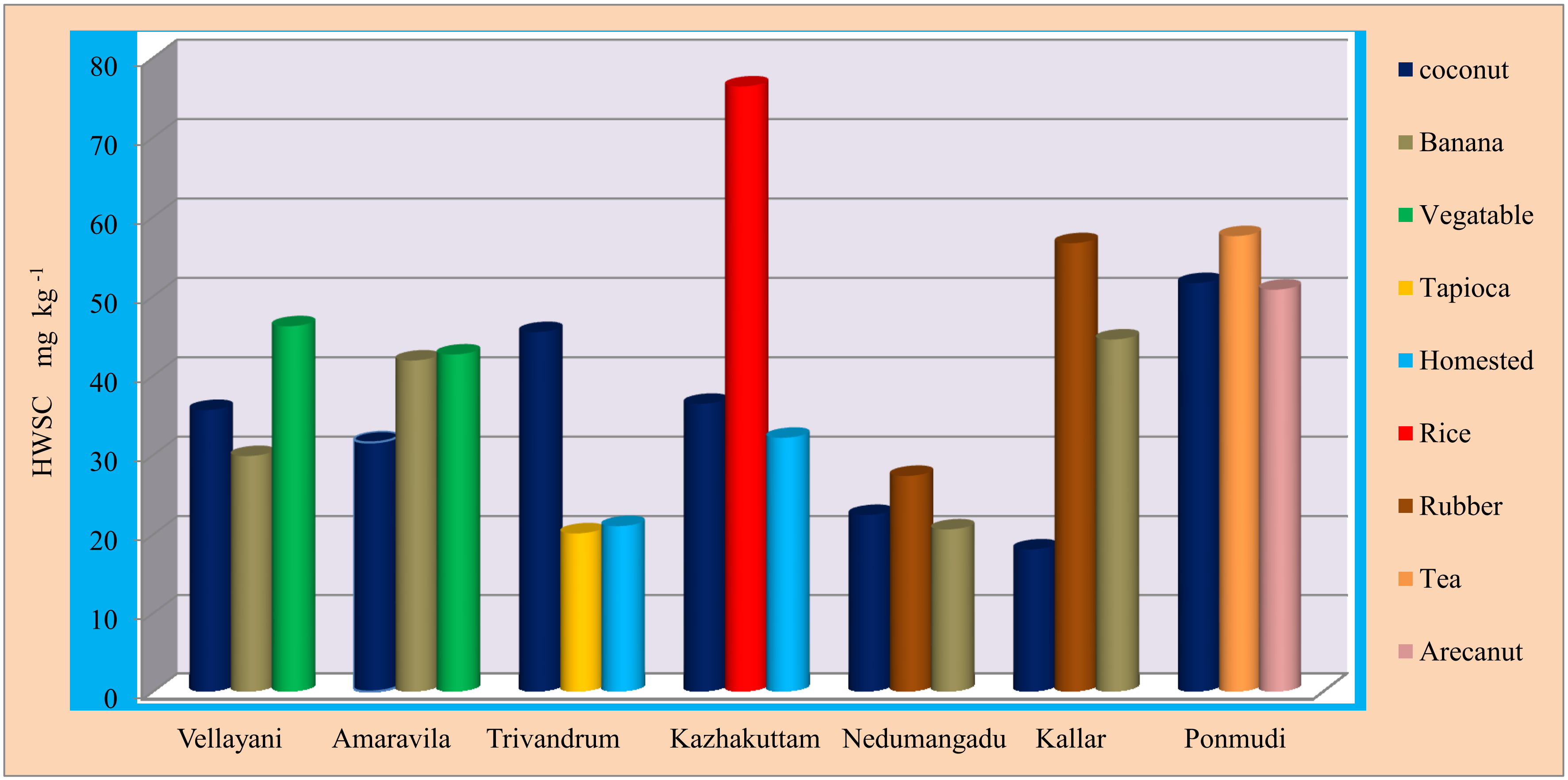


macro-aggregates, because once incorporated, decomposition occurs at slower rate, when held within macro-aggregates due to physical protection within macro-aggregates and also due to more chemically recalcitrant nature of the partially decomposed intra-aggregate particulate organic matter (Elliot, 1986).

5.2.3. Hot water soluble carbon

Hot water soluble carbon (HWSC) concentration in soil was significantly influenced by different agricultural land uses in all the soil series (Fig. 8). In Vellayani and Amaravila series the highest HWSC was observed in vegetable land use and the lowest was observed in coconut. Rubber land use recorded the highest HWSC in Nedumangadu and Kallar series. The land use systems, *viz.,* coconut (Trivandrum series), rice (Kazhakuttam series) and tea (Ponmudi series) recorded highest HWSC compared to other land uses in the respective soil series. The HWSC is a subset of SOC pool, relatively labile in nature. It represents the easily degradable fraction of SOM, also includes soil microbial biomass (Ghani *et al.,* 1999). It may be used as stability indicator of SOM, higher value of HWSC indicates lower stability and lower value indicates higher stability of SOM. A strong positive relation was observed between HWSC and SOC, LC, POC and MC.

Fig. 8. Effect of agricultural land use system on Hot water soluble carbon in various soil series.

