

**IMPACT OF LAND USE SYSTEMS ON NUTRIENT STATUS  
AND CARBON DISTRIBUTION IN SOILS OF THIRTHAHALLI  
TALUK, SHIVAMOGGA DISTRICT**

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SCIENCES, SHIVAMOGGA - 577 204**

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***Master of Science (Agriculture)***

**In**

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**SHIVAMOGGA**

**July, 2016**



*Affectionately*  
*Dedicated to*  
*My Mother*  
*Smt. Annapurna shettar*  
*My Brother*  
*Raj shettar and my Guide*  
*Dr. K. T. Gurumurthy*

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY  
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES

SHIVAMOGGA – 577 204

CERTIFICATE

This is to certify that the thesis entitled **IMPACT OF LAND USE SYSTEMS ON NUTRIENT STATUS AND CARBON DISTRIBUTION IN SOILS OF THIRTHAHALLI TALUK, SHIVAMOGGA DISTRICT** submitted in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the College of Agriculture, Shivamogga, University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **ASHA SUBHASH SHETTAR** during the period of study in this university under my guidance and supervision, and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or similar other titles.

Shivamogga


July, 2016

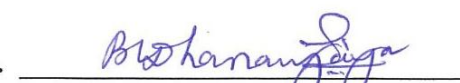
  
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*Shivamogga*

*July, 2016*



*ASHA SUBHASH SHETTAR*

# **IMPACT OF LANDUSE SYSTEMS ON NUTRIENT STATUS AND CARBON DISTRIBUTION IN SOILS OF THIRTHAHALLI TALUK, SHIVAMOGGA DISTRICT**

ASHA SUBHASH SHETTAR

## **Abstract**

An investigation was carried out during 2015-16 to study the impact of landuse systems on nutrient status and carbon distribution in soils of Thirthahalli taluk, Shivamogga district. The landuse systems studied included forest, arecanut, coconut, paddy, fallow. The present investigation indicated that texture varied from sandy loam to sandy clay loam. The highest ( $1.44 \text{ mg m}^{-3}$ ) mean BD was observed under paddy land use and highest mean moisture (35.91%) content was observed under forest land use system. The pH was acidic in all the soils under investigation. The highest mean organic carbon content ( $19.23 \text{ g kg}^{-1}$ ) was noticed in forest as compared to other land use systems. Calcium carbonate equivalent was higher (0.36%) in forest land use system.

Available mean nitrogen ( $372.7 \text{ kg ha}^{-1}$ ) and phosphorus ( $28.27 \text{ kg ha}^{-1}$ ) was highest in forest, and lower in paddy land use system, mean available potassium varied from 115.3 to  $382.2 \text{ kg ha}^{-1}$  under different land use systems. The primary nutrients decreased with depth, the mean exchangeable calcium and magnesium were higher ( $6.04$  and  $2.52 \text{ cmol (p+) kg}^{-1}$  respectively) in forest land use system. The mean available sulphur was higher ( $25.1 \text{ mg kg}^{-1}$ ) in forest as compared to other land use systems.

Highest mean Potassium permanganate oxidizable carbon content was noticed in forest ( $1182.7 \text{ mg Kg}^{-1}$ ) and lower in paddy land use systems. Highest mean cold water extractable ( $43.3 \text{ mg Kg}^{-1}$ ) and microbial biomass carbon ( $437.7 \text{ mg kg}^{-1}$ ) were observed in forest land use systems and decreased with depth. The highest mean soil organic carbon stock was recorded in forest ( $37.89 \text{ t C ha}^{-1}$ ) land use at surface depth. The humic acid and fulvic acid ratios were higher in forest land as compared to other land use systems.

July, 2016

Department of soil science  
And Agriculture Chemistry  
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Navile, Shivamogga.

  
K. T. Gurumurthy  
Major advisor

ಶಿವಮೊಗ್ಗ ಜಿಲ್ಲೆಯ ತೀರ್ಥಹಳ್ಳಿ ತಾಲ್ಲೂಕಿನ ಮಣ್ಣಿನಲ್ಲಿರುವ ಪೋಷಕಾಂಶಗಳ ಸ್ಥಿತಿ ಹಾಗೂ  
ಇಂಗಾಲ ವಿತರಣೆ ಮೇಲೆ ಭೂಬಳಕೆ ಪದ್ಧತಿಗಳ ಪ್ರಭಾವ

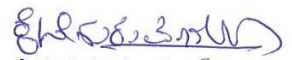
ಆಶಾ ಸುಭಾಷ್ ಶೆಟ್ಟರ್

ಸಾರಾಂಶ

ಶಿವಮೊಗ್ಗ ಜಿಲ್ಲೆಯ ತೀರ್ಥಹಳ್ಳಿ ತಾಲ್ಲೂಕಿನ ಮಣ್ಣಿನಲ್ಲಿರುವ ಪೋಷಕಾಂಶಗಳ ಸ್ಥಿತಿ ಮತ್ತು ಇಂಗಾಲದ ವಿತರಣೆ ಮೇಲೆ ಭೂ ಪದ್ಧತಿಗಳು ಬೀರುವ ಪ್ರಭಾವವನ್ನು ತಿಳಿಯಲು ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ, ಶಿವಮೊಗ್ಗದಲ್ಲಿ ಸಂಶೋಧನೆಯನ್ನು ೨೦೧೫-೧೬ ರಲ್ಲಿ ಹಮ್ಮಿಕೊಳ್ಳಲಾಗಿತ್ತು. ಅಧ್ಯಯನದ ಭೂ ಪದ್ಧತಿಗಳಾದ ಅರಣ್ಯ, ಅಡಿಕೆ, ತೆಂಗು, ಭತ್ತ ಹಾಗೂ ಪಾಳುಭೂಮಿಯನ್ನು ಒಳಗೊಂಡಿತ್ತು. ಈ ಸಂಶೋಧನೆಯಲ್ಲಿ ಮಣ್ಣಿನ ಕಣರಚನೆಯ ಮರಳುಮಿಶ್ರಿತ ಜೇಡಿ ಮಣ್ಣಿನಿಂದ ಕೂಡಿದ್ದು, ಭತ್ತದ ಭೂಬಳಕೆಯಲ್ಲಿ ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು (೧.೪೪ ಮಿ.ಗ್ರಾಂ./ಘ.ಚ.ಮೀ.) ನೈಜ ಸಾಂದ್ರತೆ ಇದ್ದು ಅತಿ ಹೆಚ್ಚು ತೇವಾಂಶವು (ಶೇ.೩೫.೯೧) ಅರಣ್ಯ ಭೂಬಳಕೆಯ ಪದ್ಧತಿಯ ಮಣ್ಣಿನಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಮಣ್ಣಿನ ಆಳ ಹೆಚ್ಚಿದಂತೆ ಹೆಚ್ಚಾಗಿರುವುದು ತಿಳಿದುಬಂದಿದೆ. ಆಮ್ಲೀಯ ರಸಸಾರವು ಎಲ್ಲಾ ಮಣ್ಣುಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದ್ದು, ಇತರ ಭೂಬಳಕೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಅತಿ ಹೆಚ್ಚು ಸರಾಸರಿ ಸಾವಯವ ಇಂಗಾಲವು ಅರಣ್ಯ ಭೂಬಳಕೆಯಲ್ಲಿ (೧೯.೨೩ ಗ್ರಾಂ./ಕಿ.ಗ್ರಾಂ.) ಕಂಡುಬಂದಿದೆ. ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು ಕ್ಯಾಲ್ಸಿಯಂ ಕಾರ್ಬೋನೇಟ್ ಪ್ರಮಾಣವು (ಶೇ. ೦.೩೬) ಅರಣ್ಯ ಭೂಬಳಕೆಯಲ್ಲಿ ಲಭ್ಯವಿರುವುದು ತಿಳಿದುಬಂದಿದೆ. ಲಭ್ಯವಿರುವ ಅತಿ ಹೆಚ್ಚು ಸರಾಸರಿ ಸಾರಜನಕ (೩೭೨.೦೭ ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಮತ್ತು ಸರಾಸರಿ ರಂಜಕಗಳ ಅಂಶವು (೨೮.೨೭ ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಅರಣ್ಯ ಭೂಬಳಕೆಯಲ್ಲಿ ಹಾಗೂ ಲಭ್ಯವಿರುವ ಸರಾಸರಿ ಪೋಟ್ಯಾಷಿಯಂ ೧೧೫.೫ ರಿಂದ ೩೮೨.೨ ಕಿ.ಗ್ರಾಂ./ಹೆ. ವರೆಗೆ ವಿವಿಧ ಭೂಬಳಕೆಯಲ್ಲಿ ಇರುವುದು ಈ ಸಂಶೋಧನೆಯಿಂದ ತಿಳಿದಿದೆ. ಪ್ರಾಥಮಿಕ ಪೋಷಕಾಂಶಗಳು ಮಣ್ಣಿನ ಆಳ ಹೆಚ್ಚಿದಂತೆ ಕಡಿಮೆಯಾಗಿರುವುದು ಕಂಡುಬಂದಿರುತ್ತದೆ. ವಿನಿಮಯ ಕ್ಯಾಲ್ಸಿಯಂ ಮತ್ತು ಮೆಗ್ನೀಷಿಯಂ ಪ್ರಮಾಣಗಳು ಅರಣ್ಯ ಭೂಮಿಯಲ್ಲಿ (೬.೦೪ ಮತ್ತು ೨.೫೨ ಸೆ.ಮೋಲ್ಸ್‌ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಅಧಿಕವಾಗಿದ್ದು ಹಾಗೂ ಇತರ ಭೂಬಳಕೆಗೆ ಹೋಲಿಸಿದರೆ ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು ಲಭ್ಯವಿರುವ ಗಂಧಕವು (೨೫.೧ ಮಿ.ಗ್ರಾಂ./ಕಿ.ಗ್ರಾಂ.) ಅರಣ್ಯ ಭೂಮಿಯಲ್ಲಿ ಹೇರಳವಾಗಿರುವುದು ತಿಳಿದುಬಂದಿದೆ. ಪೋಟ್ಯಾಷಿಯಂ ಪರ್ಮಾಂಗನೇಟ್ ಉತ್ಕರ್ಷಣೆಯ ಇಂಗಾಲ ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು ಅಂಶವು (೧೧೮೨.೭ ಮಿ.ಗ್ರಾಂ./ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಅರಣ್ಯ ಭೂ ಬಳಕೆ ಹಾಗೂ ತಣ್ಣೀರಿನ ನಕಲಿತ 'ಬಹುದಾದ ಇಂಗಾಲದ ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು ಅಂಶವು (೪೩.೩ ಮಿ.ಗ್ರಾಂ./ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಮತ್ತು ಸೂಕ್ಷ್ಮಜೀವಿಯ ಜೀವರಾಶಿ (೪೩೭.೭ ಮಿ.ಗ್ರಾಂ./ಕಿ.ಗ್ರಾಂ./ಹೆ.) ಅರಣ್ಯ ಭೂಮಿಬಳಕೆಯಲ್ಲಿ ಇರುವುದು ತಿಳಿದಿದೆ. ಅರಣ್ಯ ಭೂಬಳಕೆಯಲ್ಲಿ ಸರಾಸರಿ ಅತಿ ಹೆಚ್ಚು (೩೭.೮೯ ಟಿ.ಸಿ./ಹೆ) ಮಣ್ಣಿನ ಸಾವಯವ ಇಂಗಾಲದ ಸಂಗ್ರಹ ದಾಖಲೆಯಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ನೆಲಗೊಬ್ಬರ ಆಮ್ಲ ಮತ್ತು ಫೆಲ್ಡ್ಸ್ ಆಮ್ಲಗಳ ಅನುಪಾತಗಳು, ಇತರ ಭೂಮಿಯ ಬಳಕೆಗೆ ಹೋಲಿಸಿದರೆ ಅರಣ್ಯ ಭೂಮಿಯಲ್ಲಿ ಅಧಿಕವಾಗಿರುವುದು ತಿಳಿದುಬಂದಿದೆ.

ಜುಲೈ, ೨೦೧೬

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ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ  
ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕಾ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಶಿವಮೊಗ್ಗ.



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(ಪ್ರಧಾನ ಸಲಹೆಗಾರರು)

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# *Introduction*

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## I. INTRODUCTION

Land-use change is one of the main reason for environmental change being a major issue of global environmental change. This change influences the basic resources of land and a variety of natural processes, including the soils which are not static and hence more susceptible to changes in their nutrient and moisture content. The dynamic soil nature describes the condition of a specific soil due to land use and management practices.

Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone. Land-use changes are also known to be important drivers for soil redistribution, by influencing surface run off, erosion and sedimentation processes.

Many researchers have reported that change of land use, implemented locally such as long term cultivation, deforestation, overgrazing and mineral fertilization can cause significant variations in soil properties, terrestrial cycles and reduction of output and that the conversion of natural forests to other forms of land-use can provoke soil erosion and lead to a reduction in soil organic-content, loss of soil quality and modification of soil structure and its stability.

The most significant land-use change affecting soils world over within the past few decades has been decrease in forest cover and intensified agriculture. Cultivation reduces soil carbon content and changes the distribution and stability of soil aggregates. Land use changes, especially cultivation of deforested land may rapidly diminish soil quality which may lead to a permanently degraded land.

Different land use systems influences soil aggregation, aggregate stability and overall soil health. Land use changes have a great influence on many soil physico-chemical properties, mostly soil organic matter affecting its quality attributes and fertility.

Carbon sequestration in soils is based on the assumption that fluxes or movements of carbon from the air to the soil can be increased, while the release of soil carbon back to the atmosphere is decreased. Instead of being a carbon source, soils could be transformed into carbon sinks, absorbing carbon instead of emitting it.

Soil carbon is an important part of terrestrial carbon pool and soils of the world are potentially viable sinks for atmospheric carbon.

It is estimated that world's soil contains about 1500 Gt of organic carbon to a depth of 1m and a further 900 Gt from 1-2 m. However, soil is deteriorating at an alarming rate in developing countries like Nepal due to land use changes, lowering carbon sequestration. The complex mechanisms and processes regulating carbon sequestration in soil are inadequately understood. Soil organic carbon (SOC) content exhibits considerable variability both spatially and horizontally according to land use and vertically within the soil profile.

The soil organic carbon diminishes with depth regardless of vegetation, soil texture and clay size fraction. Removal of trees from the forest displaces a large amount of sequestered carbon and consequently reduces carbon held in terrestrial biomass. The negative impact of deforestation on soil organic carbon decrease is more pronounced in the upper soil layer. Gradual conversion of forest and grassland to cropland has resulted in historically significant losses of soil carbon worldwide.

The information about the impact of land use changes on the labile carbon pools and microbial carbon in the soils can eventually improve the knowledge and organic carbon dynamics in different land use systems. The study will be useful to identify suitable land use systems that can maintain the soil sustainability / soil health and thus crop productivity. Adoption of best land use and management practices will benefit the farmer in realizing the optimum crop yield of different crop species. The data base will be useful to the researchers and planners which helps in maintaining soil health for sustainable agriculture.

Keeping these in view, the present investigation was undertaken to study the impact of land use systems on nutrient and carbon distribution in soils of Thirthahalli Taluk, Shivamogga district, with the following objectives.

1. To study the soil fertility status of different land use systems.
2. To study the impact of land use systems on carbon fraction in soil and
3. To bring about relationship between soil properties and soil carbon fraction under different land use systems.

# *Review of Literature*

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## II. REVIEW OF LITERATURE

The information available based on scientific works in India and abroad on characterization of soils under different land use systems and to know the effect of land use systems on some physical and chemical properties of soils are reviewed and presented in this chapter.

### 2.1 Physical properties of soil

Physical properties such as particle size distribution, bulk density, and maximum water holding capacity plays crucial role in deciding soil fertility and crop growth.

#### 2.1.1 Particle size distribution

Soil texture determines a number of physical and chemical properties of soils. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Foth, 1990). It is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil (Miller and Donahue, 1995).

Chavan *et al.* (1995) reported that the soils were sandy loam to clay loam in texture under forest. The clay content increased in the lower depth. This was due to high rainfall resulting in the vertical or downward movement of clay in the soil through the voids created by the plant roots and decomposed organic matter.

Soil texture is one of the inherent soil physical properties less affected by management. The rate of increase in stickiness or ability to mould as the moisture content increases depend on the content of silt and clay, the degree to which the clay particles are bound together into stable granules and the organic matter content of the soil (White, 1997). Over a very long period of time pedogenic processes such as erosion, deposition, eluviations and weathering can change the textures of various soil horizons (Brady and Weil, 2002).

Soil texture affects the amount of carbon in different pools. In soils with a high level of fine particles (clay and silt), about 30 per cent of soil organic carbon

tends to be found in the passive pool (in the form of charcoal and physically protected carbon), whereas in soils with a low level of fine particles is about 4 per cent (Skjemstad and Spouncer, 2003).

Textural classes of the soil vary from sandy loam to clay loam. Soils on the hill top and hill side have relatively higher clay content (23.40 to 34.20%) with 12.50 to 87.50 per cent coarse fragments as they occur on the hill slopes (Masri Satanggang *et al.*, 2006)

Deepak (2010) reported that the texture varied from sandy loam to sandy clay loam in different land use system and the soils were dominant in sand but accumulation of clay and silt was observed in sub surface layer with simultaneous decrease in sand content.

Bahilu *et al.* (2014) observed that all land use types did not show a significant variation in sand and silt content but relatively there is highest proportion of sand and lowest proportion of clay content in the cultivated land compared to grazing and Enset farm land. A relative variation in proportion of sand and clay content in the cultivated land could be due to soil erosion.

### **2.1.2 Bulk density**

Narain *et al.* (1990) reported that irrespective of forest covers in Doon valley, bulk density of soil was found to increase and pore space decreased with increase in soil depth. In surface depth (0-30 cm) bulk density was lowest and pore space was highest under brush wood followed by eucalyptus and the sal forest, which may due to the organic carbon content of the soil.

Measurement of soil bulk density (the mass of a unit volume of dry soil) is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as indicator of aeration status and water content (Baruah and Barthakulh, 1997). Bulk density also provides information on the environment available to soil microorganisms. White (1997) stated that values of bulk density ranges from  $< 1 \text{ g/cm}^3$  for soils high in OM, 1.0 to  $1.46 \text{ g/cm}^3$  for well-aggregated loamy soils and 1.2 to  $1.8 \text{ g/cm}^3$  for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils

having low and high bulk density exhibit favorable and poor physical conditions, respectively.

Ashok (1998) studied the properties of an Alfisols under selected forest plantation in Bangalore and he observed that bulk density of soil under different trees maximum reduction in bulk density was found in eucalyptus among different trees studied.

Wakene (2001) reported that bulk density was higher at the surface than the subsurface horizons in the abandoned and lands left fallow for twelve years. The changes in the physical soil attributes on the farm fields can be attributed to the impacts of frequent tillage and the decline in organic matter content of the soils. Ahmed (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth.

The studies of Woldeamlak and Stroosnijder (2003) and Mulugeta (2004) revealed that the bulk density of cultivated soils was higher than the bulk density of forest soils. Soil bulk density increased in the 0-10 and 10-20 cm layers relative to the length of time, the soils were subjected to cultivation.

Gupta (2004) reported that the bulk densities of soil horizons are inversely related to the amount of pore space and soil organic matter. Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in the reduction of the total porosity.

Patil and Jagdish Prasad (2004) reported that bulk density of the profile soil samples ranged from 1.48 to 1.67 Mg m<sup>-3</sup> and the bulk density increased with increase in depth of soils in all the land use systems due to low organic matter content of lower layers and compaction from the pressure of the upper layers.

Soils having high per cent of sand or gravel have more bulk density than those high clay content and it showed an irregular increase with depth, in all pedons (Masri Satanggang *et al.*, 2006)

Kirankumar (2008) reported that the bulk density of the surface soils varied from 1.45 to 1.56 Mg m<sup>-3</sup>, the highest value was recorded in agri system – rice (1.56 Mg m<sup>-3</sup>), while lowest value was recorded in silvisystem (1.45 Mg m<sup>-3</sup>).

Amir *et al.* (2010) significant higher bulk densities of the tea cultivation soil as compared to the natural forest soil (increase from 0.25 to 0.44 g cm<sup>-3</sup>) is attributed namely to the compaction by machinery and human traffic due to forest clearing and subsequent agricultural practices and the reduction of organic matter content.

Deepak (2010) observed that the significant higher exchangeable calcium content in agrisystem as compared to other land use systems and lowest exchangeable calcium content was observed in silvisystem.

Ahukaemere and Akpan (2012) reported that the average bulk density of the soil varied from 1.31-1.43 Mg m<sup>-3</sup>. Bulk density increased with depth in all the farms studied. Results on bulk density were less than the critical limits for root restriction (1.75 – 1.85 g cm<sup>-3</sup>) indicating the potential of the soil to support rice production. The percentage total porosity of the soil ranged between 46 – 50 per cent, with the surface horizons containing higher pore spaces.

Yihenew and Getachew (2013) observed that highest bulk density (0-15 cm) was found in the cultivated land followed by the soil under Eucalyptus plantations. In contrast, the lowest bulk density values of 1.18 and 1.08 Mg m<sup>-3</sup> were observed under the natural forest. The grassland had lower bulk density than the cultivated land which could be due to restricted grazing at the grassland to harvest fodder and free grazing on crop lands after harvest and continuous ploughing at the same depth of cultivated lands.

### **2.1.3 Maximum water holding capacity**

Ravikumar *et al.* (1993) studied the effect of tree forest plantation on physical properties of soil. They reported that the available water holding capacity increased with plantations as compared to control.

Dagar *et al.* (1995) observed that different tree species are known to have different influence on soil properties including WHC. Water storage within 180 cm

soil depth was maximum ( $32.3 \text{ cm m}^{-1}$ ) under evergreen forests and minimum ( $18.0 \text{ cm m}^{-1}$ ) under teak, which was related to soil organic matter content.

Wakene (2001) reported that the highest (526 mm/m) and the lowest (275 mm/m) of soil water content at FC were observed in the deeper subsoil (90-140 cm) layer of the continuously cultivated farmer's field and the surface (0-16 cm) soil layer of the abandoned research field. Similarly, the highest (391 mm/m) and the lowest (174 mm/m) of soil water contents at PWP were recorded for the subsoil (45-80 cm) layer of the land left fallow for fifteen years and surface (0-16 cm) layer of the abandoned research field.

Total available water was the highest in natural forest land followed by grass land in both soil sampling depths and sites. Higher clay and organic carbon provided large surface area required for absorption and retention of water molecules (Materechera and Mkhabela, 2001). Natural forest soils have more available water holding capacity compared to the cultivated lands. Natural forest soils have more available water holding capacity as compared to the cultivated lands (Ayobi, 2011).

Soil water content at FC, PWP and available water holding capacity (AWHC) were found to increase with depth for the soil under different management practice (Wakene, 2001; Ahmed, 2002). The increases of these three components of soil moisture with depth were correlated positively with the clay fractions of the soils, which increased with profile depth. Variation in topography, land use and soil attributes all affect the distribution of soil moisture (Ahmed, 2002; Brady and Weil, 2002).

Yiheneu and Getachew (2013) observed that soil moisture content at FC for all land use systems showed an increasing trend with depth. The highest water content at permanent wilting point (PWP) of 22.30 and 23.28 per cent were found under the natural forest and grass land respectively, whereas the lowest values (20.42 and 21.14 per cent) were found under the cultivated land and forest land use respectively.

## **2.2 Chemical properties of soil**

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect the processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil.

### **2.2.1 Soil reaction (pH)**

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment.

Lepsch *et al.* (1994) indicated that forested lands converted into cultivated areas in tropical regions undergo important changes in soil properties, including loss of organic matter, increase in bulk density and decrease in pH and exchangeable cations.

The degree and nature of soil reaction influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of commercial fertilizers and other farming practices (Rowell, 1994; Miller and Donahue, 1995; Tisdale *et al.*, 1995 )

While studying acid soil of West Bengal soil, Chand and Biswapathi Mandal (2000) reported that the pH of red soils ranged from 4.7 to 5.6. The lower value explained that the soil were negatively charged and contained highest amount of exchangeable and extractable aluminium.

The relative decline in soil pH at the surface of the soils under eucalyptus plantation and natural forest land could be also due to oblong shaped canopy leading the rain to form big drops consequently enhancing leaching of basic cations as well by

releasing organic acids associated with mineralization of organic matter (Mohammed *et al.*, 2005).

Soil pH increased consistently with depth in all land use systems. This pattern of variability in soil pH suggested that the increase in bases with increase in depth that could be attributed to the downward movement of solutes by leaching within a profile (Mohammed *et al.*, 2005). Malo *et al.* (2005) also reported that the increase in pH with soil depth could be associated with enhanced carbonate levels and less weathering rates.

Rudramurthy *et al.* (2007) reported that the acidic pH of different land use systems might be due to the fact that, these soils are derived from acidic igneous granite rocks. He also observed that irrespective of land use systems, in general increase in soil pH down the profile was due to increase in basic cations in lower of the profile.

Amir *et al.* (2010) reported that soil pH value was higher in the top soil horizon of the forest ecosystem as compared to the tea plantation in top soil horizon. The low pH values of the soils of the tea cultivation sites are due to the intensive application of nitrogen fertilizers. Also, this is attributed to the addition of litter and plant residues to the soils under tea plantation.

The soil pH values were the highest in ravines under *Acacia senegal* and lowest in soil under *Leucaena leucocephala*. Variations in pH among land use systems reflect differences in uptake of exchangeable bases, N fixation, production of litter high in organic acid content and the stimulation of mineral weathering (Githae *et al.*, 2011).