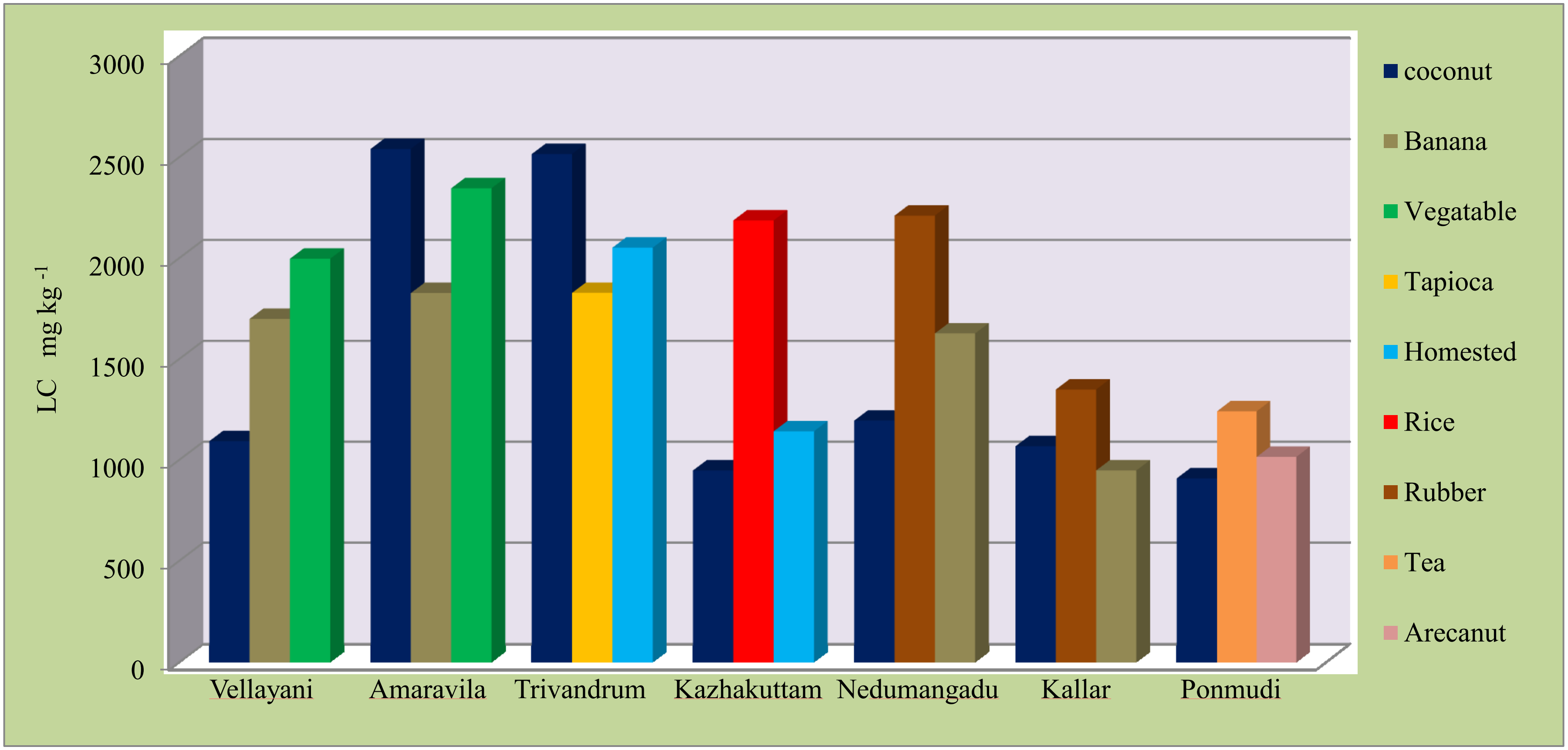


5.3.4. Labile carbon

The labile carbon (LC) varied significantly due to the influence of different agricultural land use systems in all soil series. (Fig. 9) In Vellayani series LC concentration was higher in vegetable compared to coconut and banana. In Amaravila and Trivandrum series, coconut land use possessed significantly higher LC value. Rubber land use recorded the highest LC concentration in Nedumangadu and Kallar soil series. In Kazhakuttam and Ponmudi the land use systems, *viz.*, rice and tea registered the highest LC concentration, respectively, compared to other land use systems. Labile carbon represents an easily decomposable fraction of soil organic matter that decomposes within few weeks or months. Higher level of LC indicates greater turnover of organic matter and higher availability of other nutrients also. The labile fraction of SOC might have significant effect on soil quality and are therefore, more sensitive indicators of the effects of land use compared with SOC as reported by He *et al.* (2008).

Six *et al.* (2002) suggested that enhanced protection of SOM by aggregates resulted in an accumulation of more labile C within aggregates. There was a strong positive relation existed between labile carbon and SOC, POC and MC. The soil properties *viz.,* silt and clay fractions, CEC and BD were also positively related with LC. Labile fraction of organic carbon were largely dependent on the amount of SOC in the soil as reported by Mc Lauchlan and Hobble (2004).

Fig. 9. Effect of agricultural land use systems on Labile Carbon in various soil series.



5.3.5 Particulate organic carbon

The total particulate organic carbon concentration was found to be higher in vegetable (Vellayani and Amaravila series), homestead (Trivandrum series), rice (Kazhakuttam series), rubber (Nedumangadu and Kallar series) and tea (Ponmudi series) compared to other land uses in respective series (Fig. 10-12). Among the different fractions, particulate organic carbon in very fine fraction (<53 µm) was found to be very higher than fine (53-250 µm) and coarse (>250 µm) fractions. Among the land uses, vegetable (Vellayani and Amaravila series), coconut (Trivandrum), rice (Kazhakuttam series), rubber (Nedumangadu and Kallar series) and tea (Ponmudi series) significantly influenced the fine, very fine and coarse fractions of POC. Particulate organic carbon represents the uncomplexed organic matter, which mainly consists of partially decomposed plant and animal residue, root fragments etc. It is the most active pool of the SOC and is a sensitive indicator of soil management effects on SOC (Elliott *et al.,* 1994). The coarse fraction represents the unprotected pool of SOM, which is the labile fraction consists of plant residues in various stages of decomposition along with microbial biomass. (Cambardella and Elliott, 1992). POC is considered as an effective measure of active SOM pool. POC is positively correlated with soil carbon pools *viz.,* SOC, LC, HWSC and MC and also with soil properties *viz.* CEC, TWSA, BD, silt and clay. Chen *et al.* (2007) also found a positive correlation among soil carbon pools in oak forest in China.

Fig. 10. Effect of agricultural land use systems on particulate organic carbon under Vellayani and Amaravila soil series.

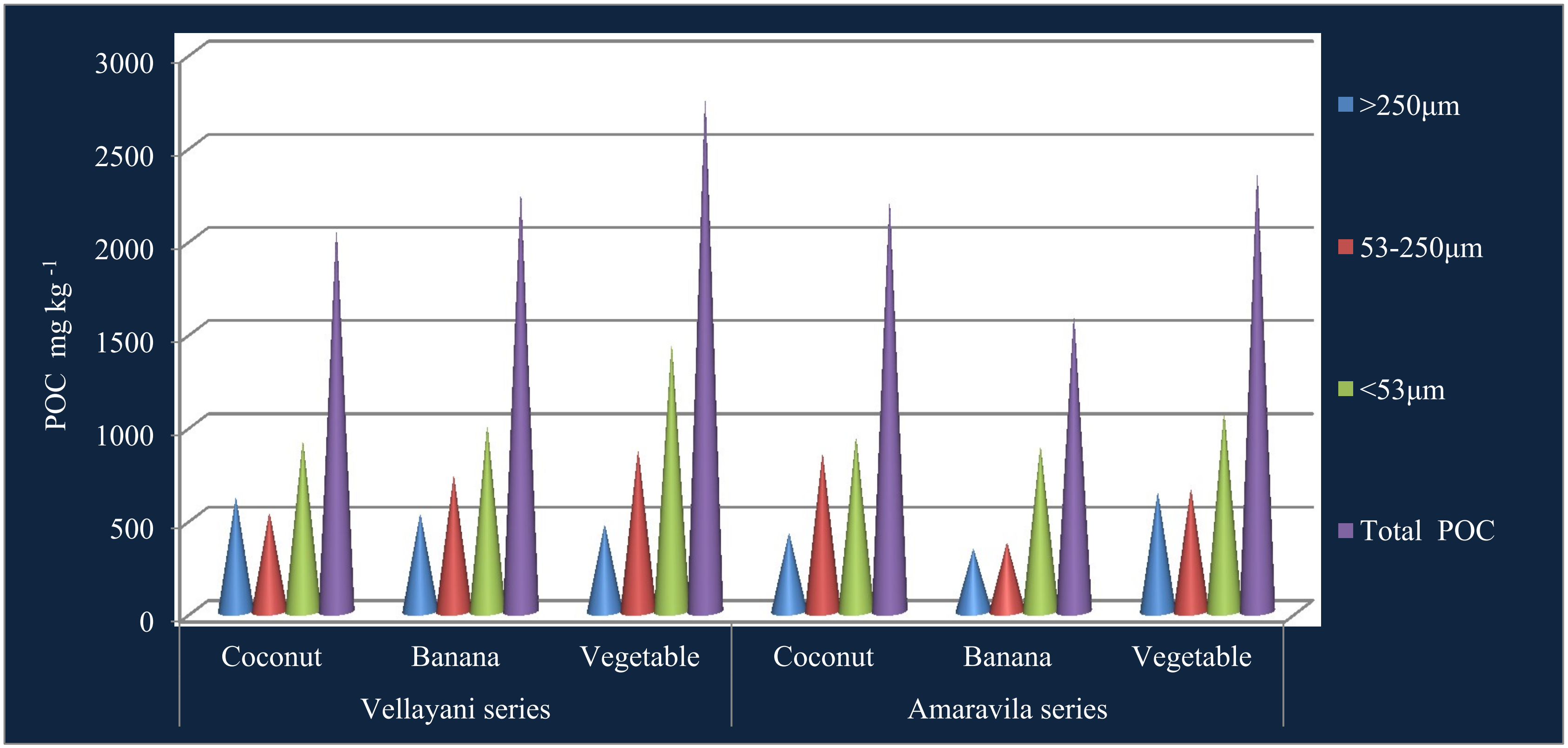


Fig. 11. Effect of agricultural land use systems on particulate organic carbon under Trivandrum and Kazhakuttam soil series.