Yihenew and Getachew (2013) reported that the soil pH range of 5.01-5.61 indicated moderately acidic soil condition under all the land use systems. Soils under eucalyptus plantations were more acidic, owing to more uptake of basic cations by the trees and poor return rate to the soil.

Significant effect of land use on soil pH was found (5.22 in forest and (5.72) in grassland), however, variation in soil pH with respect to depth was non significant. (Pal *et al.*, 2013)

### 2.2.2 Electrical conductivity (EC)

While characterizing the soils of the trans- Yamuna plain, Walia and Rao (1990) reported that these soils were very low ranging from 0.08 to 0.4 dS m<sup>-1</sup> and did not show any specific relationship with the depth indicating the low amount of soluble salts in the soils.

Contractor and Badanur (1996) reported that there was a significant difference in electrical conductivity of soils due to different plantation. The electrical conductivity was higher in soils planted with *Albegia lebbek* and *Eucalyptus tereticornis*.

Balamurugan *et al.* (2000) studied the physical and chemical properties of soils and they observed a slight increase in pH of the *Eucalyptus citrodora* vegetation whereas, there was no appreciable change in electrical conductivity of the other soils.

Rudramurthy *et al.* (2007) recorded low electrical conductivity of soils under tobacco, paddy, sugarcane land use systems, while it was high under mixed forest land use systems.

Kirankumar (2008) reported that the electrical conductivity of the surface soils ranged from 0.04 to 0.15 dS m<sup>-1</sup>. In general current fallow land recorded lowest electrical conductivity than other land use systems. Also results indicated that, all most all the soils were found to be low in electrical conductivity indicating low amount of soluble salts in the soils.

The soil electrical conductivity was higher under cropped area than other land use systems. It is due to inflow of soluble salts through irrigation water. Many workers advocated the use of good quality of irrigation water to control soil salinity in agricultural land (Ahmed *et al.*, 2012).

### 2.2.3 Organic carbon (OC)

Dalal and Mayer (1986) reported that the rate of organic carbon loss declined exponentially as the clay content in the soil increased. Similarly, overall rate of loss of soil organic carbon declined as aggregation in soil increased, thus reducing the accessibility of organic carbon to microorganisms and degradative enzymes. It is

therefore, primarily the clay that protects soil organic matter from decomposition, when soil is cultivated.

Conversion from native forest to agricultural land has varying influences on soil carbon stocks, depending on the type of forest ecosystem and the post-conversion land management practices (Eswaran *et al.*, 1992).

Net change in soil organic carbon depends not only on the current management practices, but also on the management history of the soil. Long-term experiments are the primary source of information to determine the effect of cropping systems and other management practices on carbon and nitrogen dynamics in soils (Leigh and Johnston 1994). In addition, long-term experiments are the best to evaluate the sustainability of agricultural systems (Barnett *et al.*, 1995).

Gregorich *et al.* (1995) reported that the concentration of organic carbon in the forest soil decreased with depth by more than 10-fold in the surface 30 cm, from 139 g/kg soil in the 0-15 cm layer to 12 g/kg soil in the 15-30 cm layer. In contrast, the organic carbon concentration under corn was similar for soil layers within the plow layer, ranging between 19 and 21 grams carbon per kg of soil. However, the mass of organic carbon in the surface 10 cm of the forest soil was about three times greater than the soil under corn, but below 10 cm, the quantity of organic carbon in the forest was similar to that of the soils cultivated for corn. Thus, the surface layer is most relevant to assess the impact of management practices on soil organic matter, because surface soils are easily modified directly by cultivation.

Soil organic carbon under different land use in India (Jha *et al.*, 1997) showed that total stock to 30 cm depth, is highest in forest (9 Gt) followed by agriculture (6 Gt) and least in barren land (0.37 Gt). Soil carbon content under different plantations followed the order Eucalyptus>Shisham>Khair>Teak>Chir pine. Among the natural forest species, Deodar soils accumulates highest organic carbon followed by Quercus, Chir pine, Spruce and Khail.

Intensification of agricultural management or cultivation practices is known to alter the soil organic matter status. Typically, soil organic matter carbon levels decrease first few years after cultivation and then stabilizes (Paustian *et al.*, 1997). As cultivation caused increased polymerization and cross linking of major soil organic

matter components leading to the formation of larger molecules, with higher molecular weights, stability and complexity thus, the soil organic matter content is highly dynamic and its accumulation or loss, determined largely by biomass-C additions, climate, soil parameters and management practices.

Management of soil organic matter is considered as the additional factor determining the soil organic carbon content in any soils (agriculture and forest) (Baldock and Nelson, 2000).

Relative addition of organic materials (compost, farm yard manure, municipal and industrial waste) to the soil during cultivation may induce significant changes in the quality, chemical composition and molecular size of soil organic matter and thereby it helps in the preservation and maintenance of soil organic matter in these soils (Schnitzer, 2000).

Agricultural management affects the accumulation of soil organic carbon by influencing the amount of plant residues returned to the soil (Campbell *et al.*, 2000) and the rate at which the residues and organic matter decompose. Significant changes in organic carbon due to land management practices can only be observed after longer time periods.

Solomon *et al.* (2002) studied the impact of land use changes on the amount and structural composition of SOM in bulk soils and size separates on natural forests, tea plantations and 25 year-cultivated fields. Forest clearing and continuous cultivation led to significant depletion of total SOC from the surface soils. The largest depletion occurred from the labile SOM associated with the sand separates.

Conversion of natural forest or grasslands to cropped systems leads to decrease in soil organic carbon in terrestrial ecosystems with the increase in atmospheric CO<sub>2</sub> concentration (Mann *et al.*, 2002).

The soil organic carbon concentration reflects soil and ecosystem processes as well as past management of both agricultural and non-agricultural soils. A loss of soil organic carbon due to inappropriate land use or the use of poor soil management or cropping practices can cause a decline in soil quality and potentially lead to emissions of carbon into the atmosphere. On the other hand, appropriate land use and soil

management can lead to an increase in soil organic carbon, improve soil quality and partially mitigate the rise of atmospheric CO<sub>2</sub> (Lal, 2004).

Type of soil also has an influence on soil organic matter content, it ranged from very low (< 0.1 per cent) in desert soils to very high (≈ 100 per cent) in organic soils. Normally, surface soils contain more organic matter and decreases as the depth increases and related soil fertility components are also show same trend (Waiker *et al.*, 2004).

The soil organic carbon in the surface (top 10 cm layer) was greater in pasture ( $29 \pm 3 \text{ Mg ha}^{-1}$ ) than in cultivated soils, but was similar to those under forest and no-till (NT). Among tillage practices (plough, chisel and NT) only the surface 0-5 cm soil layer under NT exhibited higher soil organic carbon and nitrogen concentrations (Puget and Lal, 2005).

Rudrappa *et al.* (2006) reported that management practices, such as no-tillage and high intensity cropping sequences, have the potential to enhance C and N sequestration in agricultural soils. Use of 100 per cent NPK with farmyard manure was the most efficient management system in accumulating as well as sequestering organic C in 0–45 cm soil profile. Microbial metabolic quotient was significantly lower in 100 per cent NPK + FYM to make it the most efficient manuring practice to preserve organic carbon in the soil. A low microbial quotient suggests a higher accumulation of resistant organic C pool. Total organic carbon could be a better predictor of microbial biomass C than of particulate organic C.

Rice grown on converted barren land with organic manure and crop rotations helped in increasing the soil organic carbon content in barren land converted to paddy field (Zhang *et al.*, 2007).

Salinger (2007) revealed that the conversion of forest land to agricultural land-use invariably resulted in the release of large quantities of CO<sub>2</sub> in to the atmosphere and rapid decline of soil organic carbon stocks.

Kirankumar (2008) observed that the highest organic carbon content was noticed in silvisystem and the lowest was recorded in agrisystem (Tobacco). In

general, soils under silvisystem and hortisystem were contained higher organic carbon as compared to other land use systems.

Majumder *et al.* (2008) found that the application of chemical fertilizers (NPK) along with organics in a sandy loam soil increased the soil organic carbon by 24.3 per cent as compared to the control treatment.

Purakayastha *et al.* (2008) reported that a good NPK fertility with organic amendments helps in sequestering atmospheric CO<sub>2</sub> into soil organic carbon by increased plant growth and subsequently, the return of organic carbon to the soil for storage as soil organic matter.

Carbon in soil organic matter is the major source of CO<sub>2</sub> in the carbon cycle and sensitive C reservoir to climate change and atmospheric CO<sub>2</sub> concentrations. Management of soil organic matter requires a thorough understanding of the dynamics and changes in soil organic matter composition and in the structural features of humic substances induced by land use (Navarrete *et al.*, 2010).

Negi and Gupta, (2013) reported that the forest soils are considered rich in organic carbon as they received continuous litter fall from the vegetation. About 40 per cent of the total soil organic carbon stock of the global soil resides in forest ecosystem.

Pal *et al.* (2013) organic carbon content was higher in surface layer of forest land–use (3.01 per cent), followed by grassland (2.16 per cent) and least in deeper soil layers of agriculture (0.36 per cent). As a general trend, organic carbon decreased with the increase in the depth of soil.

#### **2.2.4 Available nitrogen, phosphorus and potassium in soil**

Sharma and Gupta (1989) reported that the changes in soil fertility status under six different tree covers over barren sand dunes in Rajasthan. The overall fertility status improved under tree cover in comparison to barren sand dunes. Organic carbon increased from 0.03 to 0.47 per cent and total nitrogen from 0.007 to 0.043 per cent and available P<sub>2</sub>O<sub>5</sub> from 14.95 to 33.68 kg ha<sup>-1</sup> under *Prosopis cineraria* cover. Among the five tree species tried *viz.*, *Prosopis juliflora*, *Acacia senegal*, *Acacia*

*tortilis*, *Prosopis cineraria* and *Capparis deciduas* the maximum improvement was observed under *Prosopis juliflora* cover.

Singh *et al.* (1990) studied the effect of different plant covers on soil characteristics in Doon valley. They noticed the highest amount of organic carbon, total nitrogen, available phosphorus and potassium, exchangeable magnesium and cation exchange capacity in eucalyptus plantations and the lowest in soils under chir plantation. Available nitrogen in agricultural soils and exchangeable calcium in soils under teak were highest in amount. Available nitrogen in agricultural soils and exchangeable calcium were lowest in soils under sal and agriculture, respectively. They also reported that highest amount of mineral nutrients in the surface depth.

Nitant *et al.* (1992) evaluated that chemical properties of soil in Yamuna ravines under eroded bare, agriculture and mixed forest land use. Calcium carbonate equivalent content and pH were lower and organic matter content and CEC were higher in forest soils. As regards fertility status, forest soils were rich in available N, P, S and Zn than in the agriculture soils. They reported that the forest species in medium to deep ravines were not only useful from view point of production but also good enough in improving the properties and fertility status of soil.

Ravikumar *et al.* (1993) observed that the effect of forest plantation on the native soil fertility. After 8 years of the plantation, soil samples from 20 to 80 cm depth were analysed. The pH of value of soil ranged from 7.96 to 9.14 and highest carbon and exchangeable Mg was observed under *Dalbergia sissoo* plantation, available nitrogen, phosphorus under *Eucalyptus sp* and available K under *Lecanea sp*. The lowest content of organic carbon, available P<sub>2</sub>O<sub>5</sub>, Ca was observed under *Albizia lebbeck* and exchangeable Mg under *Prosopis sp*.

Chavan *et al.* (1995) evaluated the effect of tree species on properties of lateritic soil. They noticed that the organic carbon, available nitrogen, phosphorus, potassium increased very markedly in the surface layer. The CEC and exchangeable cations were also found to increase due to the decomposition of organic matter added through leaf litter. Calcium was the dominant among the cations. In general, the soils under the forest cover showed higher nutrient status.

The nitrogen content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi arid and arid regions due to low organic matter content (Tisdale *et al.*, 1995).

Contractor and Badanur (1996) studied that soils (shallow Vertisols) collected from beneath the canopy of 14 years old plantations of eight forest species in contiguous area and cultivated fields (control) and revealed that available nitrogen and P<sub>2</sub>O<sub>5</sub> content and CEC were significantly higher under forest plantation as compared with control. Availability of nitrogen and P<sub>2</sub>O<sub>5</sub> was highest under teak plantation due to higher litter fall in comparison to other species. However, the available potassium content decreased significantly under different plantations except under teak over the control. Among the exchangeable cations, calcium was dominant and its status was significantly higher under teak as compared with other plantations due to higher accumulation of litter, which further resulted in higher organic carbon. The highest CEC was observed in soils under eucalyptus. They further suggested that teak, bengali jali, tamarind and neem were the most suitable for dry tract of northern Karnataka.

The available nitrogen, phosphorus and potassium were higher in soil under forest plantation as compared to cultivated lands. The available nutrients decreased with increase in depth as reported by Ashok (1998). In Karnataka, about 10.3 per cent of soils fall under low category, 35.8 per cent under medium and 53.9 per cent under high category of available nitrogen status (Shivaprashad *et al.*, 1998).

Animon *et al.* (1999) showed that soils under acacia and eucalyptus showed an improving trend with respect to available nitrogen, phosphorus and potassium content of the soil. Soil phosphorus and potassium content was enhanced by eucalyptus and by acacia respectively.

Balamurgan *et al.* (2000) reported that available nitrogen, phosphorus and potassium were higher in forest plantation soils as compared to agricultural soils and all available nutrients decreased with increase in depth. And appreciable increase in CEC, total and available nutrients in sites under vegetation than under open spaces. The available nitrogen, phosphorus and potassium available in the open spaces ranged

from 34-109, 9.3- 10.9, 132-143 kg ha<sup>-1</sup>, respectively. The corresponding values under vegetation varied from 38-192, 9.9-13.9 and 159-184 kg ha<sup>-1</sup>. The higher CEC and nutrient status were due to increase in organic matter and humus under plantation depth.

Wakene (2001) reported that there was a 30 and 76 per cent depletion of total nitrogen from agricultural fields cultivated for 40 years and abandoned land, respectively, compared to the virgin land.

Mulugeta (2004) stated that the levels of soil organic carbon and total nitrogen in the surface soil (0-10 cm) were significantly lower, and declined increasingly with cultivation time in the farm fields as compared to the soil under the natural forest.

Average total nitrogen increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils (Nega, 2006). The considerable reduction of total nitrogen in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation.

Fantaw *et al.* (2007) noticed that conversion of native forest to the cultivation result in a distinct decrease in the amount of SOC and total nitrogen of the surface soil due to the lower supply and return of organic matter to the soil system. Soil carbon content and total nitrogen can be protected and maintained through improving existing land use practices and proper crop land management.

Chaturvedi *et al.* (2008) observed that nutrient status under agri-silvicultural system. The chemical properties of the top soil (0-15 cm) showed a slight improvement in soil fertility over initial soil properties in terms of pH, EC, organic carbon, available N, available K<sub>2</sub>O. Among the plantations of different density, pH, EC and available P<sub>2</sub>O<sub>5</sub> did not show any specific trend, while the rest parameters showed increasing trend with the increase in the density of the plantations. The increase in soil organic carbon and available nitrogen compared to their initial value was believed to be due to the effect of litter addition.

Upadhyaya *et al.* (2008) examined the nutrient status under *Acacia*-rice agroforestry system. They observed that nearer the tree canopy, the available nitrogen (198.6 kg ha<sup>-1</sup>) and organic carbon (0.404 per cent) increased up to 5.0 meter and subsequently decreased as the distance increased up to 7.0 meter and more from the base of the tree.

Pal *et al.* (2013) effect of land-use and soil depth on available nitrogen, phosphorus and potassium in soil. Highest nitrogen content was found under forest (699, 654, 623 and 597 kg/ ha, at 0-15, 15-30, 30-45 and 45-60 cm depth, respectively), followed by grassland, horticulture and agriculture and least under wasteland. Nitrogen content decreased significantly with soil depth. A similar trend was found in the case of available phosphorus and potassium also, although the depth effect was non significant.

### **2.2.5 Exchangeable calcium and magnesium in soils**

Sreerangappa (1998) found that the high values of exchangeable calcium and magnesium in both surface and subsurface soils of horti-pature whereas, a lower value was recorded in surface and subsurface soils of horticulture system. Changes of these nutrients were due to the decomposition of organic matter added through the roots of grasses and the leaf litter.

Dhananjaya (2000) studied that the highest values of exchangeable calcium and magnesium were reported in surface and subsurface soils in silvi-pasture system whereas, the lower values were recorded in natural systems.

Raina and Pradeep Kumar (2000) reported the physico-chemical characters and fertility status of some forest nursery soils of district Sirmour in Himachal Pradesh. They observed that available Ca and Mg in adequate amounts. Exchangeable calcium and magnesium contents decrease with age of species and were probably utilized in crop developments. Accumulation of all nutrients was greater in 0-30 cm layer compared to 15-30 cm layer.

Patil and Jagdish Prasad (2004) studied the soils of plantation (*Shorea robusta*) in Dindori district of Madhya Pradesh. The exchangeable calcium and magnesium is dominated by Ca followed by Mg. The Ca and Mg have a tendency of

decrease with depth. Relatively high and low exchangeable calcium and magnesium in pedon 1 and pedon 2 respectively are attributed to their parent material.

Sarade and Jagdish Prasad (2008) observed that the exchangeable calcium and magnesium was found to dominant cations on the exchangeable complex and these cations increased with depth. Similar results were reported by Vara Prasad Rao *et al.* (2008).

Kirankumar (2008) reported that the exchangeable calcium content was highest in agrisystem (rice) and the lowest in silvisystem, as compared to other land use system, and the highest magnesium contents was observed under the soils of agrisystems- tobacco and lowest in hortisystem.

Deepak (2010) observed that the significant higher exchangeable calcium content in agrisystem as compared to other land use systems, and lowest exchangeable calcium content was observed in silvisystem.

Pal *et al.* (2013) exchangeable cations were significantly influenced by land use change. Exchangeable Ca was highest in grassland at 0-15 cm depth and least in waste land at 45–60 cm depth. The Mg content was highest in grassland at 15-30 cm and least in horticulture at 45-60 cm soil layer.

#### **2.2.6 Available sulphur**

Ashoka (2001) reported that 12 soil series representing black, red, and coastal soils from different agro-climatical zones of Karnataka and 12 surface soil samples from each series were analyzed for sulphur status and distribution of different forms of sulphur, relationships between sulphur and various soil properties. The  $\text{CaCl}_2$  extracted sulphur content in black, red and coastal soils ranged between 5.08 to 59.95 ppm, 8.66 to 27.15 ppm and 7.26 to 20.32 ppm respectively.

Wakene and Heluf (2003) reported that the highest total sulphur was observed on the surface layer of virgin land and decreased with soil depth due to low organic matter contents.

Habtamu *et al.* (2014) reported significant differences was observed in available sulphur due to the interaction effects of land use and soil depth. The highest

available sulphur (11.1 ppm) was observed on the surface layer of forest land and lowest (2.8 ppm) in the subsurface layer of cultivated land that showed an increase of 293.9 per cent which might be due to high organic matter content on the surface layer of forest land.

### **2.3 Soil organic carbon fractions**

Carbon storage in the forest vegetation and soils in Indian forests as evaluated by Ravindranath *et al.* (1997) for the reference year 1986 are 4178.95 Tg and 5399.33 Tg, respectively. Lal and Singh (2000) estimated the carbon pool of Indian forests to be in the range of 2026.72 million tonnes for the year 1995. Carbon storage in vegetation in India was 8.6 billion tonnes in the year 1880, 7.7 billion tonnes in 1920, 6.39 billion tonnes in 1950, 5.23 billion tonnes in 1970 and 4.39 billion tonnes in 1980.

A comparative analysis of soil carbon stocks under man made and natural land use systems was made by Nagaraj *et al.* (2001) in Eastern Dry Zone of Karnataka. They reported that carbon stocks ranged from 26.46 t ha<sup>-1</sup> in dryland agricultural system to 89.2 t ha<sup>-1</sup> in mixed forest at 0-50 cm depth. Among natural systems, ungrazed grass land and mixed forest recorded higher level of soil organic carbon. Grazed land and litter removed teak plantations recorded lower level of SOC at 39.32 t ha<sup>-1</sup> and 32.7 t ha<sup>-1</sup>, respectively.

Mishra *et al.* (2002) reported lower active carbon content in agriculture land uses as compared to the natural vegetation with higher intensity management. Highest active carbon content was recorded under forest land use system followed by horticulture land use system.

Singh *et al.* (2003) observed the vegetation status of Common Access Resources (CARs) and carbon stock in some selected villages of 10 degraded sites in arid areas of Gujarat and Rajasthan. The study revealed that the high vegetation status in Gujarat resulted greater carbon stock compared to that in Rajasthan. Carbon in the form of vegetation biomass ranged from 1.96 to 2.83 Mg ha<sup>-1</sup> in Rajasthan. Soil carbon was 3.60 to 6.38 Mg ha<sup>-1</sup> in Gujarat compared to 1.13 to 5.18 Mg ha<sup>-1</sup> in Rajasthan with sandy soils.

Organic carbon sequestration in soils under different land use systems of Dasagondanahally watershed of Bangalore North studied by Nideesh (2003) and showed that organic carbon stocks in whole soil to a depth of 100 cm exhibited the following order: Eucalyptus>Horti-silvi pasture>Vegetables>Ragi-Maize-Potato crop rotation.

Divya (2004) studied the labile carbon under different plantations *viz.*, evergreen forest, semi evergreen forest, teak plantation, cardamom plantation, coffee plantation, rubber plantation and cashew plantation. The results also showed that the labile carbon content was maximum in surface horizon and it decreased gradually with increasing depth. The labile carbon in evergreen forest, varied from 708.9 to 717.1 mg kg<sup>-1</sup>, in semi evergreen forest, ranges from 709.1 to 715.0 mg kg<sup>-1</sup> in teak plantation varied from 713.2 to 715.5 mg kg<sup>-1</sup>, in cardamom plantation varied from 708.4 to 718.9 mg kg<sup>-1</sup>, in rubber plantation ranges from 710.8 to 718.6 mg kg<sup>-1</sup> and in cashew plantation varied from 711.0 to 716.7 mg kg<sup>-1</sup>.

Makumba *et al.* (2007) studied the effect of long term impact of a glyricidia-Maize intercropping system on carbon sequestration in southern Alawi and observed that, after 10 years of continuous application of tree prunings, C sequestered in the topsoil (0–20 cm) in glyricidia-maize was 1.6 times more than in sole-maize. A total of 123–149 Mg C ha<sup>-1</sup> were sequestered in the soil (0–20 cm depth), through root turnover and pruning application in the gliricidia- maize system.

Navarrete *et al.* (2010) reported reduction in soil organic matter and in its fractions when forest is converted to other land uses. Karen *et al.* (2010) observed increase in the active carbon with increase in the altitudes of the alpine pasture lands. In different age groups of the apple orchard soils, the active carbon content varied from 2.9 to 5.0 g kg<sup>-1</sup>. High litter fall and the application of FYM in the apple orchard soils were responsible for the significant increase in the active carbon content.

Jamala and Oke (2013) The organic carbon fractions were observed to decrease with depth. The top layer recorded the highest concentration of these fractions. All the different land use types showed highest accumulation of the various carbon fractions in the surface layer (0-15cm). This result provides valuable

information for implementing tillage practices (such as zero tillage) that can favour carbon sequestration and improve soil quality.

Manna *et al.* (2013) reported that after 39 years of continuous cropping, climatic parameters which alter active pools of C seem to be a general cause of declining soybean yield. The gradual depletion of one or more nutrients may have collectively contributed to the decline in crop yield. It was suggested that temperature has a strong effect on carbon mineralization, depending on the types and extents of substrate utilization. Depletion of organic pools is most likely to be the major concern to reduce significantly active and slow pool of carbon. It impacts the concomitant decrease of C mineralization rates in the aggregates there by reduces in the nutrient-supplying capacity of the soil.

Ratnayake *et al.* (2014) studied changes in the soil carbon stock under different agricultural management practices in North Sri Lanka and reported that the potential stable carbon was highest in home garden abandoned for 20 years (15.40 t ha<sup>-1</sup>) followed by annual crop-organic fertilizer only (11.17 t ha<sup>-1</sup>) as compared to the agricultural land uses.

Venkanna *et al.* (2014) evaluated the carbon stocks in major soil types and land use systems in semiarid tropical region of southern India. The results indicated that Vertisols and associated soils contained greater total C stocks, followed by Inceptisols and Alfisols. The soil organic carbon (SOC) stock was highest in Alfisol (52.84 Mg ha<sup>-1</sup>) followed by Inceptisols (51.26 Mg ha<sup>-1</sup>) and Vertisol and associated soils (49.33 Mg ha<sup>-1</sup>). Among the different land use systems, total carbon stock was highest in forest soils (87.29 Mg ha<sup>-1</sup>) followed by fodder system (60.03 Mg ha<sup>-1</sup>), paddy (57.12 Mg ha<sup>-1</sup>), maize (52.12 Mg ha<sup>-1</sup>), cotton (44.98 Mg ha<sup>-1</sup>), red gram (48.44 Mg ha<sup>-1</sup>), intercrop (45.69 Mg ha<sup>-1</sup>), chilli (49.50 Mg ha<sup>-1</sup>), permanent fallow (59.49 Mg ha<sup>-1</sup>) and lowest in castor system (36.86 Mg ha<sup>-1</sup>).