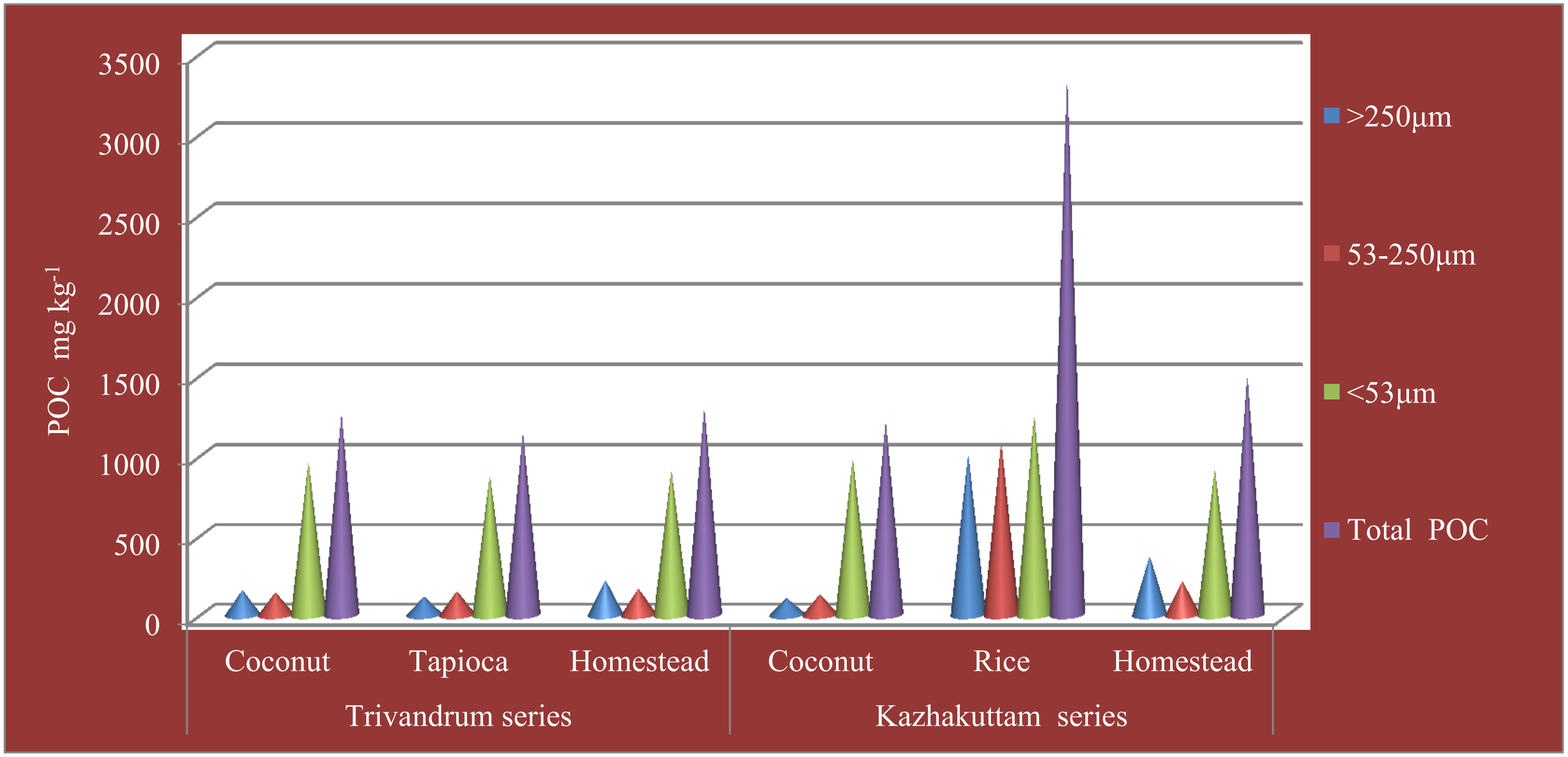
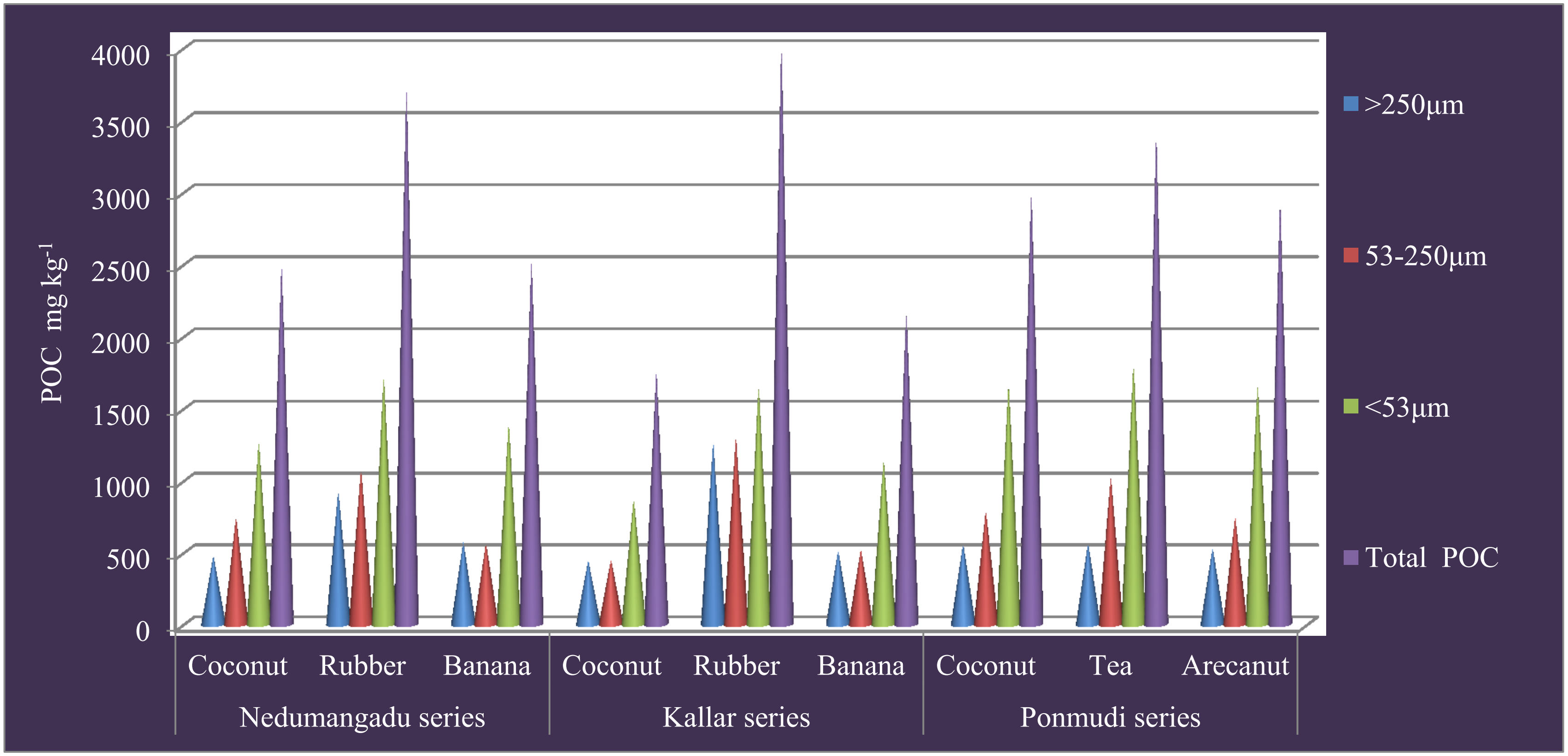


Fig. 12. Effect of agricultural land use systems on particulate organic carbon under Nedumangadu, Kallar and Ponmudi soil series.



5.3.6 Mineralizable carbon

Cumulative amount of carbon mineralized in 15 days of incubation ranged from 2.86 to 5.84 mg C kg^{-1} soil (Fig. 13). Higher amount of carbon was mineralized in banana (Vellyani series), coconut (Amaravila series), rubber (Nedumangadu and Kallar series), rice (Kazhakuttam series), tapioca (Trivandrum series) and arecanut (Ponmudi series) land uses. Application of organic sources resulted in increased carbon mineralization in surface soils. Irrespective of the land uses, (Fig.14 to 20) cumulative carbon mineralized increased from 0 to 15^{th} day of incubation.

The differences in the rates of C mineralization are indicative of variable amounts of labile organic carbon accumulated in different systems as reported by Manjumder *et al.* (2008).

The mineralizable carbon was strongly and positively related with CEC, SOC, HWSC, POC and LC in all series except Amaravila and Trivandrum, whereas negative relation was observed with sand content pH and EC Wei *et al.* (2008) reported that soil carbon fraction were significantly and positively correlated with each other.

Fig. 13. Effect of agricultural land use systems on mineralizeble carbon in various soil series.

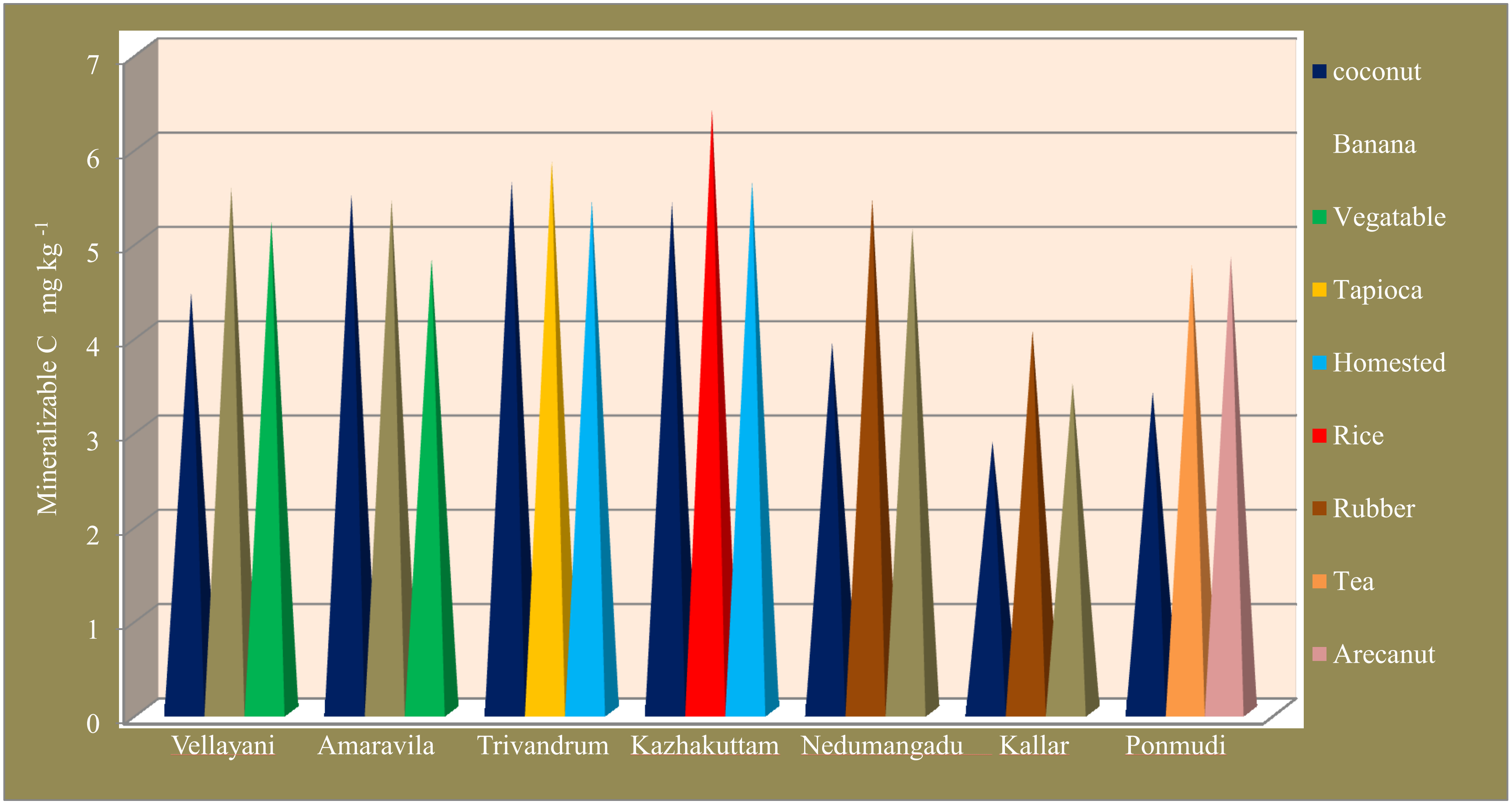
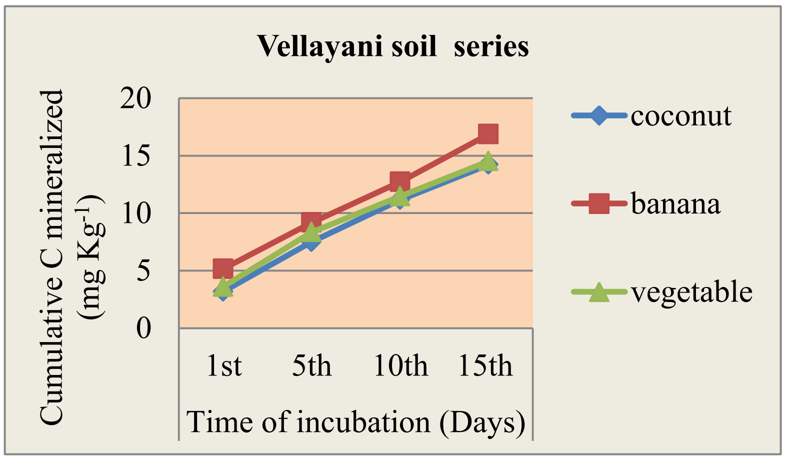


Fig. 14. Cumulative C mineralized (mg kg^{-1}) in Vellayani soil series. Fig. 15. Cumulative C mineralized (mg kg^{-1}) in Amaravila soil series.



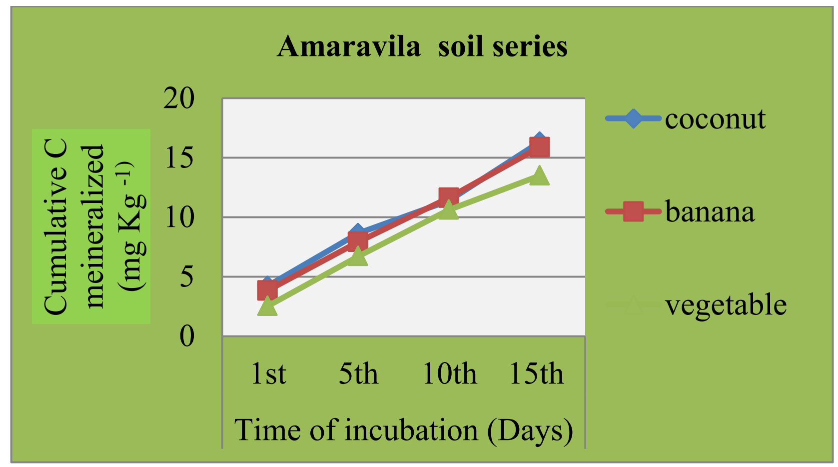
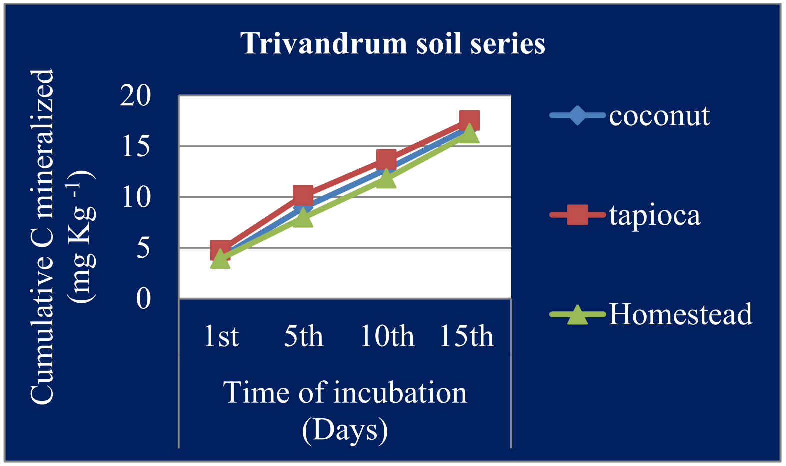


Fig.16.Cumulative C mineralized (mg kg^{-1}) in Trivandrum soil series. Fig.17. Cumulative C mineralized (mg kg^{-1}) in Kazhakuttam soil series



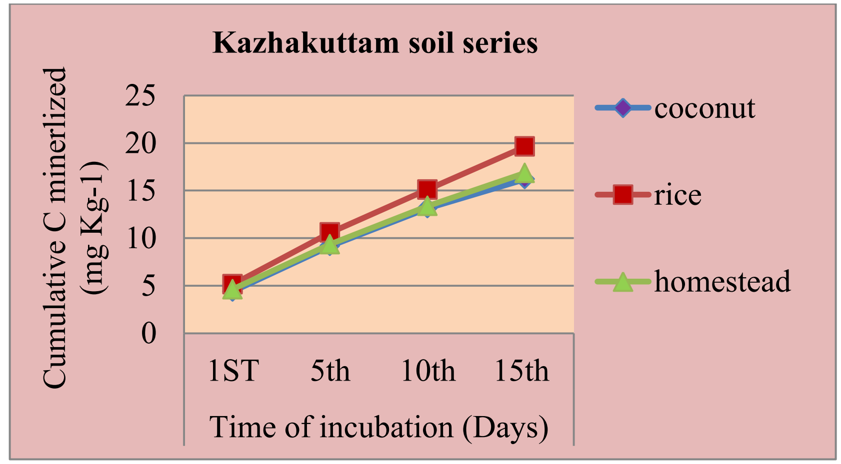


Fig. 18. Cumulative C mineralized (mg kg^{-1}) in Nadumangadu soil series.