### **2.3.1 Microbial biomass carbon (MBC)**

The microbial biomass is an essential component of organic matter turnover (Jenkinson, 1990). Under tropical conditions, continuous application of fertilizer and organic manures in balanced quantities increased the soil microbial biomass carbon and nitrogen. Microbial biomass is known to respond rapidly to any changes in

organic inputs than the SOM itself. However, the microbial biomass got declined in agricultural soils due to less organic matter additions into the soil. The addition of organic amendments increased microbial biomass C even when the organic carbon content of soil did not increase.

Ladd *et al.* (1996) added that microbial biomass carbon is a good measure of the state of the edaphic environment and its inclusion in a soil quality index leads to reduction in the number of properties that need to be considered. Thus, soil microbial biomass influences crop productivity besides nutrients cycling.

Soil microbial biomass C (SMB-C) and potentially mineralizable C (MIN-C) were considered as active fractions of SOM. These active fractions are important for supplying plant nutrients, residue decomposing and developing soil structure (Franzluebbers *et al.*, 2000).

Microbial biomass was highly correlated with total carbon and carbon in light density fraction (density < 1.59 g ml<sup>-1</sup>) of soil organic matter but less strongly correlated to medium density (1.59 – 2.0 g ml<sup>-1</sup>) fractions (Alvarez and Alvarez, 2000).

Tianyun *et al.* (2004) reported that manure alone and manure plus nitrogen and phosphorus fertilizer treatments restored TOC and MB-C to the level of the native sod, indicating the importance of manure addition in maintaining soil fertility over the long term (20 years).

Soil microbial biomass C comprises only 1 to 4 per cent of organic carbon due to its fast turnover time, the microbial biomass plays a key role in controlling nutrient cycling and energy flow (Li and Chen, 2004).

Changming *et al.* (2005) reported that combined application of chemical fertilizers and FYM or wheat straw with continuous water logging markedly increased the soil TOC, but significantly reduced the labile SOC fractions. While, alternative wetting and drying treatment increased the proportions of EOC, LFOC, POC, MBC and MBN in TOC.

Fugen *et al.* (2008) opined that both no tillage and increased cropping intensity had significant effects on soil TOC and labile C pools. Soil MBC, mineralized C and N, POM C, acid-hydrolyzable C, and DOC were all significantly greater with NT than CT, especially in the surface soil. The size of labile C pools and the significance of management effects decreased with depth. Labile C pools were more sensitive than the total SOC pool.

Sudhir *et al.* (2010) opined that use of organics alone or with fertilizers resulted in buildup of SOC compared to use of only inorganic fertilizers. Pandey *et al.* (2010) reported that minimum tillage can be a good option for SOC build-up and soil fertility management in the hot humid tropics. The net mineralization rate was positively correlated with the MBC in all tillage treatments.

Brij *et al.* (2012) observed that soil microbial biomass carbon was the highest under forest land use system and horticulture plantation. Among agriculture land use systems, the continuous application of 6 t FYM ha<sup>-1</sup> per annum to soybean-wheat cropping system significantly increased various pools of carbon.

The soil biological properties like MBC, MBN, MBP, APHA and DHA was highest under surface soil of forest (576 mg kg<sup>-1</sup> 31.24 mg kg<sup>-1</sup> 6.55 mg kg<sup>-1</sup>, 29.6 mg PNP g<sup>-1</sup>h<sup>-1</sup> and 35.65 µg respectively and least in 45-60 cm layer under wasteland Pal *et al.* (2013).

Handayani and Prawito (2013) evaluated the changes in soil structure and C pools and to quantified the availability of labile C pools under four common agroecosystems (fallow field, agroforestry, rubber tree plantation and grain cropping). Labile soil C pools examined were particulate organic C (POC), microbial biomass C (MBC) and C mineralization (C min). As a general trend, the values of POC, MBC and C min decreased in the order of agroforestry > fallow field > rubber tree plantation > grain cropping. The order of labile C pools in all fields were POC > MBC > C min. Significant increases (32 – 62%, p<0.05) in the soil organic C content was observed in agroforestry and fallow fields compared to rubber tree plantation and grain cropping systems at the depth of 0 – 20 cm. The highest available POC (43 to 82%) and MBC (2 to 5%) was found in agroforestry and fallow field. Mineralized C was about 2% in all fields indicating similar amount of active C from soil organic

matter. Improvement in soil structure properties, TOC, POC and MBC in agroforestry and fallow fields indicated better soil C sequestration and soil quality in these agroecosystems.

Rudresh, (2015) reported that the microbial biomass carbon differed significantly among the different land use systems, the higher microbial biomass carbon was observed under arecanut land use cover as compared to other land use systems

### **2.3.2 Water soluble organic carbon and potassium permanganate oxidizable carbon (PPOC)**

Labile C fractions *i.e.*, microbial biomass carbon (MBC), particulate organic carbon (POC), dissolved organic carbon (DOC), hot-water extractable carbon (HWC), and permanganate oxidizable carbon ( $\text{KMnO}_4\text{-C}$ ) respond more quickly to changes in management practices than SOC and are thus used as early and sensitive indicators of SOC changes (Haynes, 2000).

Water soluble carbon (WSC) is more sensitive to changes in the environment than SOC as a whole. Water soluble carbon is an alternative tool for monitoring adverse impacts of management on soil quality. Understanding the role of WS-C in nutrient cycling is an important factor for sustainable ecosystem management (Silveira, 2005).

At 0-15 cm soil depth, microbial biomass C and N, hot water soluble C were found in the order of  $\text{NPK+FYM} > \text{NPK} > \text{NP} > \text{N} > \text{control}$ . Over the course of experiment, application of N alone decreased the total organic C by 20.4 per cent (Manna *et al.*, 2006).

Soil organic carbon (SOC) and its fractions of readily oxidizable carbon (ROC), water-soluble carbon (WSC) and microbial biomass carbon (MBC) in the soil organic and mineral horizons were investigated for four typical forest types, including mixed coniferous broad-leaved forest (MCB), dark coniferous spruce-fir forest (DCSF), dark coniferous spruce forest (DCS) and ermans birch forest (EB), along an altitudinal gradient in the Changbai Mountain Nature Reserve in Northeast China (Zhang *et al.* 2011). The results showed significant differences in the contents of

SOC, WSC, MBC and ROC among the four forest types and between horizons. The contents of ROC in the mineral horizon, WSC in the organic horizon and MBC in both horizons in the MCB and EB forests were significantly greater than those in either DCSF or DCS forest. The proportion of soil WSC to SOC was the lowest among the three main fractions.

Jha *et al.* (2012) carried out an experiment to understand the soil carbon pools, mineralization and fluxes associated with land use change in Vertisols of central India. They indicated that water soluble carbon is the indicator of labile carbon pool. It was found highest ( $101.6 \mu\text{g g}^{-1}$ ) in forest land use followed by horticulture ( $70.6 \mu\text{g g}^{-1}$ ) and agriculture land use ( $13.8\text{-}36.1 \mu\text{g g}^{-1}$ ). The water soluble carbon was lowest under the agricultural land use was probably due to low soil organic carbon content. They reported that active carbon content under the different land use systems ranged from  $311.8$  to  $1816.8 \mu\text{g g}^{-1}$ . Under the agricultural land use, it ranged from  $311.8$  to  $555.5 \mu\text{g g}^{-1}$ .

Verma *et al.* (2013) observed that  $\text{KMnO}_4\text{-C}$  was significantly affected by nitrogen sources. On an average, all the nitrogen sources at different levels of substitution maintained higher amount of  $\text{KMnO}_4\text{-C}$  than the control. With increase in moisture content from field capacity to 2.5 cm standing water,  $\text{KMnO}_4\text{-C}$  decreased from  $3.59$  to  $2.48 \text{ mg g}^{-1}$ .

Pal *et al.* (2014) revealed that the mean values of cold water extractable carbon (CWEC) in soils collected from system of rice intensification (SRI) treatment were  $0.022 \text{ g kg}^{-1}$  soil whereas, CWEC was highest ( $0.042 \text{ g kg}^{-1}$ ) under furrow irrigated raised bed plot.

Zenon and Tymur (2014) reported that the study showed that in 0–50 cm layer of arable soil TOC content decreased by 32 per cent, CWEOC – by 23 per cent and HWEOC – by 74 per cent as compared to forest soil that confirmed a high informative role of HWEOC fraction. The profile changes of WEOC percentage were analyzed. They also show that HWEOC is much more informative indicator of soil organic matter quality than CWEOC. The most prominent changes of soil chemical properties, TOC, CWEOC and HWEOC contents in response to deforestation were observed in the top 5-cm soil layer. The contents of CWEOC and TOC in studied

0–50 cm soil profile were closely related. There was a stronger correlation between these parameters in arable soil ( $r = 0.81$ ,  $P < 0.01$ ) than in forest soil ( $r = 0.74$ ,  $P < 0.01$ ).

Zaimenko *et al.* (2014) observed that in the majority of cases not only TOC but also CWEOC and HWEOC contents were the highest in subsurface layer and decreased with depth. Strong correlations ( $0.77 < \rho < 0.99$ ,  $p < 0.01$ ) between quantitative profile changes of SOM and water-extractable organic matter fractions were found on every experimental plot. In addition, strong correlations between quantitative profile changes of CWEOC and HWEOC were found in control ( $\rho = 0.99$ ,  $p < 0.01$ ), after gradual felling ( $\rho = 0.98$ ,  $p < 0.01$ ) and after clear felling ( $\rho = 0.94$ ,  $p < 0.01$ ), and much weaker in soil after group-selection felling of hornbeam ( $\rho = 0.73$ ;  $p = 0.02$ ).

Vikas *et al.* (2014) observed that labile C pools such as  $\text{KMnO}_4$  oxidizable carbon and microbial biomass carbon (KOC and MBC) followed the trend: Forest > Horticulture > Agriculture systems > Degraded lands, where as no major variations were observed for water soluble organic carbon (WSOC) among the different land use systems. With respect to the overall soil organic carbon content, forest and horticultural soils were leading. Agricultural and degraded land had lower SOC relatively and were statistically on par with each other.

Rudresh (2015) reported that the potassium dichromate oxidizable organic carbon (PDOC) content was significantly higher in the forest cover ( $10.66 \text{ g kg}^{-1}$ ) followed by sugarcane ( $10.26 \text{ g kg}^{-1}$ ) and arecanut ( $7.81 \text{ g kg}^{-1}$ ) as compared to other land use cover. And the cold water extractable carbon content was significantly higher under maize land use cover ( $339.00 \text{ mg kg}^{-1}$ ) followed by paddy ( $303.54 \text{ mg kg}^{-1}$ ) and arecanut ( $270.60 \text{ mg kg}^{-1}$ ) land use cover as compared to other land use cover.

#### **2.4 Aliphaticity and aromaticity of humic acid (HA) and fulvic acid (FA) fractions in soils under different land use systems**

Joshi (1980) observed the nature and composition of humus in major soil orders of Rajasthan. They found that Alfisols and Mollisols were characterized by the preponderance of humic acids whereas Entisols and Vertisols registered less humic acid and significantly higher amounts of non humic and fulvic fractions. Their studies

suggested that though there were differences in the composition of humus in different soils, the nature of humic acids and fulvic acid in these soils were not very much different except the humic acid of Kota and fulvic acid of Banswara profiles.

Ranjanna (1988) reported that composition of humus in different soil group of Uttar Pradesh. They observed various humus fractions *viz.*, humic acid, fulvic acid, B-humus and humin in different soils. Maximum concentration of humic acid was noticed in surface layer of grayish black soil of Bhabhar group. Black clayey soil of Bundelkhand region contained the highest amount of P humus where as fulvic acid content was maximum in the calcareous soils of alluvial tract.

Hosmot (1999) reported that the mean value of humic acid of the soils under different vegetation groups followed the order, evergreen forest > deciduous > natural grassland > deforested cultivated land and similar trend was observed in case of fulvic acid.

Xuqiufang and Jiangeiukun (2002) examined that the content of total organic carbon (TOC), humic acid carbon (HAC), fulvic acid carbon (FAC) was more in root region soil than in non root region soil. By comparing three different ages of bamboo trees (1, 2 and 5 years old), they observed that root region soil of 3 years and 5 years old bamboo tree contained more TOC, HAC and FAC than that of 1-year bamboo trees.

Bhattacharya and Mukhopadhaya (2006) characterized the humic and fulvic substances extracted from the soils of Terai Agroecological Region of West Bengal by potentiometric titrations, viscometric measurements and visible spectrophotometry determinations. Humic acids showed higher degree of coiling than the corresponding fulvic acids, which signified the higher degree of hydrophobic character of the former than the latter. The E4/E6 ratio, showed in general, the higher amount of aliphatic moiety rather than the aromatic moiety.

Navarrete *et al.* (2010) studied the effects of land use on humus composition and the structural properties of humic substances (HS) in degraded soil in Leyte, Philippines. The results revealed that conversion of PF (primary forest) in to other land uses has led to decrease in FAs (fulvic acids), which were higher under intensive cultivation conditions, such as RF (rain forestation farming), CP (coffee plantation)

and GR (grass land). The amounts of HAs (humic acids) were small and also affected by land use.

Reddy *et al.* (2012) reported that humic acid (HA) and fulvic acid (FA) content under agricultural systems are dependent on land management *i.e.* source, form, amount, rate of organic materials added to soil and also found that forest systems with litter biomass additions are with higher FA content while, agricultural systems receiving with almost decomposed organic matter indicate higher HA than FA.

Jamala and Oke (2013) observed that the status of humic and fulvic acids follows a decreasing pattern with land use type. Thus, Plantation>Natural forest>Grazing reserve>Fallow land>Crop land. This result indicates that land use is an important factor that controls the content and availability of humic substances in the soil.

Guimaraes *et al.* (2013) observed the soil organic matter pools and carbon fractions in soil under different land uses. They reported that the soil organic matter fractions varied in the ranges 12–32.5 per cent (fulvic acids), 12–34.5 per cent (humic acids) and 40–69.5 per cent (humins). Mean values of fulvic acid, humic acid and humin varied from 0.46 to 1.08 g kg<sup>-1</sup>, 0.41 to 0.75 g kg<sup>-1</sup> and 1.60 to 2.52 g kg<sup>-1</sup>, respectively. As expected, humin contents were higher than those of the HA and FA fractions, for all land uses. More fulvic acid than humic acid were observed in all soils, with the exception of the conventional coconut orchard soil. The frequent input of fresh organic residues, especially in the case of the native forest soil, contributed to the higher proportion of fulvic acid. Irrespective of soil depth, the fulvic acid content followed the order: native forest = citrus > integrated orchard = conventional coconut. It is interesting to note that although the citrus and conventional coconut orchards presented similar concentrations of SOM, the distribution of humic fractions was very different. The proportion of fulvic acid was significantly higher in the citrus orchard soil than in the conventional coconut soil. The inverse occurred for the humic acid. The humic acid fraction did not differ significantly among soil uses.

Gislane *et al.* (2014) investigated organic matter pools and nutrient cycling in different coffee production systems in the Brazilian Cerrado. The results revealed that

the humic acids (HA) content also varied greatly among systems. In the 0–0.10 m layer, mean HA concentrations were 1.3, 1.8 and 1.5 g kg<sup>-1</sup>, respectively, for the conventional, organic and agroforestry systems. Both organic and agroforestry systems were 38 and 19% richer in HA content, respectively, as compared with the conventional system. Fulvic acids content ranged from 0.7 to 1.7 g kg<sup>-1</sup>. The maximum fulvic acid was recorded in organic system (1.7 g kg<sup>-1</sup>) and lowest in conventional system (0.7 g kg<sup>-1</sup>).

Rudresh (2015) observed that among the different land use cover paddy (4.68), arecanut (4.50) and forest (4.44) recorded higher HA and maize (4.09), sugarcane (3.98) and banana (3.86) recorded higher FA compared to other land use cover.

## **2.5 Relationship of carbon fractions with soil properties in soils under different land use systems**

Microbial biomass was highly correlated with total carbon and carbon in light density fraction (density < 1.59 g ml<sup>-1</sup>) of soil organic matter but less strongly correlated to medium density (1.59 – 2.0 g ml<sup>-1</sup>) fractions (Alvarez and Alvarez, 2000).

A significant and positive correlation was observed between soil microbial biomass and WSC in LTFE plots in India (Singh *et al.*, 2003).

Bhattacharyya *et al.* (2007) opined that the physical and chemical properties of the associated red and black soils were related to the content of organic and inorganic form of carbon in soils. Soil organic carbon (SOC) is positively correlated with total clay but soil inorganic carbon (SIC) shows a negative correlation. SOC and bulk density (BD) are negatively correlated. The correlation between SIC and BD in various bioclimatic systems indicate a positive correlation. Direct and indirect relations between SOC, SIC, soil drainage and BD were observed among 52 benchmark soils from the semi-arid tropics in India.

Sharma *et al.* (2008) observed that the available nitrogen and sulphur was significantly correlated with organic carbon ( $r = 0.436^*$  and  $r = 0.176^*$  respectively). Available phosphorus showed a significant negative correlation with CaCO<sub>3</sub>, and thus

by increase in  $\text{CaCO}_3$ , leads to fixation of P on  $\text{CaCO}_3$ , Available potassium showed positive and significant correlation with organic carbon and clay. It indicated that the availability of K increases with increase in clay content of soil.

Vikas *et al.* (2014) concluded that among the different carbon pools PPOC seemed to be strongly correlated with soil textural properties including CEC, but overall it seems that land use played a major role in determining carbon levels in soils.

# *Materials and methods*

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### **III. MATERIALS AND METHODS**

The soil samples were collected from identified cropping systems in hilly zone areas of Thirthahalli taluk, Shivamogga district to study the impact of land use systems on nutrient status and carbon distribution in soils. The details of materials used and methods adopted during the experimentation are presented in this chapter.

#### **3.1 General Description of the study area**

##### **3.1.1 Location**

The study area covered Thirthahalli, Muduba, Bjuvalli, Garthikere, Kottegadde, Billeshwara, Ripponpete, Bilikoppa, Bidarahalli, Malur, Humcha, Lingapura, Jambavalli, Tudoor, Kairi, areas of Thirthahalli taluk, Shivamogga district under paddy, arecanut, coconut, fallow and forest cropping systems (Plate 1). The study area comes under Western Ghats and south weastern area. Thirthahalli taluk located at 13° 42' North 75 ° 14' East 13.7 ° North 75.23 ° East, and it has an average elevation of 591 meters (1938 feet) above mean sea level. It is located in the dense forest of the Western Ghat region .The climate is humid and receives highest rainfall among all the zones of Karnataka, with mean annual rainfall of 900 to 3690 mm.

##### **3.1.2 Geology**

Geological environment of the Thirthahalli taluk is peninsular genesis in which soils are red sandy clay loam belong to taxonomic class *Typic Haplustalf* with 1:1 non expanding clay mineral and structure is sub angular. The topography is rolling to undulating with slope less than one per cent and the soils are acidic to neutral in reaction.

#### **3.2 Soil sample collection**

In order to study the nutrient status and soil organic carbon distribution pattern in the major land use systems such as paddy, areca nut, coconut, forest and fallow land in Thirthahalli taluk, Shivamogga district was identified for collecting the soil samples.

In each of the selected land use system, the soil samples were collected in surface and subsurface depths (0-15 cm and 15-30 cm) in 10 locations selected randomly for each land use systems. At each location 4 -5 sub soil samples were collected and pooled to get one composite sample for each depth. In all, 100 soil samples (50 from 0 - 15 cm and 50 from 15- 30 cm depth) were collected. The collected soil samples were dried, grounded,



**Plate 1. District map of Shivamogga showing Thirthahalli taluk and indicating sampling sites (shown in colour).**

stored for further analysis. The sub samples of each soil samples were separately stored at 4°C for characterizing carbon fractions in soils.

### **3.3 Methods of soil analysis**

The methods followed for analysis of physical and chemical properties of soil are given below.

#### **3.3.1 Soil physical properties**

##### **3.3.1.1 Texture**

Particle size analysis, to assess the relative proportion of sand, silt and clay, was carried out through international pipette method as per the procedure described by Piper (1966).

##### **3.3.1.2 Maximum water holding capacity and bulk density**

The maximum water holding capacity of soil and bulk density was estimated by Keen's cup method as explained by Bernard A, Keen and Henry Raczowski, (1921).

### **3.4 Soil chemical properties**

#### **3.4.1 Soil reaction (pH)**

Soil pH was determined in 1:2.5 soil to water suspension by potentiometric method involving digital systronic pH system 361 pH meter using glass electrode as described by Jackson (1973).

#### **3.4.2 Electrical conductivity (EC)**

Electrical conductivity (EC) in soil samples was measured in 1:2 soil to water extract using conductivity bridge as outlined by Jackson (1973). The results were expressed as dS m<sup>-1</sup> at 25 ° C.

### **3.4.3 Organic carbon (OC)**

Organic carbon was estimated by following the Walkley and Black wet oxidation method where using potassium dichromate with  $\text{H}_2\text{SO}_4$  and back titrated with standard ferrous ammonium sulphate as described by Jackson (1973).

### **3.4.4 Calcium carbonate equivalent (%)**

The calcium carbonate equivalent of soil samples were determined by rapid titration method using standard HCl (Piper, 1966).

### **3.4.5 Available nitrogen**

Available nitrogen in the soil was determined by alkaline potassium permanganate method as described by Subbaiah and Asija (1956).

### **3.4.6 Available phosphorus**

Available phosphorus was extracted from soil by using Bray's No.1 extractant ( $0.03 \text{ N } \text{NH}_4\text{F} + 0.025 \text{ N } \text{HCl}$ ) and the concentration of phosphorus in the extract was determined by chlorostannous reduced molybdophosphoric acid blue colour in HCl system using spectrometric method (Jackson, 1973).

### **3.4.7 Available potassium**

Available potassium was extracted from the soils using neutral  $\text{N}$  ammonium acetate in 1:5 soil to extractant ratio and the concentration of potassium present in the extract was determined by flame photometric method (Jackson, 1973).

### **3.4.8 Exchangeable calcium and magnesium**

The exchangeable calcium and magnesium were determined by leaching the soil with neutral normal ammonium acetate solution and calcium and magnesium in the leachate were determined by Versenate titration method (Jackson, 1973).

### **3.4.9 Available sulphur**

Available sulphate was extracted by ammonium acetate-acetic acid buffer and it was determined by turbidometric method (Black, 1965).

### 3.5 Labile soil carbon fractions

#### 3.5.1 Potassium permanganate oxidizable organic carbon

Potassium permanganate oxidizable organic carbon was carried out as per the procedure described by Blair *et al.* (1995).

Weighed 3 g of air-dried (< 2mm) soil in 50 ml centrifuge tube and 30 ml of 20 milli molar KMnO<sub>4</sub> was added and a blank was run. Contents were shaken for 15 minutes and centrifuged for 5 min at 2000 rpm. 2 ml aliquot of supernatant was transferred in to 50 ml volumetric flask and made up to 50 ml. Read the absorbance at 560 - 565 nm and determined the concentration of KMnO<sub>4</sub> from standard calibration curve (plot concentration versus absorbance).

$$\text{PPOC (mg kg}^{-1}\text{)} = (B-S) \times 50/2 \times \frac{\text{Volume of KMnO}_4 \text{ (ml.)} \times 1000}{1000 \times \text{weight of soil (g)}} \times 9$$

where,

B = concentration (m molar) of KMnO<sub>4</sub> in blank

S = concentration (m molar) of KMnO<sub>4</sub> in sample

50/2 = Dilution factor

9 = mg carbon oxidized by 1 M mole KMnO<sub>4</sub>

#### 3.5.2 Cold water extractable carbon

Estimation of cold water extractable carbon (CWEC) was carried out as per the method described by McGill *et al.* (1986).

Weighed 10 g of field moist soil in a 50 ml centrifuge tube add 20 ml of de-ionized water. Contents were centrifuged at 1000 rpm for 30 minutes. Supernatant was filtered, 10 ml of filtered extract was digested with 0.4 N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (2 ml), HgO (70 mg), 10 ml of concentrated H<sub>2</sub>SO<sub>4</sub> and 5 ml H<sub>3</sub>PO<sub>4</sub> taken in 500 ml conical flask. Two blanks were run with 10 ml of distilled water each along with the acid mentioned above. The mixture is boiled gently on hot plate at 105°C for 60 minutes under reflux condition.

250 ml of distilled water was added and cooled at room temperature. The excess dichromate is determined by back titration against 0.35 N ferrous ammonium sulphate to get a brick-red end point.

$$\text{CWEC (mg kg}^{-1}\text{)} = \frac{\text{Cold water extractable carbon (BTV - STV)}}{\text{X (g)}}$$

Where,

BTV = Blank titred value

STV = Sample titred value

$$\text{X (g)} = \frac{\text{Weight of wet soil (g)}}{[100 + \text{moisture (\%)}]} \times 100$$

### 3.5.3 Determination of microbial biomass carbon

The microbial biomass carbon was analyzed by following chloroform fumigation method.

Ten grams of soil sample was fumigated for 24 hr. under vacuum in vacuum desiccator using ethanol-free chloroform. After fumigation, chloroform fumes were removed by evacuation. Non-fumigated soil and fumigated soils were extracted using 50 ml. of 0.5 M K<sub>2</sub>SO<sub>4</sub> and extracts were used for determining carbon (Vance *et al.*, 1987).

- Microbial biomass carbon in soil (MB-C):

$$\text{MB-C (mg kg}^{-1}\text{)} = \frac{(\text{E}_{\text{CF}} - \text{E}_{\text{CNF}})}{\text{K}_{\text{EC}}}$$

where,

$\text{K}_{\text{EC}} = 0.25 \pm 0.05$  and it represents the efficiency of extraction of microbial biomass carbon.

$\text{E}_{\text{CF}}$  = Total weight of extractable C in the fumigated soil samples

$\text{E}_{\text{CNF}}$  = Total weight of extractable C in non-fumigated ( $\text{E}_{\text{CNF}}$ ) soil samples.

### 3.5.4 Determination of E<sub>4</sub>/ E<sub>6</sub> ratio of humic acid (HA) and fulvic acid (FA)

**Extraction and fractionation:** Ten grams of soil sample was weighed in a 250 ml Erlenmeyer flask and 50 ml of 0.1 N HCl was added to remove simple structural organic matter fraction namely sugars, polysaccharides, proteins, fats, waxes, cellulose etc by oxidation. The soil-acid mixture was boiled for 30 min and cooled. The suspension was decanted and the soil residue was retained for humic acid and fulvic acid extractions.

The soil residue was extracted with 50 ml of 0.1 M NaOH in 0.1 M sodium pyrophosphate and it was repeated thrice for complete extraction of humic fractions. The pooled alkali extract was acidified to pH 2 with 2 N HCl, stirred well and allowed to stand at room temperature for 24 hours. The soluble fulvic acid was separated from coagulate (humic acid fraction) by centrifugation. The absorbance values of humic acid (HA) and fulvic acid (FA) were recorded to determine the E<sub>4</sub>/ E<sub>6</sub> ratios as described by Stevenson (1994).

**E<sub>4</sub>/E<sub>6</sub> ratio:** The degree of humification and aromaticity of humic acid and fulvic acid was measured using E<sub>4</sub>/E<sub>6</sub> ratios. A known quantity of the sample was taken and dissolved in 10 ml of 1x10<sup>-2</sup> M NaHCO<sub>3</sub> solution. The absorbances at 465 and 665 nm were measured using UV-VIS scanning spectrophotometer and the absorbance ratio was recorded.

### 3.5.5 SOC stock estimation

The following equation was used to calculate SOC stock in soils as per the methodology given by Batjes (1996) and Bhattacharyya *et al.* (2000).

$$\text{SOC stock (t C/ha)} = \frac{\text{Organic carbon (g/kg)} \times \text{Bulk density (Mg/m}^3\text{)} \times \text{Depth (m)} \times \text{Area (10,000 m}^2\text{)}}{100}$$

### 3.6 Statistical analysis

The data obtained were subjected to statistical analysis and correlation analysis was carried out to assess the relationship of soil carbon fractions with soil properties (Sundararaj *et al.*, 1972).

# *Experimental Results*

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## IV. EXPERIMENTAL RESULTS

The study was carried out to understand the organic carbon distribution of the selected different land use systems (Forest, areca, coconut, paddy and fallow) and to study the relationship between soil physical and chemical properties of soils with carbon fraction under different land use systems. The results obtained are presented in this chapter under different headings.

- 4.1 Physical properties of soil under different land use systems
- 4.2 Chemical properties of soils under different land use systems
- 4.3 Soil carbon fractions in soils under different land use systems
- 4.4 Correlation coefficient values among the different carbon fractions with soil properties
- 4.5 Relationship among the soil carbon fractions under different land use systems
- 4.6 Aliphaticity and aromaticity of humic acid and fulvic acid fractions in soils under different land use systems

### 4.1 **Physical properties of soils under different land use systems**

The data pertaining to physical properties of soils under different land use systems is presented in Table 1.

#### **Particle size analysis**

The sand content of the soils varied from 60.50 to 72.15 and 60.90 to 70.90 per cent in surface and subsurface under forest land use system respectively. The textural class of the soils varied from sandy loam to sandy clay loam. The silt content of soils ranges from 7.25 to 12.00 and 8.10 to 12.00 per cent in surface and subsurface soils respectively and clay content was ranged from 17.60 to 30.00 and 21.00 to 31.00 per cent in surface and subsurface soils respectively in forest land use system.

In arecanut land use system, the content of sand, silt, clay was varied from 61.80 to 68.63, 6.00 to 9.26 , 22.89 to 30.44 per cent in surface soils respectively. In sub surface soils it varied from 60.20 to 67.40, 7.17 to 10.0, 23.70 to 31.00 per cent respectively. The textural class of the soils varied from sandy loam to sandy clay loam. The sand, silt and clay content in coconut land use system was ranged from

**Table 1: Physical properties of soils under different land use systems at surface and subsurface depths**

Sample no	Particle size distribution (%)							
	Forest land use system							
	Depth (cm)							
	0-15			Textural class	15-30			Textural class
Sand	Silt	Clay	Sand		Silt	Clay		
1	63.90	8.10	28.00	Scl	62.90	8.10	29.00	Scl
2	70.41	11.99	17.60	Sl	68.76	9.00	22.24	Scl
3	62.90	8.10	29.00	Scl	61.88	8.12	30.00	Scl
4	62.75	7.25	30.00	Scl	60.90	8.10	31.00	Scl
5	72.15	9.63	18.22	Sl	66.25	8.90	24.85	Scl
6	68.84	12.00	19.16	Sl	70.90	12.00	20.00	Sl
7	70.64	11.00	18.36	Sl	66.46	8.30	25.24	Scl
8	60.50	9.70	29.80	Scl	64.10	8.10	27.80	Scl
9	67.80	12.00	20.00	Sl	69.00	10.00	21.00	Scl
10	65.50	10.00	25.00	Scl	63.20	9.12	27.68	Scl
<b>Range</b>	<b>60.50 - 72.15</b>	<b>7.25 - 12.00</b>	<b>17.60 - 30.00</b>		<b>60.90 - 70.90</b>	<b>8.10 - 12.00</b>	<b>21.00 - 31.00</b>	
<b>Mean</b>	<b>66.43</b>	<b>9.97</b>	<b>23.61</b>		<b>63.20</b>	<b>9.12</b>	<b>25.78</b>	

Sl - sandy loam, Scl - sandy clay loam

**Table 1: Physical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	Particle size distribution (%)							
	Arecanut land use system							
	Depth (cm)							
	0-15			Textura l class	15-30			Textural class
Sand	Silt	Clay	Sand		Silt	Clay		
1	68.60	6.16	26.06	Scl	65.14	7.66	27.20	Scl
2	68.56	8.14	23.30	Scl	67.40	8.90	23.70	Scl
3	67.85	9.26	22.89	Scl	66.30	8.50	25.20	Scl
4	67.88	6.00	26.06	Scl	65.14	7.66	27.20	Scl
5	66.46	7.76	25.78	Scl	65.50	8.80	25.70	Scl
6	61.80	7.76	30.44	Scl	60.88	8.12	31.00	Scl
7	68.83	6.26	24.91	Scl	65.25	9.75	25.03	Scl
8	65.16	9.26	25.58	Scl	60.20	10.0	29.80	Scl
9	67.07	6.79	26.14	Scl	65.09	7.17	27.74	Scl
10	64.76	7.81	27.43	Scl	63.12	8.06	28.82	Scl
<b>Range</b>	<b>61.80 - 68.63</b>	<b>6.00 - 9.26</b>	<b>22.89 - 30.44</b>		<b>60.20 - 67.40</b>	<b>7.17 - 10.0</b>	<b>23.70 - 31.00</b>	
<b>Mean</b>	<b>66.60</b>	<b>8.48</b>	<b>25.80</b>		<b>64.40</b>	<b>8.46</b>	<b>27.13</b>	

Sl – sandy loam, Scl - sandy clay loam

**Table 1: Physical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	Particle size distribution (%)							
	Coconut land use system							
	Depth (cm)							
	0-15			Textural class	15-30			Textural class
	Sand	Silt	Clay		Sand	Silt	Clay	
1	70.05	12.00	17.95	Sl	68.95	8.65	22.40	Sl
2	71.50	10.20	18.30	Sl	66.88	9.12	24.00	Scl
3	66.30	7.20	26.50	Scl	64.20	7.80	28.00	Scl
4	65.30	9.00	25.70	Scl	64.94	9.10	25.96	Scl
5	66.20	8.90	24.90	Scl	63.32	9.59	27.12	Scl
6	70.55	11.45	18.00	Sl	65.50	8.25	26.25	Scl
7	70.80	11.90	17.30	Sl	68.70	12.10	19.20	Sl
8	72.80	8.00	19.20	Sl	63.58	9.00	27.42	Scl
9	64.10	8.75	27.15	Scl	61.90	9.20	28.90	Scl
10	64.40	7.50	28.10	Scl	63.20	8.10	28.70	Scl
<b>Range</b>	<b>64.1 - 72.8</b>	<b>7.20 - 12.00</b>	<b>17.3 - 28.10</b>		<b>61.9 - 68.95</b>	<b>7.80 - 12.1</b>	<b>19.20 - 28.90</b>	
<b>Mean</b>	<b>68.20</b>	<b>9.25</b>	<b>22.31</b>		<b>66.75</b>	<b>10.35</b>	<b>25.95</b>	

**Sl - sandy loam, Scl- sandy clay loam**

**Table 1: Physical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	Particle size distribution (%)							
	Paddy land use system							
	Depth ((cm)							
	0-15			Textural class	15-30			Textural class
Sand	Silt	Clay	Sand		Silt	Clay		
1	62.50	8.10	29.40	Scl	60.80	9.20	30.00	Scl
2	71.20	8.39	19.71	Sl	67.08	9.12	23.80	Scl
3	78.02	6.06	15.92	Sl	65.37	7.68	26.95	Scl
4	66.30	6.75	26.95	Scl	64.99	7.95	27.06	Scl
5	73.00	10.00	17.00	Sl	69.51	11.60	18.89	Sl
6	67.98	7.12	24.90	Scl	66.54	8.10	25.36	Scl
7	74.50	8.96	16.54	Sl	73.68	9.12	17.20	Sl
8	71.90	8.39	19.71	Sl	66.20	9.12	23.80	Scl
9	72.90	7.35	19.35	Sl	69.00	10.00	21.00	Scl
10	72.10	9.36	18.54	Sl	68.50	7.50	24.00	Scl
<b>Range</b>	<b>62.50 - 74.50</b>	<b>6.06 – 10.00</b>	<b>16.54 - 29.40</b>		<b>60.80 - 73.68</b>	<b>7.50 - 11.60</b>	<b>17.20 – 30.00</b>	
<b>Mean</b>	<b>71.04</b>	<b>8.48</b>	<b>20.80</b>		<b>68.63</b>	<b>8.95</b>	<b>22.40</b>	

Sl - sandy loam, Scl- sandy clay loam

**Table 1: Physical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	Particle size distribution (%)							
	Fallow land use system							
	Depth (cm)							
	0-15			Textural class	15-30			Textural class
Sand	Silt	Clay	Sand		Silt	Clay		
1	70.10	9.99	20.00	Sl	71.70	5.97	22.33	Scl
2	70.00	11.00	20.00	Sl	69.35	9.45	21.20	Scl
3	70.33	5.97	22.43	Scl	67.24	6.23	26.53	Scl
4	69.16	11.94	18.90	Sl	67.87	10.13	22.00	Scl
5	67.50	6.72	25.99	Scl	67.88	6.00	26.12	Scl
6	62.90	8.10	29.00	Scl	60.10	9.90	30.00	Scl
7	72.48	9.52	18.00	Sl	66.72	10.16	23.12	Scl
8	62.86	7.98	29.16	Scl	61.08	10.12	28.88	Scl
9	68.30	7.37	24.33	Scl	68.77	6.23	25.00	Scl
10	70.56	11.80	17.64	Sl	70.33	9.52	20.15	Scl
<b>Range</b>	<b>62.86 - 72.48</b>	<b>5.97 - 11.94</b>	<b>18.00 - 29.16</b>		<b>60.10 - 71.70</b>	<b>5.97 - 10.16</b>	<b>20.15 - 30.00</b>	
<b>Mean</b>	<b>68.41</b>	<b>9.39</b>	<b>22.54</b>		<b>67.10</b>	<b>8.37</b>	<b>24.53</b>	

Sl - sandy loam, Scl - sandy clay loam

64.10 to 72.80, 7.20 to 12.00, 17.30 to 28.10 per cent respectively in surface soils. In sub surface soils sand, silt, clay content was varied from 61.90 to 68.95, 7.80 to 12.10, 19.20 to 28.90 per cent respectively. The textural class of the soils varied from sandy loam to sandy clay loam.

In paddy land use system sand, silt and clay content was varied from 62.50 to 74.50, 6.06 to 10.00, 16.54 to 29.40 per cent respectively in surface soils and in subsurface soils it ranged from 60.80 to 73.68, 7.50 to 11.60, 17.20 to 30.00 per cent respectively. The textural class of the soils varied from sandy loam to sandy clay loam.

In fallow land, sand, silt and clay content were ranged from 62.86 to 72.48, 5.97 to 11.94 and 18.00 to 29.16 per cent respectively in surface depth. In subsurface it ranged from 60.10 to 71.70, 5.97 to 10.16, 20.15 to 30.00 per cent respectively.

Among the land use systems the highest mean sand content was recorded in paddy land use system (71.04 % and 68.63 %) and lower mean sand content was recorded in forest land use system (66.43 % and 63.20) in surface and subsurface soils respectively.

### **Bulk density**

The bulk density of surface and subsurface soils of forest, arecanut, coconut, paddy, and fallow land use systems varied from 1.23 to 1.40 Mg m<sup>-3</sup>, 1.19 to 1.35 Mg m<sup>-3</sup>, 1.12 to 1.47 Mg m<sup>-3</sup>, 1.26 to 1.54 Mg m<sup>-3</sup>, 1.32 to 1.46 Mg m<sup>-3</sup>, 1.30 to 1.48 Mg m<sup>-3</sup>, 1.25 to 1.42 Mg m<sup>-3</sup>, 1.20 to 1.52 Mg m<sup>-3</sup>, 1.35 to 1.56 Mg m<sup>-3</sup>, 1.36 to 1.54 Mg m<sup>-3</sup> respectively. The highest mean (1.44 and 1.49 Mg m<sup>-3</sup>) bulk density in surface and subsurface was observed in paddy land use system and lowest mean bulk density (1.28 and 1.32 Mg m<sup>-3</sup>) was noticed in areca land use system, respectively (Table 2).

### **Maximum water holding capacity**

Maximum water holding capacity of the surface and subsurface soil samples of forest, arecanut, coconut, paddy and fallow land use systems ranged from 29.96 to 49.45, 29.00 to 34.85, 28.00 to 32.09, 23.96 to 27.96, 23.95 to 29.15, 36.45 to 58.25, 32.12 to 42.25, 29.10 to 36.42, 26.00 to 31.12, 24.52 to 36.25 per cent respectively. The highest mean (35.91% and 43.08 %) maximum water holding capacity in surface and sub surface was found in forest land use system and lowest

**Table 2: Bulk density and maximum water holding capacity of soils under different land use systems at surface and subsurface depths**

Sample no.	Bulk density (Mg m <sup>-3</sup> )		MWHC (%)	
	Forest land use system			
	Depth (cm)			
	0-15	15-30	0-15	15-30
1	1.34	1.43	31.14	38.00
2	1.40	1.48	30.10	36.45
3	1.28	1.30	48.14	55.60
4	1.23	1.34	49.45	58.25
5	1.40	1.42	30.00	39.71
6	1.34	1.39	34.17	39.60
7	1.42	1.46	27.00	37.65
8	1.24	1.38	38.30	44.25
9	1.33	1.40	29.96	38.95
10	1.32	1.34	39.89	42.40
<b>Range</b>	<b>1.23 - 1.40</b>	<b>1.30 - 1.48</b>	<b>29.96 - 49.45</b>	<b>36.45 - 58.25</b>
<b>Mean</b>	<b>1.33</b>	<b>1.39</b>	<b>35.91</b>	<b>43.08</b>

**Table 2: Bulk density and maximum water holding capacity of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no.	Bulk density (Mg m <sup>-3</sup> )		MWHC(%)	
	Arecanut land use system			
	Depth (cm)			
	0-15	15-30	0-15	15-30
1	1.25	1.26	31.20	38.75
2	1.32	1.34	29.90	35.65
3	1.35	1.42	29.00	32.12
4	1.33	1.38	34.50	40.95
5	1.21	1.25	31.12	38.00
6	1.19	1.25	34.85	42.25
7	1.33	1.40	29.09	38.55
8	1.25	1.29	29.30	36.70
9	1.34	1.36	32.00	39.85
10	1.23	1.28	32.80	40.00
<b>Range</b>	<b>1.19 - 1.35</b>	<b>1.25 - 1.42</b>	<b>29.00 - 34.82</b>	<b>32.12 - 42.25</b>
<b>Mean</b>	<b>1.28</b>	<b>1.32</b>	<b>31.36</b>	<b>38.28</b>

**Table 2: Bulk density and maximum water holding capacity of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no.	Bulk density (Mg m <sup>-3</sup> )		MWHC (%)	
	Coconut land use system			
	Depth (cm)			
	0-15	15-30	0-15	15-30
1	1.47	1.52	27.00	30.10
2	1.44	1.50	29.30	31.46
3	1.34	1.42	30.21	33.19
4	1.38	1.46	29.78	32.16
5	1.45	1.50	29.90	32.00
6	1.47	1.53	28.00	29.45
7	1.46	1.50	28.46	29.10
8	1.44	1.48	28.96	30.12
9	1.26	1.32	31.80	34.12
10	1.12	1.20	32.09	36.42
<b>Range</b>	<b>1.12 - 1.47</b>	<b>1.20 - 1.52</b>	<b>28.00 - 32.09</b>	<b>29.10 - 36.42</b>
<b>Mean</b>	<b>1.38</b>	<b>1.44</b>	<b>29.55</b>	<b>31.81</b>

**Table 2: Bulk density and maximum water holding capacity of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no.	Bulk density (Mg m <sup>-3</sup> )		MWHC (%)	
	Paddy land use system			
	Depth (cm)			
	0-15	15-30	0-15	15-30
1	1.26	1.35	26.30	27.80
2	1.49	1.54	25.00	29.90
3	1.54	1.56	27.10	31.12
4	1.36	1.45	27.96	30.16
5	1.50	1.53	23.96	26.00
6	1.49	1.52	25.16	28.19
7	1.47	1.50	24.00	26.90
8	1.40	1.49	27.00	31.12
9	1.48	1.50	25.09	29.80
10	1.50	1.56	24.89	26.45
<b>Range</b>	<b>1.26 - 1.54</b>	<b>1.35 - 1.56</b>	<b>23.96 - 27.96</b>	<b>26.00 - 31.12</b>
<b>Mean</b>	<b>1.44</b>	<b>1.49</b>	<b>25.09</b>	<b>28.74</b>

**Table 2: Bulk density and maximum water holding capacity of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no.	Bulk density (Mg m <sup>-3</sup> )			MWHC (%)
	Fallow land use system			
	Depth (cm)			
	0-15	15-30	0-15cm	15-30cm
1	1.43	1.48	25.90	28.10
2	1.46	1.51	25.00	30.12
3	1.42	1.49	26.45	28.49
4	1.44	1.53	25.16	27.45
5	1.32	1.36	27.45	29.00
6	1.35	1.40	29.15	36.25
7	1.46	1.48	24.00	27.13
8	1.36	1.40	28.75	34.90
9	1.40	1.44	28.00	34.25
10	1.50	1.54	23.95	24.50
<b>Range</b>	<b>1.32 - 1.46</b>	<b>1.36 - 1.54</b>	<b>23.95 - 29.15</b>	<b>24.52 - 36.25</b>
<b>Mean</b>	<b>1.41</b>	<b>1.46</b>	<b>29.71</b>	<b>30.01</b>

mean (25.09% and 28.74 %) was noticed in paddy land use system respectively. (Table 2)

## **4.2 Chemical properties of soils under different land use systems**

### **Soil reaction and electrical conductivity**

The pH and electrical conductivity are the two important electrochemical properties of soils. The data on soil pH under different land use systems in soils of Thirthahalli taluk are given in Table 3.

In all the land use systems the pH values were acidic in nature (Table 3). The data indicated that the mean pH values of surface soils was slightly lower than the subsurface soils. Among the land use systems, the mean pH values ranged from 4.47 to 5.41 in surface depth and subsurface it varied from 4.86 to 5.62.

The electrical conductivity of soils under different land use systems did not varied significantly. The electrical conductivity was low in both surface and sub surface, but it was increased with depth in all the land use systems. The higher EC value was recorded under coconut ( $0.12 \text{ dS m}^{-1}$  and  $0.17 \text{ dS m}^{-1}$ ) and lowest EC value was observed under fallow land use system ( $0.03 \text{ dS m}^{-1}$  and  $0.04 \text{ dS m}^{-1}$ ) in surface and sub surface depths respectively. The EC of paddy ( $0.04 \text{ dS m}^{-1}$  and  $0.05 \text{ dS m}^{-1}$ ) and forest ( $0.03 \text{ dS m}^{-1}$  and  $0.05 \text{ dS m}^{-1}$ ) land use systems were not observed much variation in surface and sub surface depths.

### **Soil organic carbon**

The data pertaining to soil organic carbon under different land use systems is presented in Table 3.

The organic carbon status of soils was more under forest land use system as compared to paddy land use in all depths. The organic carbon status decreased with depth in all the land use systems. The surface (0-15 cm) soil was noticed higher mean organic carbon status than sub surface soils (15-30 cm). Among the different land use systems, forest land recorded significantly higher soil organic carbon status of ( $19.23 \text{ g kg}^{-1}$  and  $16.51 \text{ g kg}^{-1}$ ) followed by arecanut ( $16.04 \text{ g kg}^{-1}$  and  $11.75 \text{ g kg}^{-1}$ ), fallow land ( $14.04 \text{ g kg}^{-1}$  and  $10.95 \text{ g kg}^{-1}$ ), coconut ( $13.31 \text{ g kg}^{-1}$  and  $9.88 \text{ g kg}^{-1}$ ) in surface and subsurface depths respectively. Lowest soil organic carbon was recorded in paddy land use system ( $9.81 \text{ g kg}^{-1}$  and  $7.71 \text{ g kg}^{-1}$ ) in surface and subsurface depths



**Table 3: Chemical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	pH (1:2.5)		EC (dS m <sup>-1</sup> )		OC (g kg <sup>-1</sup> )		CaCO <sub>3</sub> (%)	
	Depth (cm)							
	Arecanut land use system							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	5.01	5.20	0.04	0.05	14.30	10.20	0.23	0.25
2	5.52	5.57	0.04	0.06	12.30	10.20	0.32	0.35
3	4.48	4.98	0.06	0.08	9.60	8.85	0.21	0.24
4	4.91	4.97	0.07	0.07	22.20	19.80	0.28	0.32
5	5.12	5.45	0.05	0.07	14.30	10.14	0.30	0.32
6	5.59	6.00	0.04	0.05	26.13	14.43	0.38	0.40
7	5.11	5.45	0.05	0.06	9.75	5.96	0.34	0.38
8	5.32	5.57	0.02	0.03	11.70	7.50	0.30	0.32
9	5.52	5.56	0.05	0.06	19.11	11.31	0.34	0.38
10	5.61	5.63	0.04	0.06	21.00	19.10	0.39	0.45
<b>Range</b>	<b>4.48 - 5.61</b>	<b>4.97 - 6.00</b>	<b>0.02 - 0.07</b>	<b>0.03 - 0.08</b>	<b>9.60 – 26.13</b>	<b>7.50 - 19.80</b>	<b>0.21 - 0.39</b>	<b>0.24 - 0.45</b>
<b>Mean</b>	<b>5.21</b>	<b>5.44</b>	<b>0.04</b>	<b>0.06</b>	<b>16.04</b>	<b>11.75</b>	<b>0.31</b>	<b>0.34</b>

**Table 3: Chemical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	pH (1:2.5)		EC (dS m <sup>-1</sup> )		OC (g kg <sup>-1</sup> )		CaCO <sub>3</sub> (%)	
	Depth (cm)							
	Coconut land use system							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	5.86	5.96	0.12	0.39	6.75	5.96	0.12	0.17
2	4.68	4.88	0.05	0.07	14.30	10.01	0.35	0.50
3	4.57	4.64	0.06	0.08	16.38	10.14	0.20	0.25
4	4.88	4.91	0.07	0.07	16.38	16.00	0.12	0.20
5	5.12	5.86	0.12	0.17	11.80	5.80	0.21	0.25
6	5.45	6.00	0.10	0.19	7.02	7.00	0.28	0.30
7	5.45	5.85	0.21	0.23	9.75	5.96	0.25	0.27
8	5.20	5.22	0.19	0.20	11.70	7.50	0.20	0.25
9	5.52	5.56	0.09	0.10	19.11	11.31	0.20	0.30
10	5.12	5.00	0.14	0.17	19.89	19.10	0.28	0.30
<b>Range</b>	<b>4.57 - 5.86</b>	<b>4.64 - 6.00</b>	<b>0.05 - 0.21</b>	<b>0.07 - 0.39</b>	<b>6.75 - 19.89</b>	<b>5.96 - 19.10</b>	<b>0.12 - 0.35</b>	<b>0.20 - 0.50</b>
<b>Mean</b>	<b>5.18</b>	<b>5.38</b>	<b>0.12</b>	<b>0.17</b>	<b>13.31</b>	<b>9.88</b>	<b>0.22</b>	<b>0.27</b>

**Table 3: Chemical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	pH (1:2.5)		EC (dS m <sup>-1</sup> )		OC (g kg <sup>-1</sup> )		CaCO <sub>3</sub> (%)	
	Depth (cm)							
	Paddy land use system							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	4.38	4.71	0.03	0.04	11.7	7.80	0.29	0.30
2	4.39	5.20	0.02	0.03	9.07	8.97	0.28	0.29
3	4.84	4.98	0.07	0.08	7.80	5.85	0.16	0.19
4	4.35	4.99	0.03	0.03	11.70	10.00	0.28	0.32
5	3.96	4.42	0.02	0.04	8.50	7.80	0.21	0.25
6	4.69	4.83	0.04	0.05	10.92	9.07	0.28	0.34
7	4.42	4.63	0.04	0.05	8.42	7.41	0.20	0.27
8	4.38	4.71	0.08	0.09	11.70	7.40	0.30	0.32
9	4.95	5.01	0.03	0.05	9.36	6.60	0.26	0.28
10	4.39	5.20	0.04	0.06	8.97	6.24	0.25	0.27
<b>Range</b>	<b>3.96 - 4.95</b>	<b>4.42 - 5.20</b>	<b>0.02 - 0.08</b>	<b>0.03 - 0.09</b>	<b>7.80 - 11.70</b>	<b>5.85 - 10.0</b>	<b>0.16 - 0.38</b>	<b>0.19 - 0.34</b>
<b>Mean</b>	<b>4.47</b>	<b>4.86</b>	<b>0.04</b>	<b>0.05</b>	<b>9.81</b>	<b>7.71</b>	<b>0.25</b>	<b>0.28</b>

**Table 3: Chemical properties of soils under different land use systems at surface and subsurface depths (continued...)**

Sample no	pH (1:2.5)		EC (dS m <sup>-1</sup> )		OC (g kg <sup>-1</sup> )		CaCO <sub>3</sub> (%)	
	Depth ( cm)							
	Fallow land use system							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	4.88	5.13	0.04	0.05	11.70	5.80	0.19	0.20
2	5.25	5.38	0.04	0.05	10.60	9.75	0.23	0.21
3	4.78	5.25	0.03	0.04	17.94	12.00	0.16	0.20
4	4.52	4.65	0.02	0.04	10.52	5.65	0.14	0.16
5	5.21	5.30	0.04	0.06	15.60	14.40	0.20	0.25
6	4.30	5.15	0.03	0.05	16.38	15.60	0.13	0.14
7	5.62	5.73	0.05	0.06	9.75	9.45	0.25	0.29
8	3.69	3.72	0.02	0.03	19.50	15.10	0.12	0.13
9	4.81	5.87	0.03	0.06	19.11	15.60	0.18	0.20
10	5.21	5.30	0.04	0.05	9.36	6.24	0.18	0.20
<b>Range</b>	<b>3.69 - 5.62</b>	<b>3.72 - 5.87</b>	<b>0.02 - 0.05</b>	<b>0.03 - 0.06</b>	<b>9.36 - 19.50</b>	<b>5.80 - 15.60</b>	<b>0.12 - 0.25</b>	<b>0.14 - 0.29</b>
<b>Mean</b>	<b>4.82</b>	<b>5.14</b>	<b>0.03</b>	<b>0.04</b>	<b>14.04</b>	<b>10.95</b>	<b>0.17</b>	<b>0.19</b>

respectively. The mean organic carbon trend under different land use systems were in the order of forest land use > arecanut land use > fallow land use > coconut land use > paddy land use system respectively.