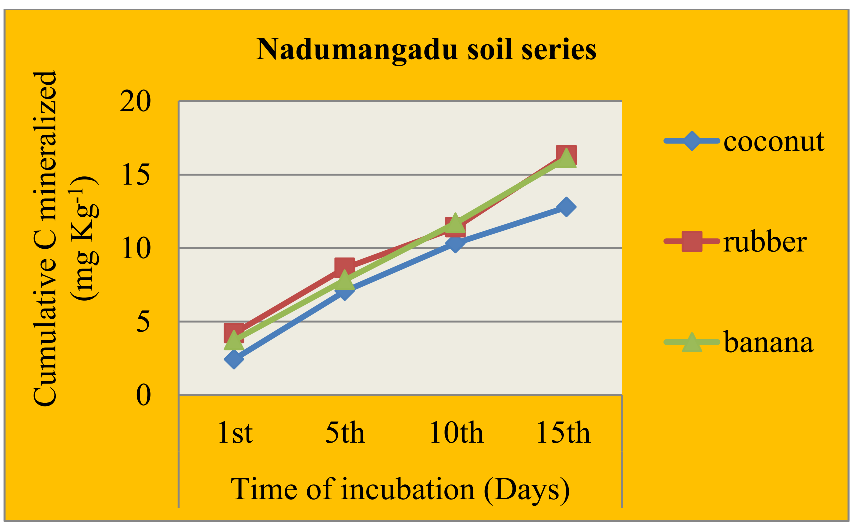


Fig. 19. Cumulative C mineralized (mg kg^{-1}) in Kallar soil series.

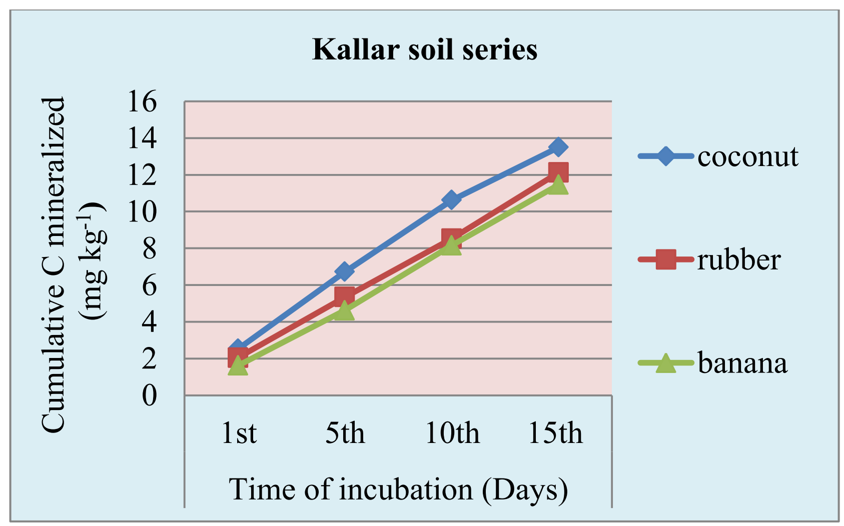
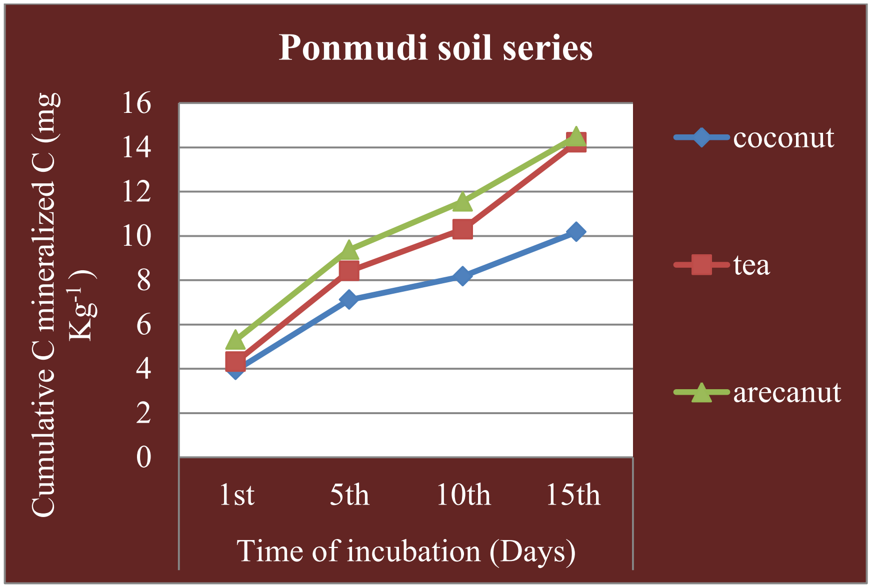


Fig 20. Cumulative C mineralized (mg kg^{-1}) in Ponmudi soil series.



SUMMARY

6. SUMMARY

Land use controls the carbon storage in terrestrial systems. Different land uses have different potentials for carbon sequestration due to differential soil organic carbon and aggregation dynamics. The present study was conducted to investigate the impact of agricultural land use systems on soil carbon pools in soil series of Thiruvannthapuram district with the specific objectives to study the soil carbon storage as different soil carbon pools and their distribution in different sized aggregates under different agricultural land use systems in major soil series like Vellayani, Amaravilla, Trivandrum, Kazhakuttam, Nedumangadu, Kallar and Ponmudi. Soil samples (0-15 cm depth) were collected from all these soil series under three agricultural land uses in each with five replications and analysed for physical and chemical properties like soil texture, bulk density, pH, EC, CEC, water stable aggregates and soil carbon pools like soil organic carbon, aggregate associated organic carbon, hot water soluble carbon, labile carbon, particulate organic carbon and mineralizable carbon as per standard procedures. The salient findings drawn from the results are summarized in this chapter.

6.1. EFFECT OF AGRICULTURAL LAND USE ON SOIL PROPERTIES.

Examination of various soil parameters revealed that the soil texture of most of the series varied from sandy loam to sandy clay loam. In all the series, the highest sand content was noticed in coconut land use. Silt and clay content were found to be more in vegetable, tapioca, rice, rubber and tea land use systems in various soil series. The soil properties *viz.,* bulk density, pH, EC, and CEC were found to be significantly influenced by different agricultural land use systems in all the series. The bulk density of the soil varied from 1.10 Mg m^{-3} in coconut land use of Vellayani series to 1.59 Mg m^{-3} in rice land use of Kazhakuttam series. The pH of various soil series ranged from 4.29 to 5.77, which were slightly acidic to moderately acidic in nature. The highest pH was recorded in tapioca land use of Trivandrum series. Electrical conductivity showed a wide range with minimum value of 0.02 dS m^{-1} in coconut land use of Amaravila series to a maximum value of 0.13 dS m^{-1} in rice land use of Kazhakuttam series. The cation exchange capacity of soil under different agricultural land use systems of various soil series ranged from 3.65 to 6.88 c mol (p^+) kg^{-1} soil. The highest value was recorded in vegetable land use of Vellayani series. The land use systems *viz.,* vegetable in Vellayani and Amaravila series, tapioca in Trivandrum series, rice in Kazhakuttam series, rubber in Nedumangadu and Kallar series and tea in Ponmudi series possessed highest CEC compared to other land uses in the respective series. With respect to water stable aggregates distribution, the macro aggregates constituted greater proportion compared to micro aggregates is all the soil series. The micro aggregates (0.1-0.25 mm) were found to be high in land uses like banana in Vellayani, Amaravila and Nedumangadu series, homestead in Trivandrum and Kazhakuttam series and coconut in Kallar and Ponmudi series. The macro aggregates were found to be high in coconut land use system in Vellayani, Amaravila, Trivandrum and Kazhakuttam series, rubber in Nedumangadu and Kallar series and tea in Ponmudi series.