### **Calcium carbonate equivalent**

There was increase in calcium carbonate equivalent with soil depth in all land use systems. The calcium carbonate equivalent was low in both surface and sub surface depths. In surface depth soils of forest, arecanut, coconut, paddy and fallow land use systems, per cent calcium carbonate equivalent ranges from 0.20 to 0.50, 0.21 to 0.39, 0.12 to 0.35, 0.16 to 0.38 and 0.12 to 0.25 per cent respectively, and in subsurface it ranges from 0.32 to 0.62, 0.24 to 0.45, 0.20 to 0.50, 0.19 to 0.34 and 0.14 to 0.29 per cent respectively. The mean calcium carbonate equivalent content under different land use system were in the order of forest land use system > arecanut land use system > coconut land use system > paddy land use system > fallow land use systems, respectively (Table 3).

### **Available nitrogen**

The data on available nitrogen in soils of Thirthahalli taluk under different land use systems are presented in Table 4.

Available nitrogen status in soils showed wide variation under different land use systems. The available nitrogen status decreased with soil depth in all the land use systems. Among the different land use systems, the higher mean content of available nitrogen was observed in forest (372.7 kg ha<sup>-1</sup> and 323.6 kg ha<sup>-1</sup>) at surface and sub surface soil respectively, followed by arecanut (348.6 kg ha<sup>-1</sup> and 317.4 kg ha<sup>-1</sup>), coconut (324.8 kg ha<sup>-1</sup> and 263.6 kg ha<sup>-1</sup>), fallow (247.9 kg ha<sup>-1</sup> and 225.2 kg ha<sup>-1</sup>) and paddy (232.4 kg ha<sup>-1</sup> and 209.2 kg ha<sup>-1</sup>) land use systems at surface and sub surface soil respectively.

### **Available phosphorus**

The data on available phosphorus of Thirthahalli taluk soils under different land use systems at surface and sub surface soils are presented in Table 4.

The higher status of the available phosphorus was observed in forest and it was decreased with depth in all land use systems. Highest mean available phosphorus status was noticed in soil of forest land (28.2 kg ha<sup>-1</sup> and 23.7 kg ha<sup>-1</sup>) followed by arecanut (25.0 kg ha<sup>-1</sup> and 22.9 kg ha<sup>-1</sup>), fallow (24.3 kg ha<sup>-1</sup> and 20.0 kg ha<sup>-1</sup>), coconut (23.5 kg ha<sup>-1</sup> and 21.7 kg ha<sup>-1</sup>) and paddy (20.0 kg ha<sup>-1</sup> and 17.40 kg ha<sup>-1</sup>) at surface and sub surface depths respectively.

### **Available potassium**

The data pertaining to available potassium under different land use systems at surface and subsurface is presented in Table 4.

In all the land use systems surface soils contains higher available potassium as compared to subsurface soils. The highest mean available potassium status was recorded in the soil of forest (382.2 kg ha<sup>-1</sup> and 338.5 kg ha<sup>-1</sup>) followed by arecanut (368.5 kg ha<sup>-1</sup> and 333.5 kg ha<sup>-1</sup>), coconut (281.0 kg ha<sup>-1</sup> and 242.0 kg ha<sup>-1</sup>), where as lowest was observed in fallow (138.2 kg ha<sup>-1</sup> and 124.9 kg ha<sup>-1</sup>) and paddy land use systems (115.3 kg ha<sup>-1</sup> and 111.4 kg ha<sup>-1</sup>) at surface and subsurface depths respectively.

### **Exchangeable calcium**

The data pertaining to exchangeable calcium under different land use systems at surface and sub surface soils is presented in Table 4.

The result indicated that the exchangeable calcium status of subsurface soil recorded higher values of calcium in all the land use systems, where as lowest exchangeable calcium was recorded in surface soil in all the land use systems studied under investigation.

The highest exchangeable calcium was observed in forest (4.6 and 5.0 cmol (p<sup>+</sup>) kg<sup>-1</sup>), followed by coconut (3.5 and 4.0 cmol (p<sup>+</sup>) kg<sup>-1</sup>), arecanut (3.0 and 4.0 cmol (p<sup>+</sup>) kg<sup>-1</sup>), fallow (3.4 and 3.5 cmol (p<sup>+</sup>) kg<sup>-1</sup>) and paddy land use systems (2.8 and 3.3 cmol (p<sup>+</sup>) kg<sup>-1</sup>) at surface and subsurface depths respectively.

**Table 4: Macro nutrients status in different land use systems at surface and subsurface depths**

Sample no.	Available N (kg ha <sup>-1</sup> )		Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )		Available K <sub>2</sub> O (kg ha <sup>-1</sup> )		Exch. Ca cmol (p+) kg <sup>-1</sup>		Exch. Mg cmol (p+) kg <sup>-1</sup>		Available S (mg kg <sup>-1</sup> )	
	Forest land use system											
	Depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	327.0	319.4	28.2	22.0	402.3	398.2	4.6	4.9	2.5	2.8	23.6	23.3
2	310.9	298.0	26.5	20.2	398.2	360.6	4.4	4.9	2.9	3.0	22.7	21.8
3	434.7	317.0	30.1	25.9	330.0	305.0	5.0	5.2	2.1	2.2	24.9	24.0
4	492.3	454.3	33.4	27.0	407.8	388.8	5.1	5.1	2.7	2.8	32.0	24.3
5	301.6	289.1	23.8	19.6	398.0	348.0	4.1	4.8	2.8	2.9	22.7	21.8
6	380.6	327.6	29.4	24.1	420.0	315.0	4.8	5.1	2.1	2.4	24.8	21.8
7	298.1	256.1	21.2	18.2	210.0	150.0	4.0	4.6	2.5	2.6	21.8	15.3
8	439.0	307.7	32.3	28.1	398.2	360.6	4.9	5.3	2.3	2.4	30.0	24.7
9	326.4	316.2	27.7	24.9	437.7	351.2	4.8	5.0	2.4	2.8	23.4	21.5
10	416.7	351.0	30.0	26.6	420.0	407.8	4.8	5.1	2.9	2.9	24.8	21.8
<b>Range</b>	<b>298.0 - 492.3</b>	<b>289.0 - 454.3</b>	<b>18.2-33.4</b>	<b>18.2-28.1</b>	<b>220.- 437.7</b>	<b>150.0-407.8</b>	<b>4.0 -5.1</b>	<b>4.6 -5.3</b>	<b>2.1 -2.9</b>	<b>2.2 -3.0</b>	<b>21.8-32.0</b>	<b>15.39-24.7</b>
<b>Mean</b>	<b>372.7</b>	<b>323.6</b>	<b>28.2</b>	<b>23.7</b>	<b>382.2</b>	<b>338.5</b>	<b>4.6</b>	<b>5.0</b>	<b>2.5</b>	<b>2.6</b>	<b>25.1</b>	<b>22.3</b>

**Table 4: Macronutrients status in different land use systems at surface and subsurface depths (continued...)**

Sample no.	Available N (kg ha <sup>-1</sup> )		Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )		Available K <sub>2</sub> O (kg ha <sup>-1</sup> )		Exch. Ca cmol (p+) kg <sup>-1</sup>		Exch. Mg cmol (p+) kg <sup>-1</sup>		Available S (mg kg <sup>-1</sup> )	
	Arecanut land use system											
	Depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	385.1	319.5	24.3	28.6	300.0	285.0	3.6	4.1	2.4	2.8	23.6	22.9
2	325.0	298.3	23.8	22.7	395.0	325.0	3.1	3.9	2.4	2.5	21.8	20.1
3	250.2	234.6	17.7	17.1	435.0	325.0	2.6	3.2	1.8	1.9	20.1	19.7
4	400.0	385.0	30.7	22.2	405.0	360.0	4.0	4.3	2.8	2.8	24.0	23.6
5	385.1	340.1	23.8	22.7	335.0	325.0	3.2	3.8	2.4	2.5	22.0	20.1
6	425.2	366.4	32.1	29.6	435.0	400.0	4.2	4.4	2.9	3.0	24.8	23.9
7	286.4	240.6	21.0	19.3	350.0	335.0	2.9	3.9	1.7	1.9	12.0	10.7
8	301.2	298.5	21.6	18.2	400.0	380.0	3.0	4.0	2.5	2.9	20.5	19.2
9	343.3	320.0	26.5	24.3	305.0	385.0	3.9	4.2	2.1	2.4	23.6	22.0
10	385.0	366.1	28.7	24.9	325.0	315.0	3.9	4.3	2.6	2.8	23.7	22.5
<b>Range</b>	<b>250.2 -425.2</b>	<b>234.6 -385.0</b>	<b>17.7 -32.1</b>	<b>17.1 - 29.6</b>	<b>300 - 435</b>	<b>285 - 400</b>	<b>2.6 - 4.2</b>	<b>3.2 - 4.4</b>	<b>1.7 -2.9</b>	<b>1.9 - 3.0</b>	<b>12.0- 24.8</b>	<b>10.7 - 23.9</b>
<b>Mean</b>	<b>348.6</b>	<b>317.4</b>	<b>25.0</b>	<b>22.9</b>	<b>368.5</b>	<b>333.5</b>	<b>3.04</b>	<b>4.01</b>	<b>2.3</b>	<b>2.5</b>	<b>21.6</b>	<b>20.5</b>

**Table 4: Macronutrients status in different land use systems at surface and subsurface depths (continued...)**

Sample no.	Available N (kg ha <sup>-1</sup> )		Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )		Available K <sub>2</sub> O (kg ha <sup>-1</sup> )		Exch. Ca cmol (p+) kg <sup>-1</sup>		Exch. Mg cmol (p+) kg <sup>-1</sup>		Available S (mg kg <sup>-1</sup> )	
	Coconut land use system											
	Depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	214.1	200.0	14.4	13.3	165.0	150.0	2.6	2.9	2.6	2.8	15.3	12.0
2	354.8	341.8	29.1	26.5	330.0	315.0	3.5	4.0	2.8	2.9	21.7	22.0
3	388.8	238.3	29.5	23.8	315.0	210.0	3.9	4.4	2.2	2.4	21.9	19.9
4	398.0	250.8	30.0	29.6	310.0	240.0	3.9	4.3	2.2	2.4	21.8	19.9
5	294.0	238.3	23.8	21.4	225.0	240.0	3.4	3.9	2.8	2.8	21.7	21.1
6	257.1	250.8	14.4	13.3	225.0	195.0	2.9	3.3	2.1	2.2	16.5	10.9
7	259.5	225.7	14.9	13.8	210.0	165.0	3.2	3.7	2.8	2.9	19.9	16.5
8	260.5	250.8	22.7	19.9	315.0	305.0	3.6	4.1	2.0	2.2	21.5	16.5
9	398.2	344.9	30.5	29.6	325.0	270.0	4.1	4.6	2.4	2.5	22.7	20.6
10	423.3	294.7	31.0	30.0	390.0	330.0	4.3	4.8	2.6	2.8	22.9	21.6
<b>Range</b>	<b>214.1-423.3</b>	<b>200.0 -344.9</b>	<b>14.4 -31.0</b>	<b>13.3 -29.6</b>	<b>165.0-390.0</b>	<b>150.0-330.0</b>	<b>2.6 - 4.3</b>	<b>2.9 -4.8</b>	<b>2.0-2.8</b>	<b>2.2-2.9</b>	<b>15.3 - 22.9</b>	<b>10.9 -22.0</b>
<b>Mean</b>	<b>324.8</b>	<b>263.6</b>	<b>23.5</b>	<b>21.7</b>	<b>281.0</b>	<b>242.0</b>	<b>3.5</b>	<b>4.0</b>	<b>2.4</b>	<b>2.5</b>	<b>20.6</b>	<b>18.2</b>

**Table 4: Macronutrients status in different land use systems at surface and sub surface depths (continued...)**

Sample no.	Available N (kg ha <sup>-1</sup> )		Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )		Available K <sub>2</sub> O (kg ha <sup>-1</sup> )		Exch. Ca cmol (p+) kg <sup>-1</sup>		Exch. Mg cmol (p+) kg <sup>-1</sup>		Available S (mg kg <sup>-1</sup> )	
	Paddy use system											
	Depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	288.9	247.6	17.7	15.5	114.6	108.0	3.2	3.4	1.7	2.8	28.5	24.8
2	222.9	196.6	23.8	17.5	125.0	124.0	2.8	3.1	2.0	2.1	19.9	12.3
3	202.9	196.6	26.5	22.5	119.3	116.8	2.4	2.9	2.0	2.1	12.2	10.7
4	258.0	237.3	14.4	13.8	105.3	103.5	3.3	3.7	1.9	2.0	24.2	23.8
5	216.7	185.6	12.7	11.6	103.0	100.1	2.5	3.2	1.9	2.4	12.3	12.2
6	237.2	220.1	24.3	20.8	136.2	125.1	3.0	3.6	2.0	2.5	21.8	19.2
7	206.4	196.5	24.0	18.7	124.0	114.9	2.6	2.7	2.2	2.4	16.5	15.3
8	244.4	216.7	16.6	14.4	102.9	102.0	3.1	3.7	2.1	2.5	21.8	21.7
9	223.6	199.5	26.5	21.9	115.0	114.6	2.9	3.4	2.3	2.6	21.6	20.7
10	222.9	196.0	22.3	17.7	108.2	105.7	2.7	3.3	2.9	3.1	19.9	16.5
<b>Range</b>	<b>202.0 -288.0</b>	<b>185.6 -247.0</b>	<b>12.7-26.5</b>	<b>11.6-22.5</b>	<b>102.9 -136.2</b>	<b>100.1 - 125</b>	<b>2.4 - 3.3</b>	<b>2.7 - 3.7</b>	<b>1.7 - 2.9</b>	<b>2.0 -2.8</b>	<b>12.2-28.5</b>	<b>10.7-24.8</b>
<b>Mean</b>	<b>232.4</b>	<b>209.29</b>	<b>20.0</b>	<b>17.4</b>	<b>115.3</b>	<b>111.4</b>	<b>2.8</b>	<b>3.3</b>	<b>2.0</b>	<b>2.3</b>	<b>19.9</b>	<b>17.6</b>

**Table 4: Macronutrients status in different land use systems at surface and subsurface depths (continued...)**

Sample no.	Available N (kg ha <sup>-1</sup> )		Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )		Available K <sub>2</sub> O (kg ha <sup>-1</sup> )		Exch. Ca cmol (p+) kg <sup>-1</sup>		Exch. Mg cmol (p+) kg <sup>-1</sup>		Available S (mg kg <sup>-1</sup> )	
	Fallow land use system											
	Depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
1	237.2	225.7	24.9	21.6	141.9	135.4	3.1	3.2	2.0	2.1	21.8	19.2
2	225.6	200.7	31.0	29.6	140.3	130.3	2.9	3.1	2.5	2.8	21.5	19.9
3	234.9	225.0	23.8	19.3	141.9	135.4	3.6	3.8	2.1	2.5	19.9	16.5
4	225.7	196.3	22.7	16.6	128.8	104.1	3.0	3.2	1.8	1.9	22.7	20.6
5	275.8	250.8	22.8	18.2	129.7	110.0	4.0	4.2	2.1	2.5	21.7	21.1
6	288.2	275.9	21.6	17.7	110.0	99.8	3.8	4.0	2.3	2.3	21.9	19.9
7	200.7	175.6	33.1	26.8	169.7	150.1	2.6	2.8	2.1	2.3	15.3	12.0
8	341.0	301.0	17.1	13.8	169.7	150.1	4.1	4.2	2.2	2.4	22.9	21.6
9	249.7	225.7	21.6	15.5	110.0	104.1	4.0	4.3	2.1	2.5	21.5	16.5
10	200.7	175.6	24.3	21.0	140.3	130.3	2.3	2.6	2.5	2.9	16.5	10.9
<b>Range</b>	<b>200.7 -341.0</b>	<b>175.6 -301.0</b>	<b>17.1 -33.1</b>	<b>13.8 - 29.6</b>	<b>110.0 -169.0</b>	<b>99.8 -150.1</b>	<b>2.3 -4.1</b>	<b>2.6 -4.3</b>	<b>1.8-2.5</b>	<b>1.9 -2.9</b>	<b>15.3-22.7</b>	<b>10.9-21.6</b>
<b>Mean</b>	<b>247.9</b>	<b>225.2</b>	<b>24.3</b>	<b>20.0</b>	<b>138.2</b>	<b>124.9</b>	<b>3.4</b>	<b>3.5</b>	<b>2.1</b>	<b>2.4</b>	<b>20.6</b>	<b>17.8</b>

### **Exchangeable magnesium**

The data on exchangeable magnesium under different land use systems are presented in Table 4. The highest mean exchangeable magnesium status of the surface and subsurface soils was noticed in forest land use system (2.5 and 2.6  $\text{cmol (p}^+) \text{ kg}^{-1}$ ) respectively, and the lowest was observed in paddy land use system (2.0 and 2.3  $\text{cmol (p}^+) \text{ kg}^{-1}$ ) at surface and subsurface depths respectively.

### **Available sulphur**

The available sulphur status of the surface soil samples under different land use systems varied from 21.8 to 32.0, 12.0 to 24.8, 15.3 to 22.9, 12.2 to 28.5 and 15.3 to 22.7  $\text{mg kg}^{-1}$  in forest, arecanut, coconut, paddy, and fallow land use systems respectively. In subsurface layer it varied from 15.3 to 24.7, 10.7 to 23.9, 10.9 to 22.0, 10.7 to 24.8 and 10.9 to 21.6  $\text{mg kg}^{-1}$  in forest, arecanut, coconut, paddy, and fallow land use systems respectively. Whereas lowest mean available sulphur status was recorded in paddy land use system (19.9  $\text{mg kg}^{-1}$  and 17.6  $\text{mg kg}^{-1}$ ) in surface and sub surface depths respectively and highest mean available sulphur status was noticed in forest land use system (25.1  $\text{mg kg}^{-1}$  and 22.3  $\text{mg kg}^{-1}$ ) in surface and sub surface depths respectively (Table 4).

### **4.3 Soil carbon fractions in soils under different land use systems**

The potassium permanganate oxidizable organic carbon content of the surface soil samples under different land use systems varied from 923.5 to 1942.2, 526.0 to 1453.0, 449.0 to 927.0, 319.0 to 594.0 and 306.0 to 778.5  $\text{mg kg}^{-1}$  in forest, arecanut, coconut, paddy, and fallow land use systems respectively. In subsurface layer it varies from 402.7 to 1360.0, 490.5 to 1026.0, 330.2 to 882.0, 220.5 to 357.5 and 202.7 to 506.5  $\text{mg kg}^{-1}$  in forest, arecanut, coconut, paddy, and fallow land use systems respectively. Whereas lowest mean potassium permanganate oxidizable organic carbon content was recorded in paddy land use system (429.3  $\text{mg kg}^{-1}$  and 276.7  $\text{mg kg}^{-1}$ ) in surface and sub surface soils respectively, and highest mean potassium permanganate oxidizable organic carbon content was noticed in forest land use system (1182.7  $\text{mg kg}^{-1}$  and 802.6  $\text{mg kg}^{-1}$ ) in surface and sub surface soils respectively. (Table 5)

The cold water extractable organic carbon content of the surface soil samples under different land use systems varied from 35.2 to 57.1, 24.4 to 46.9, 28.4 to 41.9, 14.9 to 29.8 and 19.2 to 24.7 mg kg<sup>-1</sup> in forest, arecanut, coconut, paddy, and fallow land use systems respectively. In subsurface layer it varies from 30.1 to 43.9, 23.6 to 42.0, 24.1 to 29.6, 11.7 to 20.0 and 14.9 to 23.6 mg kg<sup>-1</sup> in forest, arecanut, coconut, paddy, and fallow land use systems respectively. Whereas highest mean cold water extractable organic carbon content was recorded in forest land use system (43.3 mg kg<sup>-1</sup> and 36.5 mg kg<sup>-1</sup>), in surface and sub surface soils respectively and the lowest mean cold water extractable organic carbon content was noticed in paddy land use system (21.3 mg kg<sup>-1</sup> and 16.2 mg kg<sup>-1</sup>) in surface and sub surface depths respectively. (Table 5)

The microbial biomass carbon content of the surface soil samples under different land use systems varied from 168.0 to 584.0, 192.0 to 476.0, 280.0 to 428.0, 186.0 to 408.0 and 264.0 to 392.0 mg kg<sup>-1</sup> in forest, arecanut, coconut, paddy, and fallow land use systems respectively. In subsurface layer, it varies from 128.0 to 388.0, 180.0 to 372.0, 244.0 to 376.0, 152.0 to 344.0 and 208.0 to 368.0 mg kg<sup>-1</sup> in forest, arecanut, coconut, paddy, and fallow land use systems respectively. Whereas highest mean microbial biomass carbon content was recorded in forest land use system (437.7 mg kg<sup>-1</sup> and 297.4 mg kg<sup>-1</sup>), in surface and sub surface depths respectively. And the lowest mean microbial biomass carbon content was noticed in paddy land use system (287.7 mg kg<sup>-1</sup> 211.2 mg kg<sup>-1</sup>) in surface and sub surface depths respectively (Table5).

#### **4.3.1 SOC stock in soils under different land use systems at Thirthahalli taluk**

The data pertaining to soil organic carbon stocks under different land use systems at surface and subsurface is presented in Table 6

The soil organic carbon stock of soils varied widely among the different land use systems and decreased with depth of soil. The mean SOC stock was higher in surface (0-15 cm) soils as compared subsurface soil depths. Irrespective of depth, the SOC stock under different land use systems followed the order forest > Arecanut > Coconut > Fallow > Paddy land use systems. The highest mean SOC stock was recorded in Forest (37.89 and 34.21 t C ha<sup>-1</sup>) land use system at surface and

**Table 5: Labile carbon fractions under different land use systems at surface and subsurface depths**

Sample no	Potassium permanganate oxidizable carbon (PPOC) (mg kg <sup>-1</sup> )		Cold water extractable carbon (CWEC) (mg kg <sup>-1</sup> )		Microbial biomass carbon (MBC) (mg kg <sup>-1</sup> )	
	Forest land use system					
	Depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	1039.0	501.7	40.8	35.2	420.0	292.0
2	1015.0	483.7	40.5	36.4	396.0	296.0
3	1035.0	1025.0	44.8	39.0	512.0	308.0
4	1942.2	1360.0	57.1	43.7	584.0	360.0
5	1405.0	1246.0	38.8	30.1	396.0	252.0
6	1053.0	562.5	41.3	34.4	444.0	300.0
7	923.5	402.7	35.2	32.3	168.0	128.0
8	1212.0	956.0	50.1	43.9	508.0	388.0
9	1053.0	967.0	41.9	37.5	452.0	340.0
10	1150.0	522.0	42.0	33.0	497.5	310.0
<b>Range</b>	<b>923.5 - 1942.2</b>	<b>402.7 – 1360.0</b>	<b>35.2 - 57.1</b>	<b>30.1 - 43.9</b>	<b>168.0 – 584.0</b>	<b>128.0 – 388.0</b>
<b>Mean</b>	<b>1182.7</b>	<b>802.6</b>	<b>43.3</b>	<b>36.5</b>	<b>437.7</b>	<b>297.4</b>

**Table 5: Labile carbon fractions under different land use systems at surface and subsurface depths (continued...)**

Sample no	Potassium permanganate oxidizable carbon (PPOC) (mg kg <sup>-1</sup> )		Cold water extractable carbon (CWEC) (mg kg <sup>-1</sup> )		Microbial biomass carbon (MBC) (mg kg <sup>-1</sup> )	
	Arecanut land use system					
	Depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	660.0	632.0	35.2	30.1	400.0	284.0
2	533.2	501.7	33.1	30.1	332.0	264.0
3	526.5	490.5	24.4	23.6	192.0	180.0
4	1095.0	927.5	43.0	42.0	468.0	320.0
5	778.5	747.0	39.4	36.4	400.0	372.0
6	1453.0	1026.5	46.9	42.0	476.0	356.0
7	855.0	783.0	25.3	24.3	340.0	280.0
8	778.5	632.2	28.8	24.4	366.0	248.0
9	923.2	845.2	40.0	30.0	436.0	316.0
10	1053.0	953.5	41.1	39.4	444.0	320.0
<b>Range</b>	<b>526.0 – 1453.0</b>	<b>490.5 - 1026</b>	<b>24.4 - 46.9</b>	<b>23.6 - 42.0</b>	<b>192.0 – 476.0</b>	<b>180.0 – 372.0</b>
<b>Mean</b>	<b>865.5</b>	<b>753.9</b>	<b>35.7</b>	<b>32.2</b>	<b>385.4</b>	<b>294.0</b>

**Table 5: Labile carbon fractions under different land use systems at surface and subsurface depths (continued...)**

Sample no	Potassium permanganate oxidizable carbon (PPOC) (mg kg <sup>-1</sup> )		Cold water extractable carbon (CWEC) (mg kg <sup>-1</sup> )		Microbial biomass carbon (MBC) (mg kg <sup>-1</sup> )	
	Coconut land use system					
	Depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	594.0	535.5	28.4	26.7	280.0	244.0
2	449.0	475.5	35.2	28.4	384.0	264.0
3	535.5	330.2	37.2	25.8	392.0	352.0
4	843.0	453.0	36.2	29.6	362.0	280.0
5	485.5	783.5	34.8	27.2	324.0	284.0
6	927.0	882.0	29.3	24.7	360.0	344.0
7	488.2	389.5	33.2	29.6	386.0	308.0
8	456.0	391.5	34.2	28.8	408.0	376.0
9	778.5	725.5	39.5	24.1	420.0	300.0
10	783.0	670.5	41.9	29.6	428.0	<b>384.0</b>
<b>Range</b>	<b>449.0 – 927.0</b>	<b>330.2 – 882.0</b>	<b>28.4 - 41.9</b>	<b>24.1 - 29.6</b>	<b>280.0 – 428.0</b>	<b>244.0 – 376.0</b>
<b>Mean</b>	<b>633.9</b>	<b>563.6</b>	<b>35.0</b>	<b>27.5</b>	<b>374.4</b>	<b>313.6</b>

**Table 5: Labile carbon fractions under different land use systems at surface and subsurface depths (continued...)**

Sample no	Potassium permanganate oxidizable carbon (PPOC) (mg kg <sup>-1</sup> )		Cold water extractable carbon (CWECC) (mg kg <sup>-1</sup> )		Microbial biomass carbon (MBC) (mg kg <sup>-1</sup> )	
	Paddy land use system					
	Depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	535.0	245.2	29.8	20.0	296.0	194.0
2	432.0	225.0	20.7	11.7	276.0	206.0
3	319.6	357.7	14.9	19.5	252.0	192.0
4	506.2	220.5	24.7	15.2	186.0	152.0
5	344.2	305.5	17.5	16.8	256.0	200.2
6	483.0	297.9	24.3	16.1	408.0	344.0
7	328.5	290.4	16.3	16.3	240.0	180.0
8	594.0	282.8	24.3	16.0	400.0	264.0
9	411.7	275.2	22.3	15.7	372.0	208.0
10	339.7	267.6	18.2	15.5	192.0	172.0
Range	319.0 - 594.0	220.5 - 357.5	14.92 - 29.89	11.7 - 20.0	186.0 - 408.0	152.0 - 344.0
Mean	429.3	276.7	21.3	16.2	287.7	211.2

**Table 5: Labile carbon fractions under different land use systems at surface and subsurface depths (continued...)**

Sample no	Potassium permanganate oxidizable carbon (PPOC) (mg kg <sup>-1</sup> )		Cold water extractable carbon (CWEC) (mg kg <sup>-1</sup> )		Microbial biomass carbon (MBC) (mg kg <sup>-1</sup> )	
	Fallow land use system					
	Depth (cm)					
	0-15	15-30	0-15	15-30	0-15	15-30
1	414.5	326.5	20.9	19.6	392.0	320.0
2	306.0	202.7	21.3	20.1	392.0	208.0
3	402.7	312.7	23.6	23.3	264.0	240.0
4	396.0	290.5	20.9	19.7	376.0	368.0
5	522.0	267.7	24.4	23.2	320.0	292.0
6	562.5	449.5	24.4	23.3	376.0	352.0
7	328.5	324.0	19.5	14.9	344.0	280.0
8	778.5	506.5	24.7	22.8	360.0	252.0
9	506.5	389.2	24.4	23.6	328.0	244.0
10	330.7	267.7	19.2	17.1	332.0	292.0
<b>Range</b>	<b>306.0 - 778.5</b>	<b>202.7 - 506.5</b>	<b>19.2 - 24.7</b>	<b>14.9 - 23.6</b>	<b>264 - 392</b>	<b>208 - 368</b>
<b>Mean</b>	<b>454.7</b>	<b>333.7</b>	<b>22.3</b>	<b>20.7</b>	<b>348.4</b>	<b>284.8</b>

**Table 6: Soil organic carbon stocks under different land use systems at surface and subsurface depths (cm)**

Carbon stock t C ha <sup>-1</sup>										
Sample no.	Forest		Arecanut		Coconut		Fallow		Paddy	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	33.76	30.67	26.81	19.28	14.88	13.58	25.09	12.87	22.11	15.79
2	32.76	29.43	24.35	20.25	30.88	22.52	23.31	22.08	20.27	20.72
3	43.77	39.25	19.44	18.85	32.92	21.59	38.21	26.82	18.01	13.69
4	54.42	51.05	44.29	40.98	33.90	35.04	22.72	12.96	23.87	21.75
5	32.76	30.67	25.95	19.01	25.66	13.05	30.88	29.37	19.12	17.90
6	39.19	32.52	46.64	27.05	15.47	16.06	33.16	32.76	24.41	20.68
7	20.76	20.69	19.45	12.52	21.35	13.41	21.35	20.97	18.56	16.67
8	43.52	27.44	21.94	14.29	25.27	16.65	39.78	31.71	24.57	16.54
9	38.12	32.76	38.41	23.07	36.11	22.39	40.13	33.69	20.78	14.85
10	39.95	47.71	38.75	36.67	33.41	34.38	21.06	14.41	20.18	14.60
<b>Range</b>	<b>20.76 - 54.42</b>	<b>20.69 - 51.05</b>	<b>19.44 - 46.6</b>	<b>12.52 - 40.98</b>	<b>14.88 - 36.11</b>	<b>13.05 - 35.04</b>	<b>21.06 - 40.13</b>	<b>12.96 - 33.69</b>	<b>18.01 - 24.57</b>	<b>13.69 - 20.72</b>
<b>Mean</b>	<b>37.89</b>	<b>34.21</b>	<b>31.00</b>	<b>23.22</b>	<b>26.98</b>	<b>20.86</b>	<b>29.56</b>	<b>23.76</b>	<b>21.18</b>	<b>17.31</b>

subsurface depths, and lowest mean SOC stock was observed in paddy (21.18 and 17.31t C ha<sup>-1</sup>) land use system at surface and subsurface depths respectively.

#### **4.4 Correlation co- efficient values (r) among the different carbon fractions with soil properties are presented in (Table 7)**

Soil bulk density showed negative and non significant correlation with clay, pH, OC, CaCO<sub>3</sub> PPOC and CWEC (r=-0.05, r=-0.26 r=-0.58 and r=-0.29, r= -0.41 and r = -0.63 respectively). Soil BD showed negative and significant correlation with MBC, HA and FA (r= -0.51\*\*, r= -0.078\*\*, r= -0.230\*\* respectively) irrespective of land use systems.

Clay showed positive and significant correlation with OC (r = 0.38\*\*) and positive non significant correlation with PPOC, CWEC, MBC (r = 0.13, r = 0.11 and r = 0.12 respectively) irrespective of land use systems. CaCO<sub>3</sub> showed positive and significant correlation with PPOC, CWEC, MBC (r = 0.45\*\*, r = 0.43\*\* and r = 0.30\*\* respectively) and positive non significant correlation with PDOC (r = 0.19) irrespective of land use systems.

Soil pH showed negative significant correlation with OC, PPOC, CWEC, and MBC (r = -0.11\* r = -0.35\*\*, r = -0.40\*\* and r = -0.13\*, respectively) irrespective of land use systems. Soil pH showed negative and non significant correlation with clay and BD (r = -0.05, r = -0.26, respectively) irrespective of land use systems.

Available nitrogen showed positive and significant correlation with OC, PPOC, CWEC, MBC, HA, FA (r = 0.84\*\*, r = 0.63\*\*, r = 0.85\*\*, r = 0.75\*\*, r = 0.20\* and r = 0.37\* respectively). Available phosphorus showed positive and significant correlation with OC, PPOC, CWEC, MBC (r = 0.61\*\*, r = 0.37\*\*, r = 0.58\*\* and r = 0.49\*\* respectively). Available potassium showed positive and significant correlation with OC, PPOC, CWEC, MBC (r = 0.59\*\*, r = 0.62\*\*, r = 0.81\*\* and r = 0.64\*\* respectively) irrespective of land use systems.

Exchangeable calcium showed positive and significant correlation with OC, PPOC, CWEC, MBC (r = 0.36\*\*, r = 0.50\*\*, r = 0.48\*\* and r = 0.37\*\* respectively). Available sulfur showed positive and significant correlation with OC, PPOC, CWEC, MBC (r = 0.67\*\*, r = 0.42\*\*, r = 0.54\*\* and r = 0.66\*\* respectively) irrespective of land use systems.

**Table : 7 Correlation co- efficient values (r) among the different carbon fractions with soil properties under different land use systems**

Parameters	Clay	BD	pH	OC	CaCO <sub>3</sub>	N	P	K	Ca	mg	S	PPOC	CWEC	MBC	HA	FA
Clay	1															
BD	-0.05	1														
pH	-0.05	-0.26	1													
OC	0.38**	-0.58	-0.11	1												
CaCO <sub>3</sub>	-0.13	-0.29	0.71*	0.19	1											
N	0.23*	-0.68	0.19	0.84**	0.25*	1										
P	0.35**	-0.38	0.25*	0.61**	0.26**	0.57**	1									
K	0.02	-0.66	0.41**	0.59**	0.49**	0.76**	0.54	1								
Ca	0.09	-0.17	0.53**	0.36**	0.62**	0.31**	0.39**	0.45**	1							
Mg	-0.04	0.02	0.35**	0.02	0.32**	-0.04	0.01	-0.03	0.36	1						
S	0.24*	-0.53*	-0.04	0.67**	0.09	0.69**	0.45**	0.44**	0.19	0.09	1					
PPOC	0.13	-0.41	-0.35**	0.57**	0.45**	0.63**	0.37**	0.62**	0.50**	-0.02**	0.42**	1				
CWEC	0.11	-0.63	-0.40**	0.73**	0.43**	0.85**	0.58**	0.81**	0.48**	-0.01	0.54**	0.71**	1			
MBC	-0.12	-0.51**	-0.13*	0.63**	0.30**	0.75**	0.49**	0.64**	0.37**	-0.07	0.66**	0.67**	0.73**	1		
HA	-0.122	-0.078**	0.405	0.070	0.119	0.20*	-0.203	0.083	0.090	0.184	-0.183	0.183	0.243	0.268	1	
FA	0.061	-0.230**	-0.106	0.308*	0.101	0.37*	0.123	-0.051	-0.156	-0.275	-0.123	0.123	0.023	0.063	0.022	1

\* Significant at 5% level of significance

\*\* Significant at 1% level of significance

**Note:**

PPOC: potassium permanganate oxidizable organic carbon

MBC: microbial biomass carbon

CWEC: cold water extractable carbon

HA: humic acid FA: fulvic acid

#### **4.5 Relationship among soil carbon fractions under different land use systems**

Correlation among soil carbon fractions under different land use cover was presented in Table 8.

Organic carbon showed positive and significant correlation with CaCO<sub>3</sub>, PPOC, MBC, CWEC ( $r = 0.19^*$ ,  $r = 0.57^{**}$  and  $r = 0.63^{**}$  and  $r = 0.73^{**}$  respectively). OC showed negative and non significant correlation with HA ( $r = -0.18$ ). OC showed positive and non significant correlation with FA ( $r = 0.14$ ) irrespective of land use systems.

Per cent CaCO<sub>3</sub> equivalent showed positive and significant correlation with PPOC, CWEC, MBC ( $r = 0.45^*$ ,  $r = 0.43^*$  and  $r = 0.30^{**}$ , respectively). Per cent CaCO<sub>3</sub> equivalent showed positive and non significant correlation with FA ( $r = 0.35$ ). Per cent CaCO<sub>3</sub> equivalent showed negative and non significant correlation with HA ( $r = -0.10$ ) irrespective of land use systems.

PPOC showed positive and significant correlation with OC, CWEC, MBC, ( $r = 0.57^*$ ,  $r = 0.71^{**}$  and  $r = 0.67^{**}$  respectively). PPOC showed positive and non significant correlation with FA ( $r = 0.19$ ). PPOC showed negative and non significant correlation with HA ( $r = -0.11$ ) irrespective of land use systems.

CWEC showed positive and significant correlation with MBC ( $r = 0.73^{**}$ ). CWEC showed positive and non significant correlation with HA ( $r = 0.13$ ) and showed negative and non significant correlation with FA ( $r = -0.04$ ) irrespective of land use systems.

#### **4.6 Aliphaticity and aromaticity of humic acid and fulvic acid fractions in soils under different land use systems**

The degree of aliphaticity and aromaticity of soil organic matter fractions can be determined by the ratios of absorbances at 465 nm and 665 nm. The values of E4/E6 ratios of humic acid and fulvic acid fractions of different land use systems are presented in Table 9.

The values of E4/E6 ratios of fulvic acids were higher than that of humic acids values. This indicates that the fulvic acids have more aliphatic compounds than

**Table 8 : Correlation among the soil carbon fraction under different land use systems**

Parameters	CaCO <sub>3</sub>	OC	PPOC	CWEC	MBC	HA	FA
CaCO <sub>3</sub>	1.00						
OC	0.19*	1.00					
PPOC	0.45*	0.57*	1.00				
CWEC	0.43*	0.73**	0.71**	1.00			
MBC	0.30**	0.63**	0.67**	0.73**	1.00		
HA	-0.10	-0.18	-0.11	0.13	0.13	1.00	
FA	0.35	0.14	0.19	-0.04	-0.12	0.16	1.00

\* Significant at 5% level of significance

\*\* Significant at 1% level of significance

**Note:**

PPOC: potassium permanganate oxidizable organic carbon

MBC: microbial biomass carbon

CWEC: cold water extractable carbon

HA: humic acid

FA: fulvic acid

**Table 9: Aliphaticity and aromaticity of humic acid (HA) and fulvic acid (FA) fractions in soils under different land use systems**

Land use systems	Humic acid		Fulvic acid		HA:FA	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
Forest	5.12	3.65	5.53	4.00	0.92	0.91
Arecanut	4.39	3.20	4.70	3.58	1.37	0.89
Coconut	3.23	2.73	3.72	2.58	0.86	1.05
Fallow	2.30	1.35	3.28	2.40	0.70	0.56
Paddy	3.00	1.99	3.73	2.73	0.80	0.72

humic acid fractions. The values of E4/E6 ratios of humic acid and fulvic acid content were decreased with depth in all the land use systems. The mean values of E4/E6 ratios of fulvic acids were higher (5.53 and 4.00) in forest land use system as compared to other land use systems and it was lowest in fallow land use system (3.28 and 2.40) at surface and subsurface depths respectively. The mean values of E4/E6 ratios of humic acid were higher (5.12 and 3.65) in forest land use system as compared to other land use systems, and it was lowest in fallow land use system (3.28 and 2.40) at surface and subsurface depths respectively.

The ratio between humic and fulvic acids (HA/FA) reflects the mobility of soil organic carbon. A HA/FA ratio varied from 0.70 to 1.37 at (0-15 cm) depth, and 0.56 to 1.05 at (15-30 cm) depth.

## *Discussion*

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## V. DISCUSSION

The result of the investigation pertaining to nutrient and carbon distribution in soils of Thirthahalli taluk, Shivamogga district under different land use systems are discussed in this chapter.

- 5.1 Physical properties of soil under different land use systems
- 5.2 Chemical properties of soils under different land use systems
- 5.3 Soil carbon fractions in soils under different land use systems
- 5.4 Correlation coefficient values among the different carbon fractions with soil properties
- 5.5 Aliphaticity and aromaticity of humic acid and fulvic acid fractions in soils under different land use systems

### **5.1 Physical properties of soil under different land use systems**

#### **Particle size analysis**

The study on particle size analysis revealed that the soils were found to contain more than 50 per cent sand content. Hence, the texture of soils varied from sandy loam to sandy clay loam. The highest mean (71.04% and 68.63%) sand content was observed in paddy land use system and lowest mean (66.43% and 63.20 %) was noticed in forest land use systems at surface and subsurface soil depths respectively.

The highest mean (9.97% and 9.12 %) silt content was observed in forest land use system and lowest mean (8.48% and 8.95%) was noticed in paddy land use systems at surface and subsurface soil depths. The highest mean (25.80 % and 27.13 %) clay content in surface and subsurface was observed in arecanut land use system and lowest mean (20.80 % and 22.40 %) was noticed in paddy land use system. The texture of the soil in different land use system was between sandy loam to sandy clay loam. This may be due to the fact that those soils are derived from coarse grained and granodiorite parent materials are normally exhibit coarse texture with higher sand particles. The soils were dominant in sand content but accumulation of clay and silt was observed in the subsurface layer with decrease in sand content. Similar results

have been reported by Sahu and Mishra (1997). Higher content of finer fraction (silt +clay) in lower depths might be due to the translocation of finer particles from the surface horizons and subsequent illuviation in sub surface horizons (Khan and Chatterjee (2001).

### **Bulk density**

The highest mean (1.44 and 1.49 Mg m<sup>-3</sup>) bulk density in surface and subsurface was observed in paddy land use system and lowest mean (1.20 and 1.30 Mg m<sup>-3</sup>) was noticed in areca land use systems (Fig 1). The high bulk density under cultivated lands was due to the trampling effects. The results were in agreement with Islam and Weil, (2000) and Yihenew and Getachew (2013). And the bulk density increased with increase in depth of soils in all the land use systems. This was due to low organic matter content of lower layer and compaction from the pressure of the upper layers. Similar results were also reported by Patil and Jagdish Prasad (2004).

### **Maximum water holding capacity**

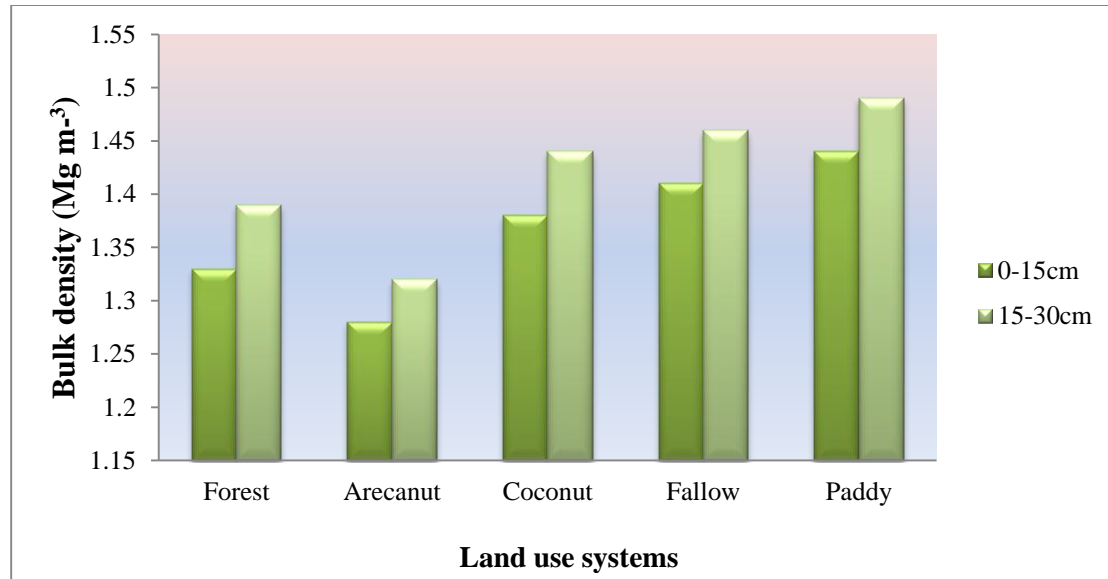
The highest mean (35.81% and 43.0 %) maximum water holding capacity in surface and sub surface was found in forest land use system and lowest mean (25.09 % and 28.74 %) was noticed in paddy land use system (Fig 2, Table 2). This is might be because of cultivation deteriorates soil structural aggregation reducing the soil water retention capacity. The results were in agreement with Yihenew and Getachew (2013) and Wakene (2001).

Total available water was the highest in natural forest land followed by grass land in both soil sampling depths and sites. Higher clay and organic carbon provided large surface area required for absorption and retention of water molecules (Materechera and Mkhabela 2001).