6.2. EFFECT OF AGRICULTURAL LAND USE ON SOIL CARBON POOLS.

Soil organic carbon content in various soil series under different land use systems varied from 2.96 to 11.67 g kg^{-1}. The highest SOC was recorded in tea land use of Ponmudi series. The agricultural land use systems *viz.,* vegetable in Vellayani, coconut in Amaravila, rubber in Nedumangadu and Kallar, homestead in Trivandrum, rice in Kazhakuttam and tea in Ponmudi series significantly increased SOC in content in soil. With respect to aggregate associated organic carbon the concentration ranged between 146 and 1725 mg kg^{-1}. The highest concentration was noticed in rice land use of Kazhakuttam series. The macro aggregates were found to be richer in carbon compared to micro aggregates in Vellayani, Amaravila and Trivandrum series. In Kazhakuttam, Nedumangadu, Kallar and Ponmudi series microaggregates were found to be richer in carbon. The land uses *viz.,* vegetable in Vellayani and Amaravila, homestead in Trivandrum, rice in Kazhakuttam, rubber in Nedumangadu and Kallar, arecanut in Ponmudi series registered higher AAOC compared to other land uses in the respective series. Hot water soluble carbon in various soil series under different land use systems varied from 18.14 to 76.45 mg kg^{-1}, where the highest value was recorded in rice land use system in Kazhakuttam series. The labile carbon concentration ranged between 909 and 2541 mg kg^{-1}. The highest labile carbon recorded in coconut land use of Amaravila series. The different agricultural land uses *viz.,* vegetable in Vellayani, coconut in Amaravila and Trivandrum, rubber in Nedumangadu and Kallar, rice in Kazhakuttam and tea in Ponmudi series registered the highest concentration of labile carbon. Total particulate organic carbon in various soil series ranged from 1130 to 3980 mg kg^{-1}, where the highest value was recorded in rubber land use of Kallar series. Particulate organic carbon in very fine fraction (<53 µm) was found to be higher than fine (53-250 µm) and coarse (>250 µm) fractions. The mineralizable carbon content in various soil series ranged from 2.86 to 6.39 mg kg^{-1}. The highest content was recorded in rice land use system of Kazhakuttam series and the lowest content was recorded in coconut land use of Kallar series. The cumulative amount of carbon mineralized was also increased from 0 to 15^{th} day of incubation in all the series under different agricultural land use systems.

The study revealed that the vegetable land use system in Vellayani and Amaravila series, homestead in Trivandrum series, rice in Kazhakuttam series, rubber in Nedumangadu and Kallar series, tea and arecanut in Ponmudi series significantly contributed to soil carbon storage as different soil carbon pools distributed in different sized aggregates of soil due to increased organic carbon addition and aggregation dynamics.

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APPENDIX

APPENDIX I

GPS READINGS

Soil series	Agricultural land use	Replication	Latitude (N)	Longitude (E)	Altitude above MSL (m)
Vellayani	Cocoonut	R1	8° 25' 33.811"	76° 59' 21.802"	25
		R2	8° 25' 39.146"	76° 59' 49.587"	33
		R3	8° 24' 53.859"	77° 0' 27.088"	40
		R4	8° 25' 14.983"	76° 59' 5.315"	44
		R5	8° 25' 25.441"	76° 58' 33.967"	57
	Banana	R1	8° 26' 0.143"	76° 59' 16.623"	9
		R2	8° 25' 52.629"	77° 0' 1.922"	11
		R3	8° 24' 41.690"	77° 0' 17.195"	49
		R4	8° 24' 33.926"	76° 59' 25.121"	13
		R5	8° 25' 55.080"	76° 58' 35.935"	71
	Vegetable	R1	8° 25' 51.909"	76° 59' 0.268"	11
		R2	8° 25' 20.332"	76° 59' 51.756"	28
		R3	8° 25' 17.079"	77° 0' 20.240"	40
		R4	8° 25' 0.401"	76° 59' 25.246"	17
		R5	8° 25' 38.083"	76° 58' 22.350"	63
Amaravila	Coconut	R1	8° 25' 33.575"	77° 2' 29.020"	76
		R2	8° 24' 44.502"	77° 2' 6.109"	76
		R3	8° 23' 41.902"	77° 1' 8.918"	74
		R4	8° 23' 32.095"	77° 3' 37.127"	69
		R5	8° 23' 8.057"	77° 2' 45.695"	66
	Banana	R1	8° 25' 27.879"	77° 2' 20.023"	65
		R2	8° 24' 58.866"	77° 2' 21.591"	58
		R3	8° 24' 28.539"	77° 1' 46.067"	67
		R4	8° 23' 54.348"	77° 3' 32.151"	52
		R5	8° 23' 24.811"	77° 3' 8.718"	48
	Vegetable	R1	8° 25' 29.043"	77° 2' 26.796"	55
		R2	8° 24' 54.427"	77° 2' 10.919"	45
		R3	8° 24' 2.480"	77° 1' 44.321"	75
		R4	8° 23' 46.970"	77° 3' 39.494"	38
		R5	8° 23' 4.674"	77° 3' 12.909"	26

Soil series	Agricultural land use	Replication	Latitude (n)	Longitude (e)	Altitude above MSL (m)
Trivandrum	Coconut	R1	8° 35' 29.047"	76° 52' 41.633"	36
		R2	8° 38' 2.143"	76° 52' 56.197"	49
		R3	8° 37' 16.801"	76° 51' 33.047"	55
		R4	8° 38' 35.526"	76° 51' 5.155"	26
		R5	8° 39' 32.519"	76° 50' 15.185"	51
	Topioca	R1	8° 36' 50.937"	76° 53' 3.937"	34
		R2	8° 38' 24.929"	76° 52' 29.819"	72
		R3	8° 37' 50.979"	76° 51' 22.144"	52
		R4	8° 39' 7.449"	76° 51' 56.019"	35
		R5	8° 40' 3.831"	76° 50' 24.724"	47
	Homestead	R1	8° 35' 8.570"	76° 54' 8.187"	39
		R2	8° 38' 24.526"	76° 53' 17.387"	31
		R3	8° 37' 30.152"	76° 52' 34.304"	37
		R4	8° 38' 23.058"	76° 51' 33.042"	38
		R5	8° 39' 7.451"	76° 50' 41.486"	21
Kazhakuttam	Coconut	R1	8° 32' 31.563"	76° 52' 6.826"	4
		R2	8° 34' 34.680"	76° 51' 19.826"	5
		R3	8° 32' 53.775"	76° 51' 46.188"	12
		R4	8° 30' 50.423"	76° 53' 46.497"	6
		R5	8° 35' 32.202"	76° 49' 14.728"	7
	Rice	R1	8° 34' 5.330"	76° 50' 31.273"	10
		R2	8° 35' 10.867"	76° 50' 43.548"	9
		R3	8° 31' 27.910"	76° 52' 43.506"	8
		R4	8° 29' 28.475"	76° 54' 39.951"	5
		R5	8° 37' 18.834"	76° 48' 5.331"	10
	Homestead	R1	8° 33' 37.649"	76° 51' 55.197"	8
		R2	8° 34' 12.134"	76° 51' 38.004"	11
		R3	8° 33' 25.534"	76° 50' 58.357"	8
		R4	8° 28' 37.482"	76° 56' 21.104"	10
		R5	8° 36' 39.564"	76° 48' 40.972"	11