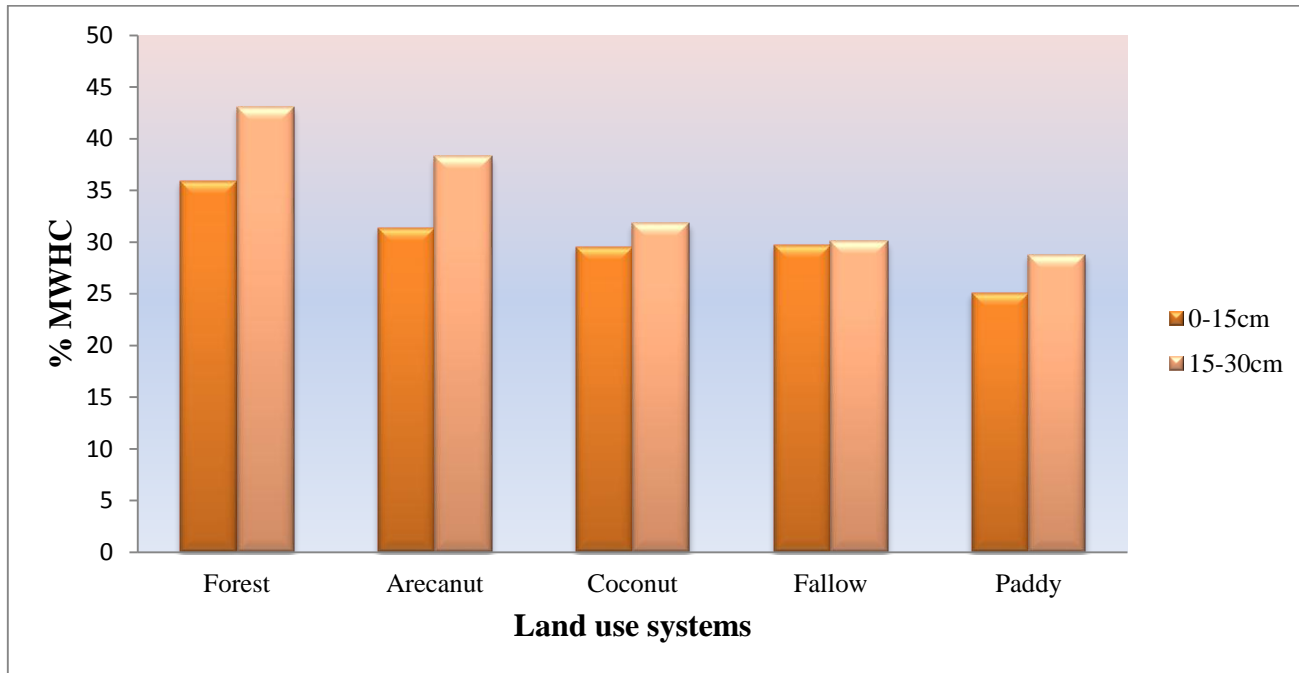
## **5.2 Chemical properties of soils under different land use systems**

### **Soil reaction and electrical conductivity**

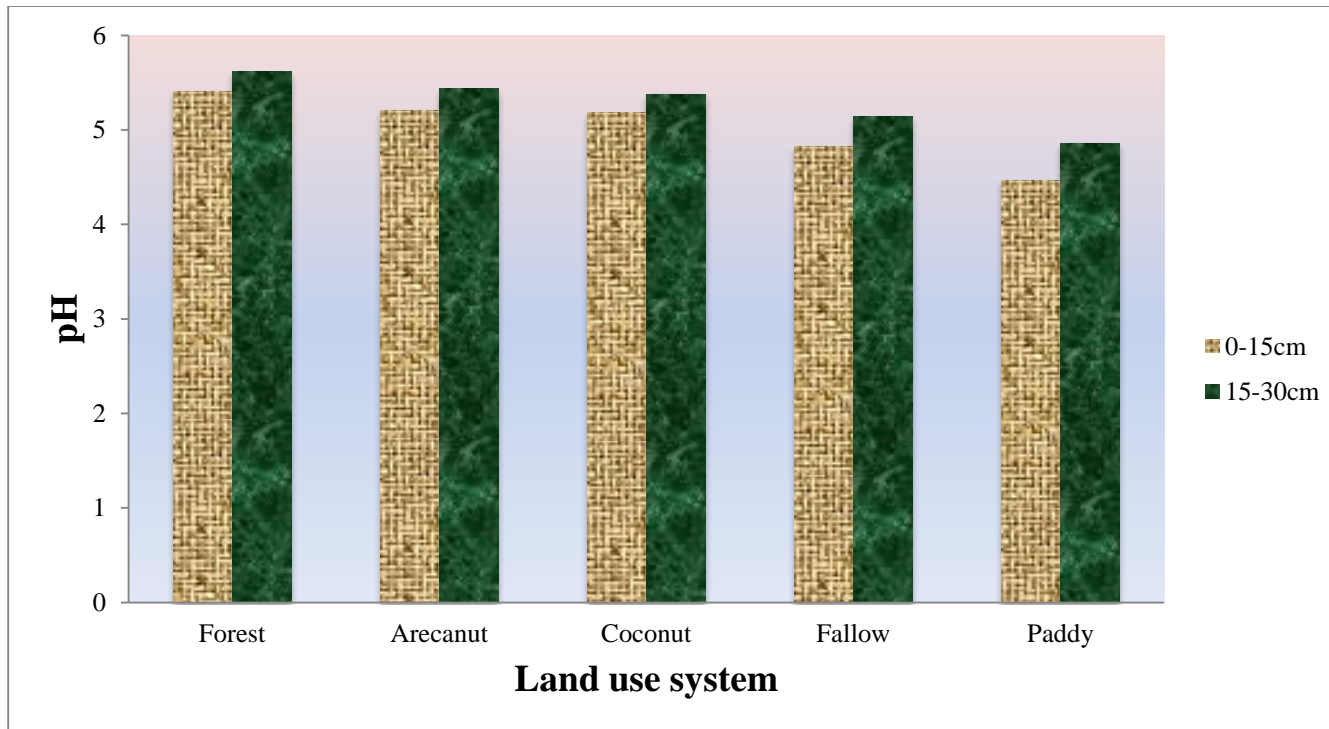
There was increase in pH with soil depth in all land use systems. The mean pH value of paddy land use system showed significantly lowest value (4.47 and 4.86) at surface and sub surface soil depths and the highest mean pH value was registered under forest land use system (5.41 and 5.62) (Fig 3). The variation in pH among the



**Fig 1 : Bulk density under different land use systems at surface and subsurface depths**



**Fig 2: Maximum water holding capacity under different land use systems at surface and subsurface depths**



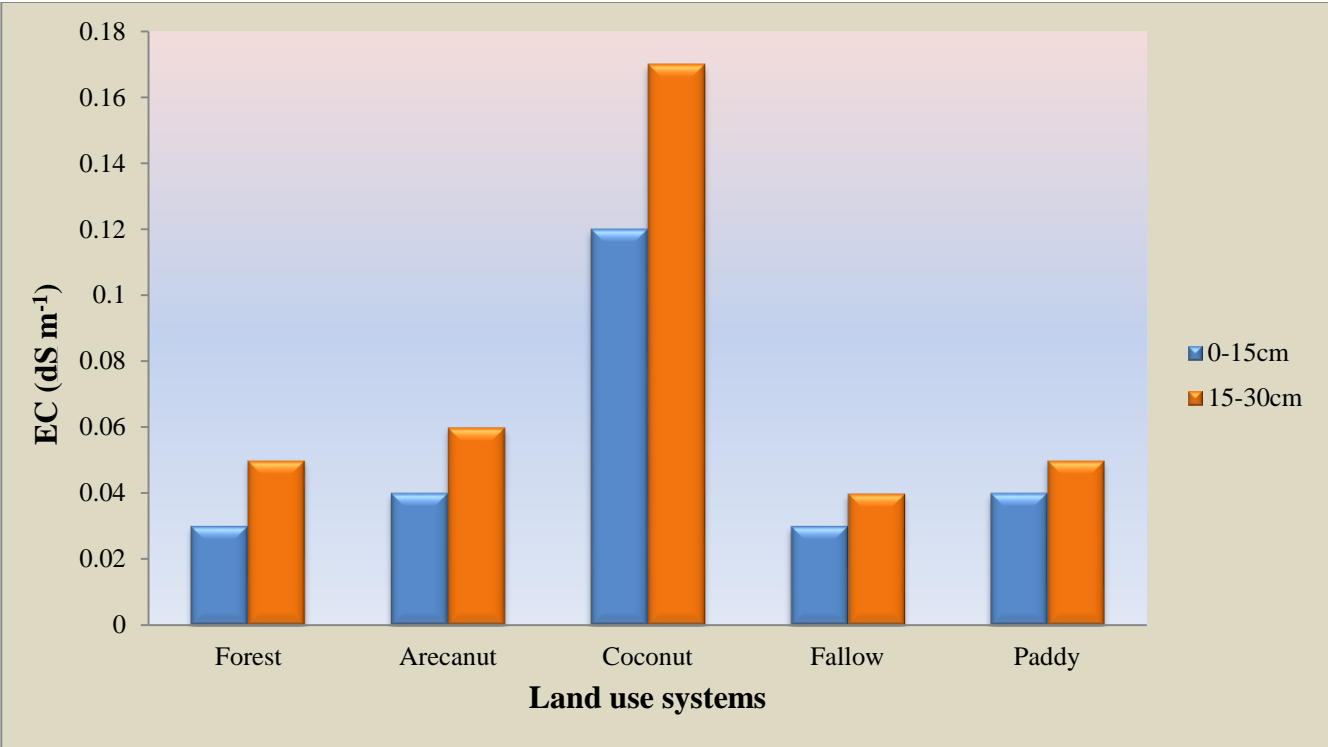
**Fig 3: Soil pH under different land use systems at surface and subsurface depths**

soils under different land use systems may be attributed to variation in rainfall within the zone, topographic position, management practices, impact of parent material (Granite & Gneiss) and leaching down of basic cations due to heavy rainfall (150 - 400 cm) and high organic matter content and pH of soils ranges from strong to slightly acidic in nature (Ananthanarayana and Perur, 1973; Gajanan *et al.*, 1978; Rao, 1992). Further, carboxylic and phenolic hydroxyl groups of organic matter increases  $H^+$  ion concentration in soil solution by deprotonation there by soil acidity increases. These results are similar to those reported by Jyothi *et al.* (2009).

Soil pH increased consistently with depth in all land use systems. This pattern of variability in soil pH suggested the increase in bases with increase in depth that could be attributed to the downward movement of solutes by leaching within a profile (Mohammed *et al.*, 2005). Malo *et al.* (2005) also reported that the increase in pH with soil depth could be associated with enhanced carbonate levels and less weathering rates.

Rudramurthy *et al.* (2007) reported that the acidic pH of different land use systems might be due to the fact that soils are derived from acidic igneous granite and metamorphic genesis rocks. He also observed that irrespective of land use systems, in general increase in soil pH down the profile was due to increase in basic cations in lower of the profile.

The EC of soils under different land use systems did not varied significantly. The EC was low in both surface and subsurface soil depths. But it was increased with depth in all land use systems (Fig 4). The higher EC value was recorded under coconut (0.12  $dS\ m^{-1}$  and 0.17  $dS\ m^{-1}$ ) and lowest EC value was observed under fallow land use (0.03  $dS\ m^{-1}$  and 0.04  $dS\ m^{-1}$ ) in surface and sub surface depths respectively. The EC of paddy (0.04  $dS\ m^{-1}$  and 0.05  $dS\ m^{-1}$ ) and forest (0.03  $dS\ m^{-1}$  and 0.05  $dS\ m^{-1}$ ) land use systems were not observed much variation in surface and sub surface depths. This was due to leaching of soluble salts due to fairly well distributed rainfall. This increase in EC under coconut plantation might be due to application of common salt as a farmer's practice. These observations are in accordance with results of Reddy *et al.* (2012).



**Fig 4: Electrical conductivity under different land use systems at surface and subsurface depths**

## Soil organic carbon

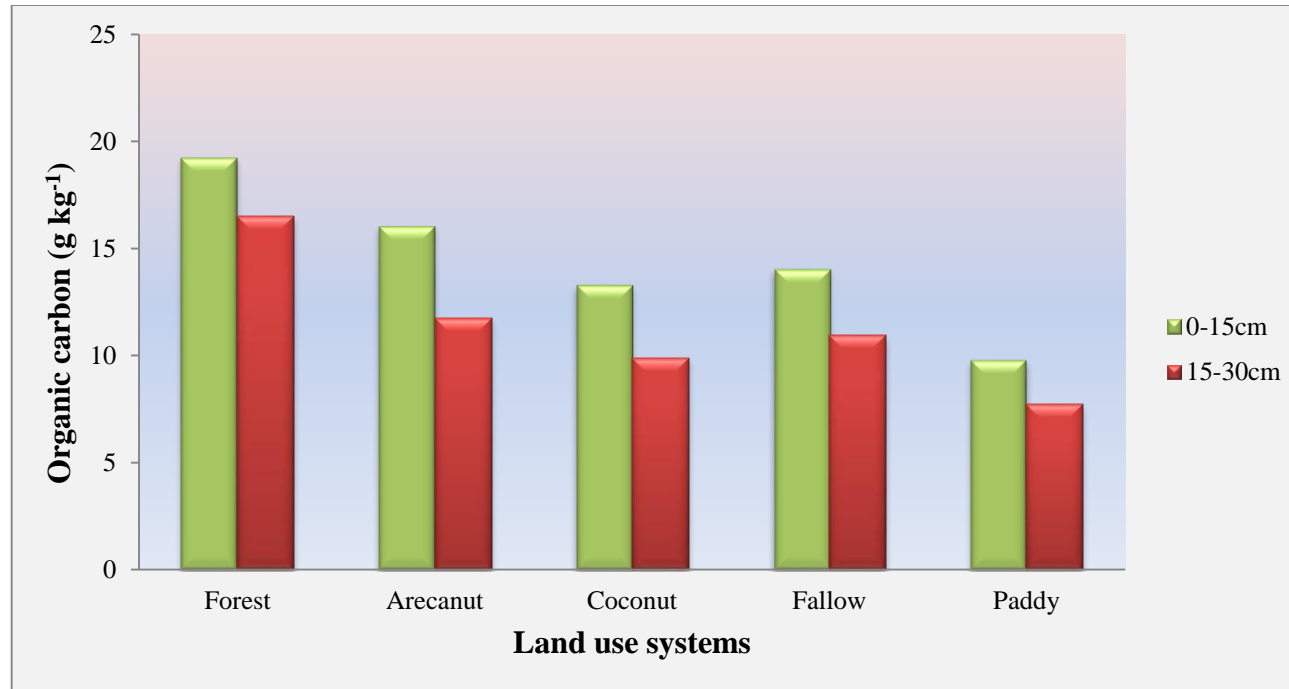
It is universally accepted that soil organic carbon has beneficial effect on soils of plant nutrients, which in turn increases the productive capacity of soil biological, chemical and physical properties as well as it is a contributor.

The organic carbon status of the soils was more under forest land use systems as compared to paddy land use in all depths. The organic carbon status decreased with depth in all the land use systems. The surface (0-15 cm) soil registered higher mean organic carbon status than sub surface (15-30 cm). Among the different land use systems, forest land recorded significantly higher soil organic carbon status of (19.23 g kg<sup>-1</sup> and 16.51 g kg<sup>-1</sup>) followed by arecanut (16.04 g kg<sup>-1</sup> and 11.75 g kg<sup>-1</sup>), coconut (13.31 g kg<sup>-1</sup> and 9.88 g kg<sup>-1</sup>), fallow land use systems (12.83 g kg<sup>-1</sup> and 10.95 g kg<sup>-1</sup>). Lowest soil organic carbon was recorded in paddy soil (9.81g kg<sup>-1</sup> and 7.71 g kg<sup>-1</sup>) at surface and subsurface depths respectively (Fig 5). The high organic carbon status in the surface layers of the soil was due to the accumulation of organic matter in surface horizons and recycling of organic matter addition of organic manure and also crop residues remaining in soil surface (Ashok, 1998).

Increase in organic carbon of forest soil due to continuous addition of bio mass through leaf and roots has been reported by Geo Jose (2006). The lower organic carbon content in sub surface later might be attributed to lower vertical mixing of soils.

The highest potassium dichromate oxidizable organic carbon (PDOC) status was recorded in the forest and horticulture land use systems was attributed to the long term addition of carbon over more than 25-50 years in these soils coupled with minimum physical disturbance to surface soil as compared to agriculture and agri-horticulture land use systems. Similar results are also reported by (Brij *et al.*, 2012).

Higher organic carbon in forest cropping system may be attributed to continuous litter fall from the vegetation, whereas, in maize and paddy cropping systems most of the biomass was being removed from the field and generally used as animal feed. Since these soils are intensively cultivated for a long period of time. As a result organic carbon status is lower in maize and paddy cropping systems. Increase in organic carbon of soil due to continuous addition of bio mass through leaf and roots has been reported by Negi and Gupta (2013) in the case of a field crop and, for coffee



**Fig 5: Organic carbon status under different land use systems at surface and subsurface depths**

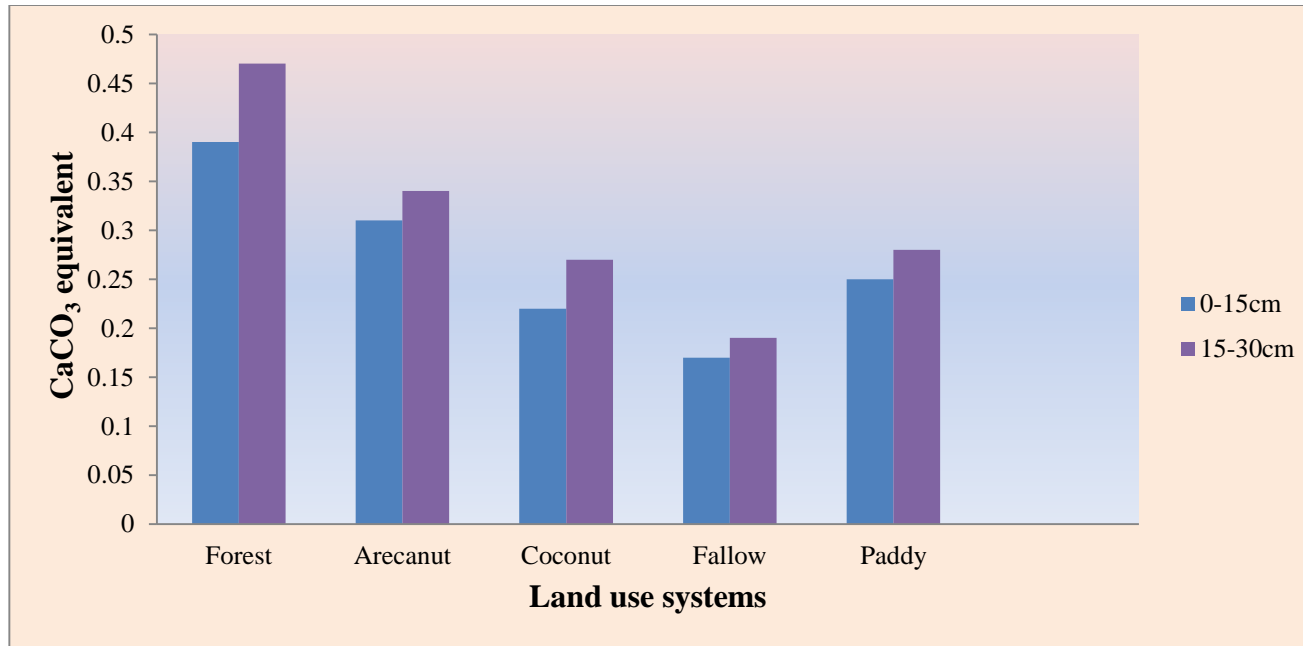
soils of south India. And decrease in organic carbon content in the case of crop lands has been reported by Wenjuan *et al.* (2009).

### **Calcium carbonate equivalent**

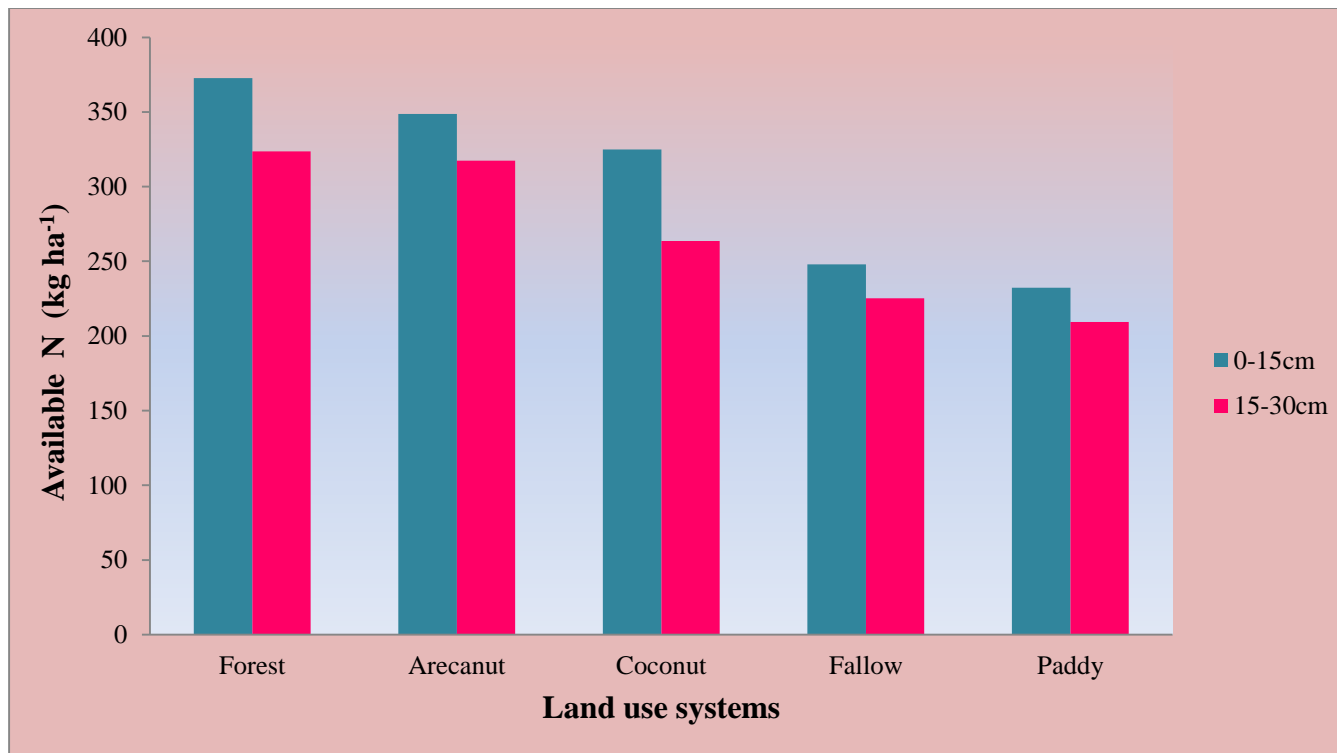
There was increase in calcium carbonate equivalent with soil depth in all land use systems. The calcium carbonate equivalent was low in both surface and sub surface depth. The highest (0.39 % and 0.47 %) value of calcium carbonate equivalent was observed in forest land use system both in surface and sub surface soil depths, and the lowest (0.17 % and 0.19 %) was in fallow land use system. The mean calcium carbonate equivalent content under different land use systems were in order of forest > arecanut > coconut land > fallow > paddy land use systems, respectively (Fig 6). Low calcium carbonate content in surface and sub surface soil is mostly associated with the soils having low pH and soils developed from acidic parent materials like granite and granitic gneiss (Ananthanarayana *et al.*, 1974; Rao, 1992) with depth in all land use systems Challa *et al.* (2000) noticed the similar trend due to higher elevation and topography, good plains within a region which is a congenial for precipitation of calcium carbonates. Similar results was made by Sharma *et al.* (1996). In general the CaCO<sub>3</sub> equivalent values are low due to high rainfall and no carbonate accumulations. Calcium carbonate equivalent generally higher at forest soil as compared to cultivated soil, Calcium carbonate equivalent varied with soil depth. Calcium carbonate equivalent although depend upon the parent material (Yaser and Mhawish, 2015).

### **Available nitrogen**

The result of the present investigation indicated that, most of the surface and sub surface soils found to be low to medium in available nitrogen. The available nitrogen status decreased with soil depth in all land use systems. Among the different land use systems forest land use recorded significantly higher available nitrogen (372.7 kg ha<sup>-1</sup> and 323.64 kg ha<sup>-1</sup>) and paddy land use system recorded lowest (232.2kg ha<sup>-1</sup> and 209.9 kg ha<sup>-1</sup>) available nitrogen at surface and subsurface depths respectively (Fig 7). Which may be a result of higher organic matter accumulation due to increased above and below ground biomass (root biomass) and reduced litter decomposition rates conversely, the organic carbon and total N contents of the



**Fig 6: Calcium carbonate equivalent content under different land use systems at surface and subsurface depths**



**Fig 7: Available nitrogen status under different land use systems at surface and subsurface depths**

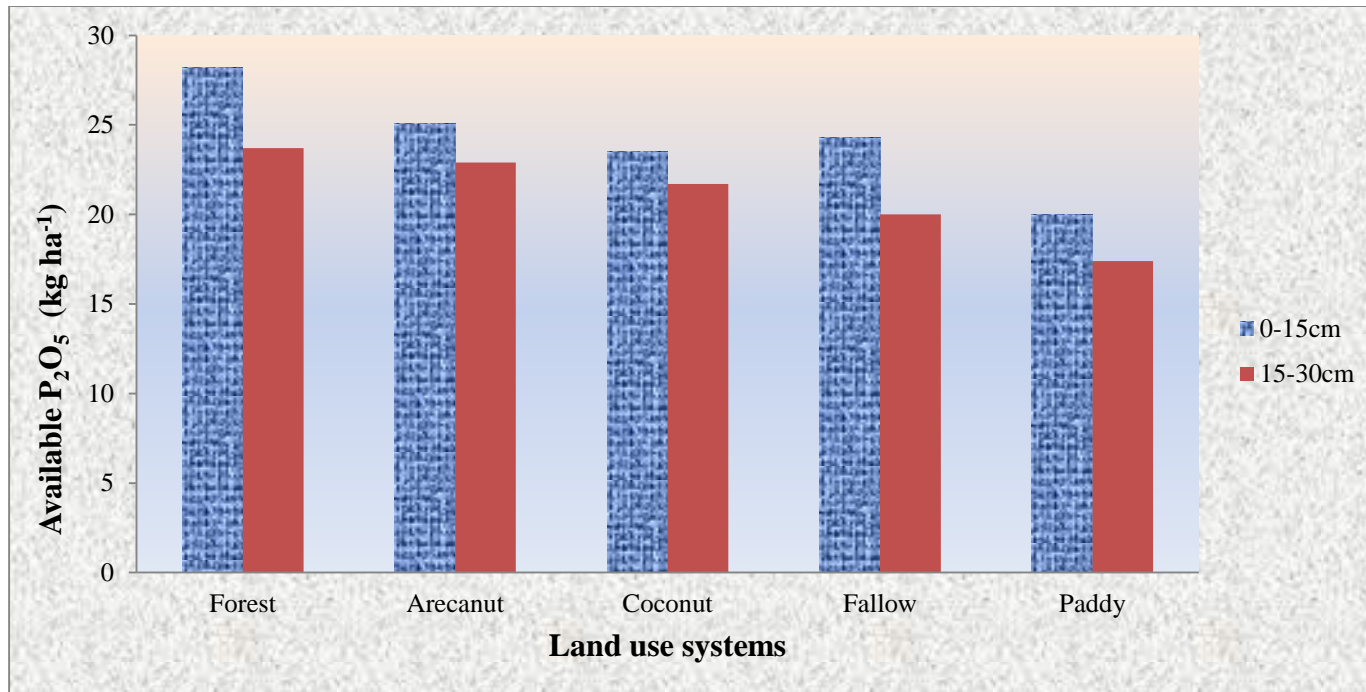
mineral soil were significantly lower in the crop lands compared to the native forest sites, which is likely the consequence of the reduced amount of organic material being returned to the soil system, and high rates of oxidation of soil organic matter due to tillage, and loss of organic matter by water erosion (Fantaw *et al.*, 2007). It was observed that available nitrogen decreased with increase in soil depth. This could be due to decrease in organic carbon content and microbial population in lower depth. Similar findings were reported by Loganathan and Krishnamurthy (1996) Chavan *et al.* (1995), Sreerangappa (1995) and Ashok (1998).