Soil series	Agricultural land use	Replication	Latitude (n)	Longitude (e)	Altitude above MSL (m)
Nadumangadu	Coconut	R1	8° 36' 6.897"	77° 2' 19.049"	68
		R2	8° 36' 41.085"	76° 58' 26.930"	88
		R3	8° 37' 11.707"	77° 1' 42.209"	85
		R4	8° 39' 0.736"	76° 58' 26.752"	132
		R5	8° 37' 52.317"	77° 3' 29.921"	110
	Rubber	R1	8° 35' 18.254"	77° 2' 44.893"	56
		R2	8° 36' 37.358"	76° 57' 37.451"	192
		R3	8° 39' 8.979"	77° 1' 41.656"	69
		R4	8° 38' 31.092"	76° 58' 8.265"	188
		R5	8° 38' 26.296"	77° 2' 54.991"	126
	Banana	R1	8° 36' 19.926"	77° 1' 12.026"	83
		R2	8° 35' 47.805"	76° 59' 0.508"	43
		R3	8° 37' 55.072"	77° 1' 7.740"	56
		R4	8° 38' 32.510"	76° 59' 57.262"	76
		R5	8° 36' 53.259"	77° 2' 34.636"	75
Kallar	Coconut	R1	8° 42' 9.322"	77° 8' 15.302"	270
		R2	8° 41' 29.947"	77° 8' 1.443"	205
		R3	8° 42' 51.736"	77° 7' 7.775"	155
		R4	8° 43' 24.840"	77° 8' 7.137"	490
		R5	8° 43' 56.082"	77° 4' 42.362"	153
	Rubber	R1	8° 41' 43.965"	77° 7' 13.397"	247
		R2	8° 40' 34.050"	77° 7' 40.850"	116
		R3	8° 43' 33.027"	77° 6' 0.726"	439
		R4	8° 43' 46.751"	77° 7' 13.324"	204
		R5	8° 42' 36.320"	77° 4' 24.557"	81
	Banana	R1	8° 41' 34.560"	77° 8' 47.565"	380
		R2	8° 40' 56.002"	77° 6' 34.881"	109
		R3	8° 42' 24.587"	77° 6' 13.128"	124
		R4	8° 42' 39.725"	77° 7' 54.987"	209
		R5	8° 43' 10.862"	77° 3' 42.233"	112

Soil series	Agricultural land use	Replication	Latitude (N)	Longitude (E)	Altitude above MSL (m)
Ponmudi	Coconut	R1	8° 41' 52.806"	77° 9' 48.240"	850
		R2	8° 44' 25.214"	77° 5' 39.577"	698
		R3	8° 44' 2.870"	77° 9' 23.487"	1078
		R4	8° 44' 55.093"	77° 6' 26.291"	603
		R5	8° 45' 1.982"	77° 7' 19.867"	664
	Tea	R1	8° 42' 25.618"	77° 10' 8.233"	765
		R2	8° 44' 31.418"	77° 6' 25.549"	509
		R3	8° 44' 29.119"	77° 9' 23.255"	1161
		R4	8° 44' 21.842"	77° 8' 11.810"	864
		R5	8° 45' 29.275"	77° 6' 40.147"	876
	Arecanut	R1	8° 41' 40.634"	77° 10' 47.066"	964
		R2	8° 43' 54.169"	77° 7' 42.908"	378
		R3	8° 43' 55.638"	77° 9' 42.829"	904
		R4	8° 44' 13.572"	77° 7' 33.175"	474
		R5	8° 45' 44.151"	77° 6' 1.489"	592

APPENDIX – II

CORRELATION STUDIES

1. Correlation between various soil properties and soil carbon pools in Vellayani soil series

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.822	1											
Clay	-0.999**	0.830	1										
BD	-0.872	0.438	0.864	1									
TWSA	0.765	-0.262	-0.755	-0.982	1								
pH	0.637	-0.086	-0.625	-0.933	0.983	1							
EC	0.948	-0.600	-0.943	-0.981	0.929	0.848	1						
CEC	-0.912	0.516	0.905	0.996	-0.961	-0.897	-0.994	1					
SOC	-0.999**	0.799	0.998*	0.890	-0.790	-0.667	-0.960	0.927	1				
HWSC	-0.626	0.958	0.638	0.165	0.021	0.199	-0.348	0.252	0.595	1			
LC	-0.983	0.705	0.980	0.946	-0.869	-0.766	-0.990	0.971	0.989	0.475	1		
POC	-0.962	0.945	0.967	0.707	-0.563	-0.406	-0.828	0.768	0.951	0.813	0.898	1	
MC	-0.678	0.139	0.667	0.951	-0.992	-0.998*	-0.875	0.919	0.707	-0.146	0.800	0.455	1

** Significant at P = 0.01 level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

2. Correlation between various soil properties and soil carbon pools in Amaravila soil series

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.972	1											
Clay	-0.768	0.596	1										
BD	0.953	-0.855	-0.925	1									
TWSA	0.988	-0.924	-0.856	0.988	1								
p^H	0.747	-0.571	-0.999**	0.913	0.840	1							
EC	-0.955	0.998	0.545	-0.821	-0.899	-0.518	1						
CEC	-0.898	0.976	0.410	-0.724	-0.821	-0.381	0.988	1					
SOC	0.900	-0.772	-0.970	0.989	0.956	0.962	-0.731	-0.618	1				
HWSC	-0.938	0.831	0.942	-0.998*	-0.980	-0.931	0.794	0.692	-0.995	1			
LC	0.367	-0.139	-0.877	0.631	0.505	0.892	-0.077	0.076	0.736	-0.666	1		
POC	-0.089	0.320	-0.568	0.215	0.063	0.594	0.379	0.516	0.353	-0.260	0.893	1	
MC	0.850	-0.950	-0.317	0.652	0.760	0.287	-0.967	-0.995	0.537	-0.616	-0.175	-0.599	1

** Significant at P = 0.01level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = total water stable aggregate, CEC = cation exchange capacity, SOC = soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

3. Correlation between various soil properties and soil carbon pools in Trivandrum soil series.

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.993	1											
Clay	-0.970	0.935	1										
BD	0.645	-0.552	-0.811	1									
TWSA	-0.179	0.064	0.412	-0.867	1								
p^H	-0.164	0.048	0.398	-0.859	0.999**	1							
EC	-0.866	0.802	0.961	-0.940	0.646	0.634	1						
CEC	-0.977	0.946	0.999**	-0.793	0.384	0.369	0.952	1					
SOC	-0.794	0.860	0.624	-0.050	-0.453	-0.467	0.386	0.648	1				
HWSC	0.999**	-0.989	-0.977	0.668	-0.209	-0.193	-0.881	-0.983	-0.776	1			
LC	0.948	-0.904	-0.996	0.855	-0.483	-0.469	-0.980	-0.993	-0.560	0.957	1		
POC	0.308	-0.196	-0.530	0.925	-0.991	-0.988	-0.742	-0.503	0.331	0.337	0.595	1	
MC	-0.028	-0.087	0.270	-0.781	0.988	0.990	0.523	0.239	-0.583	-0.059	-0.345	-0.959	1

** Significant at P = 0.01level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

4. Correlation between various soil properties and soil carbon pools in Kazhakuttam soil series.

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.999**	1											
Clay	-0.992	0.995	1										
BD	-0.951	0.960	0.981	1									
TWSA	-0.985	0.980	0.958	0.886	1								
pH	0.932	-0.942	-0.969	-0.998*	-0.858	1							
EC	-0.959	0.967	0.986	0.999**	0.897	-0.996	1						
CEC	-0.424	0.451	0.530	0.681	0.265	-0.722	0.663	1					
SOC	-0.843	0.859	0.902	0.967	0.741	-0.980	0.961	0.844	1				
HWSC	-0.960	0.968	0.987	0.999**	0.900	-0.996	0.999**	0.659	0.959	1			
LC	-0.870	0.884	0.923	0.979	0.774	-0.989	0.974	0.815	0.998*	0.972	1		
POC	-0.881	0.894	0.931	0.983	0.788	-0.992	0.978	0.802	0.997*	0.977	0.999**	1	
MC	-0.846	0.862	0.904	0.968	0.744	-0.981	0.962	0.841	0.999**	0.961	0.998*	0.997	1

** Significant at P = 0.01 level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

5. Correlation between various soil properties and soil carbon pools in Nedumangadu soil series

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	0.170	1											
Clay	-0.939	-0.497	1										
BD	0.037	0.991	-0.378	1									
TWSA	0.632	0.870	-0.859	0.797	1								
pH	-0.866	-0.639	0.985	-0.532	-0.934	1							
EC	0.805	-0.447	-0.553	-0.561	0.050	-0.401	1						
CEC	0.452	0.955	-0.731	0.907	0.977	-0.837	-0.163	1					
SOC	-0.161	0.945	-0.187	0.980	0.662	-0.353	-0.714	0.806	1				
HWSC	0.535	0.923	-0.792	0.864	0.992	-0.885	-0.069	0.995	0.747	1			
LC	-0.136	0.953	-0.212	0.984	0.681	-0.377	-0.696	0.821	0.999**	0.763	1		
POC	0.272	0.994	-0.586	0.971	0.917	-0.716	-0.350	0.981	0.905	0.958	0.916	1	
MC	-0.519	0.753	0.195	0.834	0.333	0.023	-0.925	0.526	0.926	0.443	0.917	0.680	1

** Significant at P = 0.01 level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

6. Correlation between various soil properties and soil carbon pools in Kallar soil series.

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.989	1											
Clay	-0.983	0.948	1										
BD	-0.579	0.457	0.716	1									
TWSA	-0.523	0.395	0.667	0.997*	1								
pH	0.947	-0.983	-0.874	-0.288	-0.223	1							
EC	-0.329	0.460	0.154	-0.578	-0.632	-0.613	1						
CEC	-0.638	0.521	0.766	0.997*	0.989	-0.359	-0.516	1					
SOC	-0.925	0.862	0.978	0.844	0.806	-0.756	-0.052	0.882	1				
HWSC	-0.992	0.964	0.998*	0.676	0.624	-0.900	0.209	0.729	0.965	1			
LC	-0.727	0.621	0.838	0.980	0.965	-0.469	-0.408	0.992	0.932	0.806	1		
POC	-0.774	0.675	0.875	0.964	0.944	-0.531	-0.343	0.981	0.956	0.846	0.997*	1	
MC	-0.954	0.902	0.992	0.796	0.753	-0.809	0.032	0.838	0.996	0.984	0.898	0.927	1

** Significant at P = 0.01 level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC = Mineralizable carbon.

7. Correlation between various soil properties and soil carbon pools in Ponmudi soil series.

-	Sand	Silt	Clay	BD	TWSA	pH	EC	CEC	SOC	HWSC	LC	POC	MC
Sand	1												
Silt	-0.711	1											
Clay	-0.955	0.472	1										
BD	0.812	-0.167	-0.948	1									
TWSA	-0.980	0.561	0.994	-0.910	1								
pH	-0.567	0.982	0.298	0.019	0.396	1							
EC	0.823	-0.187	-0.954	0.999**	-0.918	0.090	1						
CEC	-0.126	-0.607	0.413	-0.681	0.317	-0.745	-0.666	1					
SOC	-0.318	-0.439	0.584	-0.811	0.497	-0.599	-0.800	0.980	1				
HWSC	-0.323	-0.434	0.588	-0.814	0.501	-0.595	-0.803	0.979	0.999**	1			
LC	-0.690	-0.017	0.873	-0.982	0.817	-0.204	-0.978	0.804	0.905	0.908	1		
POC	-0.292	-0.463	0.562	-0.795	0.473	-0.621	-0.783	0.985	0.999**	0.999**	0.893	1	
MC	-0.999**	0.699	0.960	-0.822	0.984	0.552	-0.833	0.143	0.335	0.340	0.702	0.309	1

** Significant at P = 0.01 level, * significant at P = 0.05 level.

BD = Bulk density, TWSA = Total water stable aggregate, CEC = Cation exchange capacity, SOC = Soil organic carbon, HWSC = Hot water soluble carbon, LC = Labile carbon, POC = Particulate organic carbon, MC =Mineralizable carbon.

ABSTRACT

IMPACT OF AGRICULTURAL LAND USE SYSTEMS ON SOIL CARBON POOLS IN SOIL SERIES OF THIRUVANANTHAPURAM DISTRICT

by

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(2014-11-243)

ABSTRACT

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ABSTRACT

An investigation entitled "Impact of agricultural land use systems on soil carbon pools in soil series of Thiruvananthapuram district" was carried out to study the soil carbon storage as different soil carbon pools and their distribution in different sized soil aggregates under different agricultural land use systems in soil series of Thiruvananthapuram district. The seven major soil series of Thiruvananthapuram district namely Vellayani, Amaravila, Trivandrum, Kazhakuttam, Nedumangadu, Kallar and Ponmudi were selected and three agricultural land use systems were identified in each soil series. Surface soil samples (0-15 cm) were collected and analysed for soil physico-chemical properties and soil carbon pools.

Examination of various soil parameters revealed that the soil texture in most of the soil series varied from sandy loam to sandy clay loam. The bulk density of soil varied from 1.10 to 1.59 Mg m^{-3}. The highest BD was recorded in rice land use of Kazhakuttam series. The pH of various soil series ranged from 4.29 to 5.77. The highest value was recorded in tapioca land use of Trivandrum soil series. EC of the soils ranged from 0.02 to 0.13 dS m^{-1}. The highest EC was recorded in rice land use of Kazhakuttam series. The CEC of the soil was significantly influenced by different land uses in all the soil series and the values ranged between 3.65 and 6.88 c mol (p^{+}) kg^{-1}. The highest CEC was possessed by vegetable land use of Vellayani series.

The effect of agricultural land use systems on the extent of different sized water stable aggregates *viz.,* 5-8, 2-5, 1-2, 0.5-1, 0.25-0.5 and 0.1-0.25 mm were found to be significant. The highest total water stable aggregate of 95.08 % was registered in rubber land use system of Nedumangadu series.

Soil organic carbon (SOC) content in various soil series under different land use systems varied from 2.96 to 11.67 g kg^{-1}. The agricultural land use systems *viz.,*

vegetable (8.73 g kg^{-1}), coconut (7.96 g kg^{-1}), rubber (9.37 and 9.93 g kg^{-1}), homestead (7.30 g kg^{-1}), rice (9.96 g kg^{-1}) and tea (11.97 g kg^{-1}) significantly increased SOC in various soil series. With respect to aggregate associated organic carbon, macro aggregates were found to be richer in carbon compared to micro aggregates in Vellayani, Amaravila and Trivandrum series. In the other soil series, micro aggregates were found to be richer in carbon. The agricultural land use systems *viz.,* vegetable (1657 mg kg^{-1}, 1400 mg kg^{-1}), homestead (667 mg kg^{-1}), rice (1725 mg kg^{-1}), rubber (1132 and 1364 mg kg^{-1}) and arecanut (1344 mg kg^{-1}) significantly increased AAOC in various soil series.

Hot water soluble carbon in various soil series under different land use systems varied from 20.66 to 76.45 mg kg^{-1}, where the highest value was recorded in rice land use system in Kazhakuttam series. With respect to labile carbon, the land use systems *viz.,* vegetable (1997 mg kg^{-1}), coconut (2541 mg kg^{-1}), rubber (2211 and 1349 mg kg^{-1}), coconut (2516 mg kg^{-1}), rice (2187 mg kg^{-1}) and tea (1241 mg kg^{-1}) registered significantly higher content in various soil series. Particulate organic carbon (POC) in very fine fraction (<53 μm) was found to be higher than fine (53-250 μm) and coarse (>250 μm) fractions. Total POC in various soil series under different land use systems varied from 1130 to 3980 mg kg^{-1}, where the highest value was recorded in rubber land use system of Kallar series. The mineralizeble carbon concentration was found to be the highest under rice land use of Kazhakuttam series (6.39 mg kg^{-1}) and the lowest under coconut land use of Kallar series (2.86 mg kg^{-1}).

The study revealed that vegetable land use system in Vellayani and Amaravila series, rubber in Nedumangadu and Kallar series, homestead in Trivandrum series, rice in Kazhakuttam series and tea and arecanut in Ponmudi series significantly contributed to soil organic carbon storage as different soil carbon pools in different sized aggregates compared to other land uses in the respective soil series.