### **Available phosphorus**

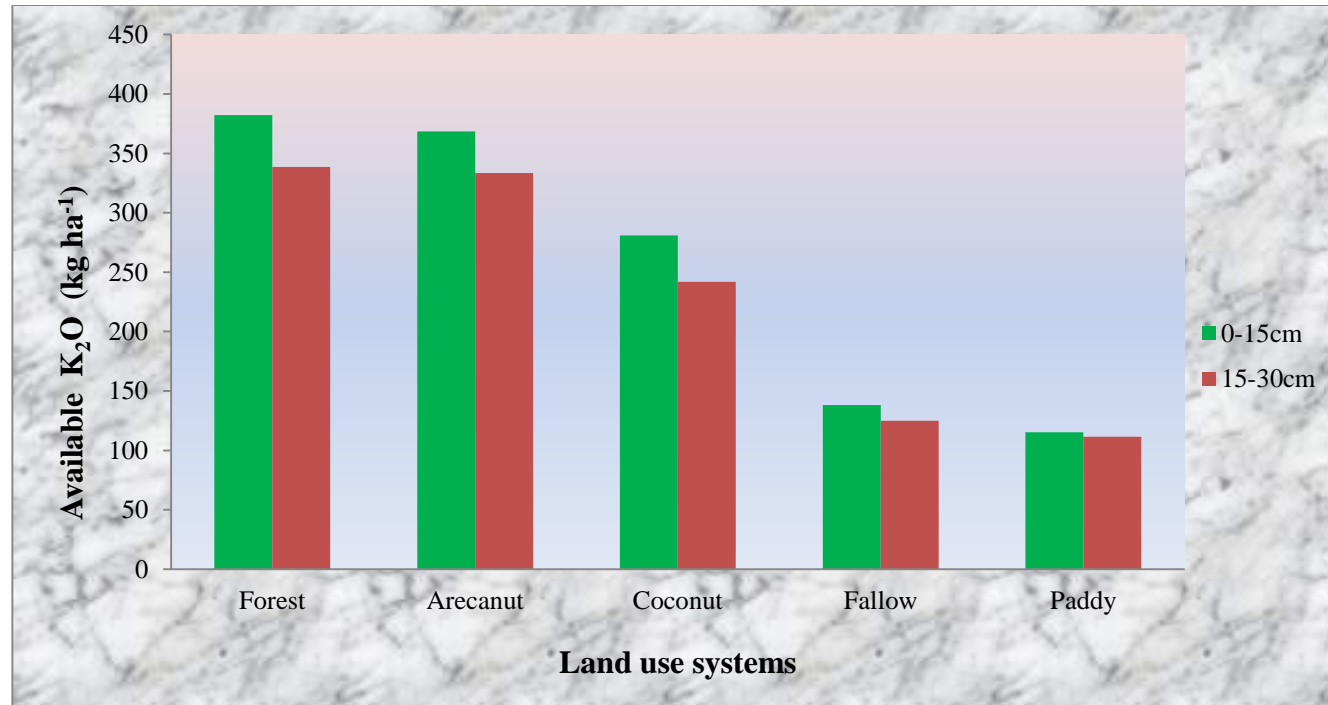
In general most of the surface and subsurface soils were medium in available phosphorus status. The available phosphorus status decreased with depth in all land use systems. The available phosphorus in, surface depth (0-15 cm) was higher than subsurface depths. Higher available phosphorus was noticed in soil of forest (28.27 kg ha<sup>-1</sup> and 23.7 kg ha<sup>-1</sup>) and lowest was in paddy (20.0 kg ha<sup>-1</sup> and 17.40 kg ha<sup>-1</sup>) land use system at surface and subsurface depths respectively (Fig 8). The higher available phosphorus status in forest land use system can be attributed to high organic matter which released phosphorus during its mineralization. Available phosphorus content in all land use systems decreased with increasing soil depth. This could be due to the increased clay and reduced organic matter content with increasing depth of the soil. Organic compounds in soils increase phosphorus availability by the formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of H<sub>2</sub>PO<sub>4</sub> from adsorption sites, the coating of Fe/Al oxides by humus to form a protective cover and reduced phosphorus fixation. Moreover, decomposing of OM releases acids that increase the solubility of calcium phosphates (Yihenew and Getachew., 2013) The results were in agreement with the reports of Yihenew (2002).

### **Available potassium**

The present investigation as reported that the most of the surface soils were low to high in available potassium. The surface depth registered higher available potassium content than sub surface depth in all the land use systems. The highest mean available potassium content was recorded in the soil of forest (382.2 kg ha<sup>-1</sup> and 338.5 kg ha<sup>-1</sup>) and lowest was recorded in paddy land use system (115.36 kg ha<sup>-1</sup> and 111.47 kg ha<sup>-1</sup>) at surface and sub surface depths respectively (Fig 9). This could



**Fig 8: Available phosphorus status under different land use systems at surface and subsurface depths**



**Fig 9: Available potassium status under different land use systems at surface and subsurface depths**

be due to the effect of continuous cultivation and crop removal. This result is supported by previous findings that indicate intensity of weathering, cultivation and use of acid forming inorganic fertilizers affect the distribution of potassium in the soil system and enhance its depletion (Malo *et al.*, 2005).

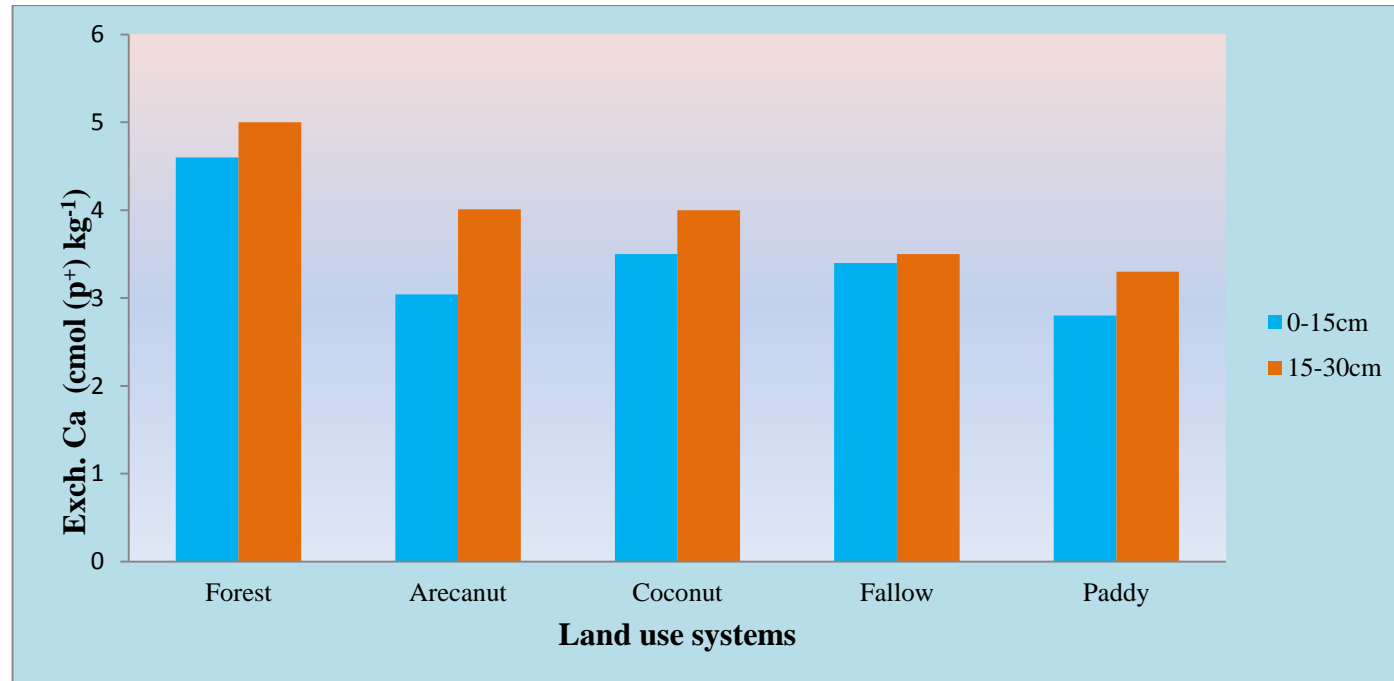
### **Exchangeable calcium and magnesium**

Calcium was the dominant cation over magnesium in all the land use system and it increased with increase in depth under all the land use systems, the mean values of calcium status of surface and subsurface soil were higher (4.6 and 5.0 cmol (p<sup>+</sup>) kg<sup>-1</sup>), in forest land use system and lower (2.8 and 3.3 cmol (p<sup>+</sup>) kg<sup>-1</sup>) in paddy land use system ( Fig 10, 11). The higher calcium status in forest land use system can be attributed to lesser leaching of cations in forest land use system with grass than other land use systems as observed by Hayens and Goh (1980). Further, leaf fall and pasture roots could also contributed to the increased amount of calcium and magnesium in soils. The highest exchangeable Ca was observed on the surface layer of forest land whereas lowest on the surface layer of cultivated land which might be due to high organic matter and relatively high pH on the surface layer of forest land and its leaching from the surface layer of cultivated land. (Habtamu *et al.*, 2014)

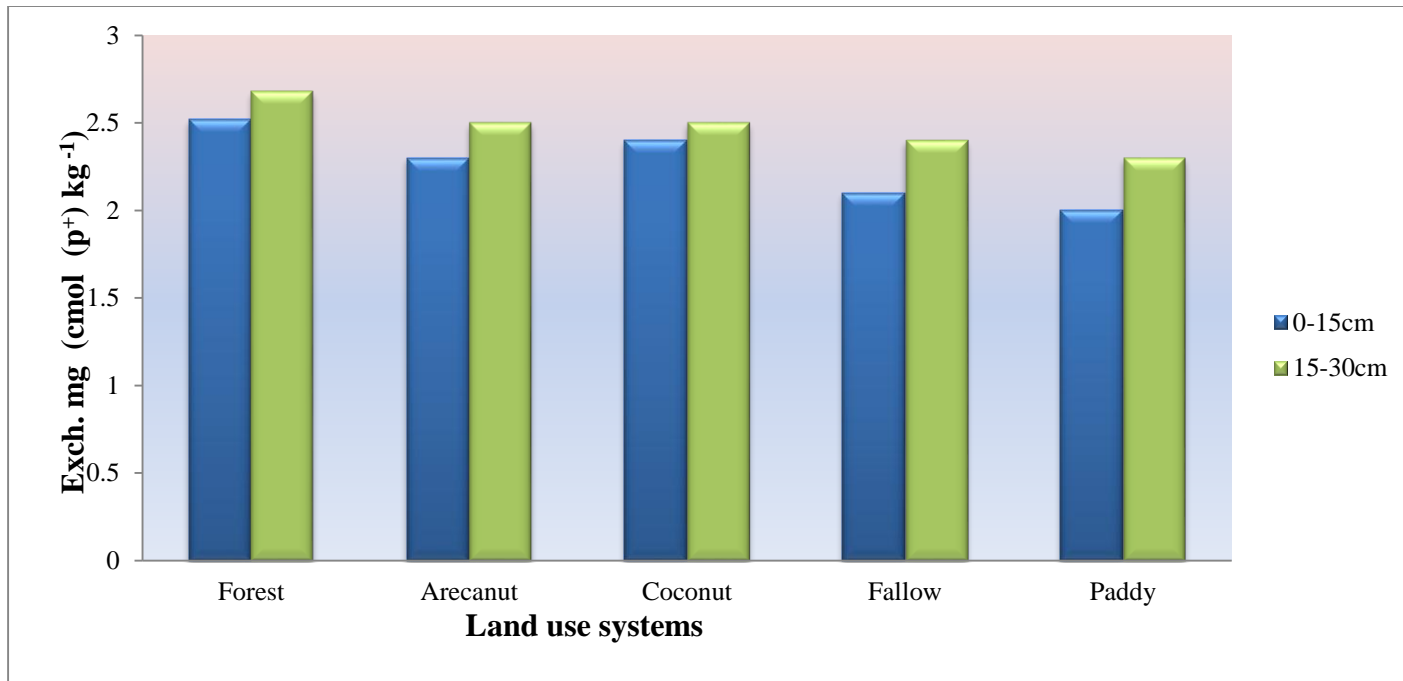
### **Available sulphur**

A significant variation in available sulphur was observed among the different land use systems. Available sulphur status was more than the critical limit. The lowest mean available sulphur status was recorded in paddy land use system (19.9 mg kg<sup>-1</sup> and 17.6 mg kg<sup>-1</sup>) in surface and sub surface depths respectively. Highest mean available sulphur status was noticed in forest land use system (25.1 mg kg<sup>-1</sup> and 22.3 mg kg<sup>-1</sup>) in surface and sub surface depths respectively (Fig 12). The status of available sulphur appears to be depend on the combined action of factors namely nature of parental materials, rainfall, clay and organic matter content in the soil. Similar results were observed by (Tawande *et al.*, 1976 ) and (Habtamu *et al.*, 2014).

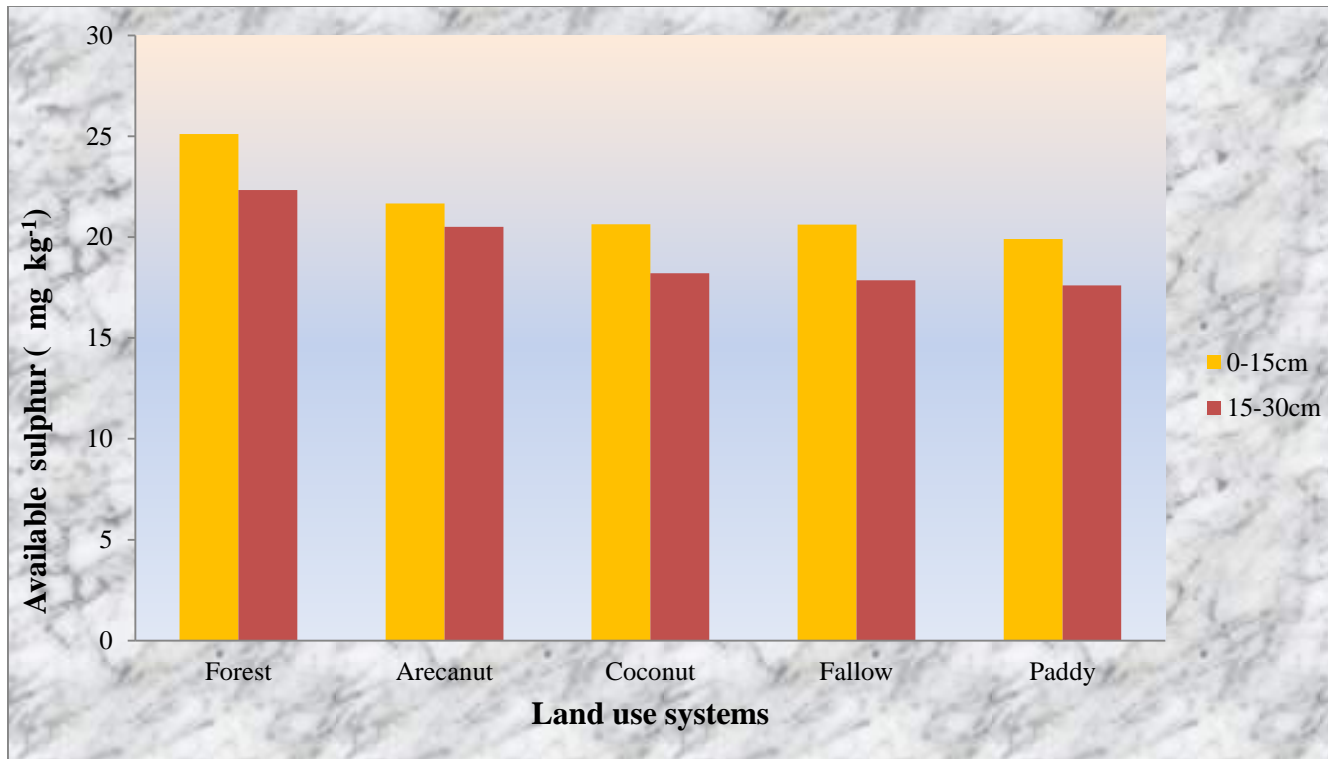
In general available sulphur content was decreased with depth in all the land use system. Decreased in available sulphur was due to low organic carbon content (Tawande *et al.*, 1976) and reducing microbial population are the possible reasons for such decreasing trend.



**Fig 10 : Exchangeable calcium status under different land use systems at surface and subsurface depths**



**Fig 11: Exchangeable magnesium status under different land use systems at surface and subsurface depths**



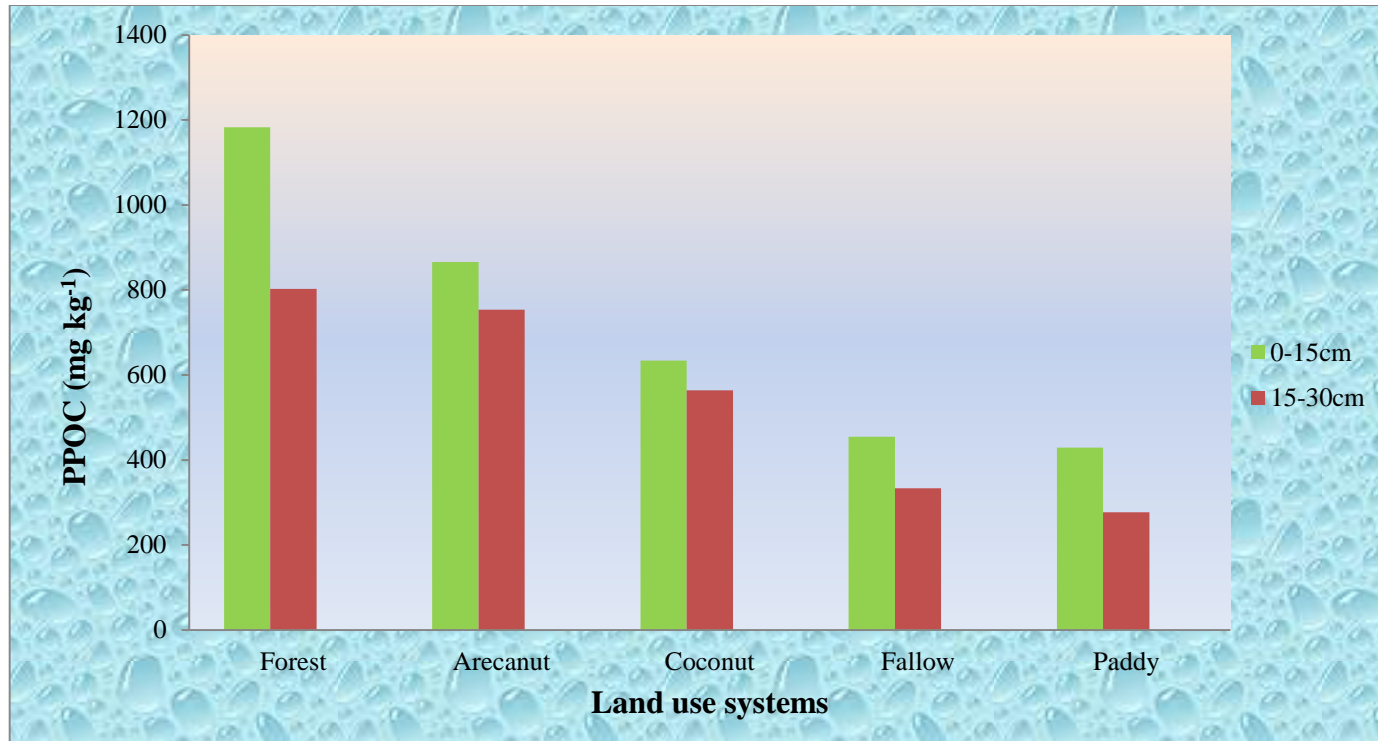
**Fig 12: Available sulphur status under different land use systems at surface and subsurface depths**

### 5.3 Soil carbon fractions in soils under different land use systems

The potassium permanganate oxidizable organic carbon content of the soils varied among the different land use systems. However significantly higher mean potassium permanganate oxidizable organic carbon content was observed under forest (1182.7 mg kg<sup>-1</sup> and 802.66 mg kg<sup>-1</sup>) followed by arecanut, (865.5 mg kg<sup>-1</sup> and 753.9 mg kg<sup>-1</sup>), coconut (633.9 mg kg<sup>-1</sup> and 563.6), paddy (429.3 mg kg<sup>-1</sup> and 276 mg kg<sup>-1</sup>) and fallow (454.7 mg kg<sup>-1</sup> and 333.7 mg kg<sup>-1</sup>) land use systems at surface and sub surface depths, respectively. Lower mean potassium permanganate oxidizable organic carbon was observed under paddy land use system (429.39mg kg<sup>-1</sup> and 276.78 mg kg<sup>-1</sup>) at surface and subsurface depths respectively (Fig 13). This might be due to changes in land use and management can have detrimental effect on soil carbon. Land use determines the amount of carbon being contributed to the soil and forest systems tend to have the largest input of carbon to the soil. The trend of forests and plantation soils having higher levels of active fractions of carbon, lack of biomass addition to soil, crop residue removal, and conventional tillage practices in agricultural production systems enhance carbon losses from the soil. The hilly region also faces large scale soil erosion from agricultural and degraded lands. Tillage and unprotected surfaces are known to promote soil erosion, thereby taking the soil carbon out of the local eco-system. Forest soils on the other hand remain unaltered by anthropogenic practices like tillage, and litter fall tends to accumulate, decompose and contributes to the soil carbon. Low concentration of potassium permanganate oxidizable organic carbon in agricultural land use systems can be attributed to tillage practices. Cultivation period have a negative effect on labile carbon (Vikas *et al.*, 2014).

Verma *et al.* (2010) reported that PPOC status significantly affected by nutrient management treatment within the short period under tropical environment. On the contrary, Mtambanengwe and Mapfumo (2008) did not show any significant changes in PPOC content of soil due to nutrient management system.

The term water soluble organic carbon (WSOC) is defined as the entire pool of water soluble organic carbon either sorbed on soil or sediment particles or dissolved in interstitial pore water. The present investigation also found that the cold water extractable organic carbon content varied among the different land use systems, and it decreased with increase in depth irrespective of the land use change. The cold water extractable organic carbon content was more under the forest and horticulture

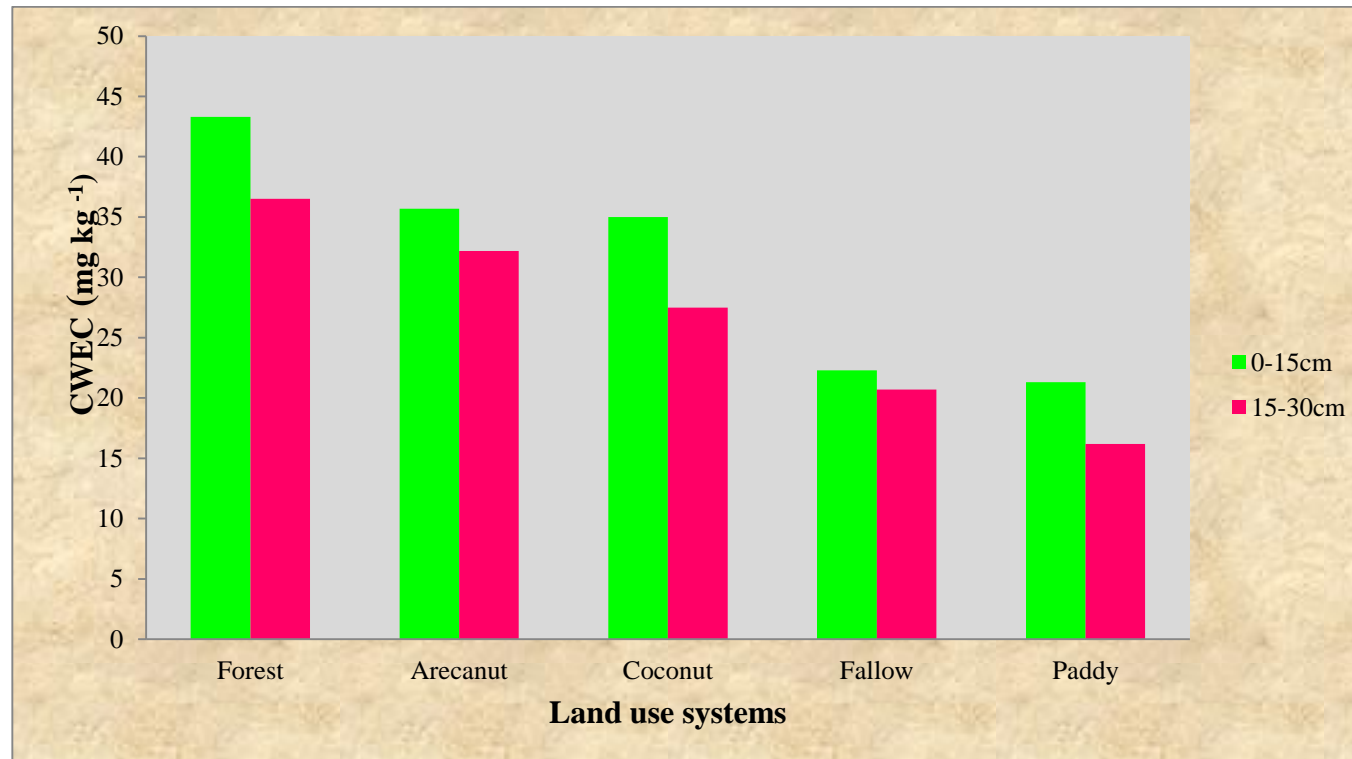


**Fig 13: Potassium permanganate extractable carbon (PPOC) (mg kg<sup>-1</sup>) in soils under different land use systems at surface and subsurface depths**

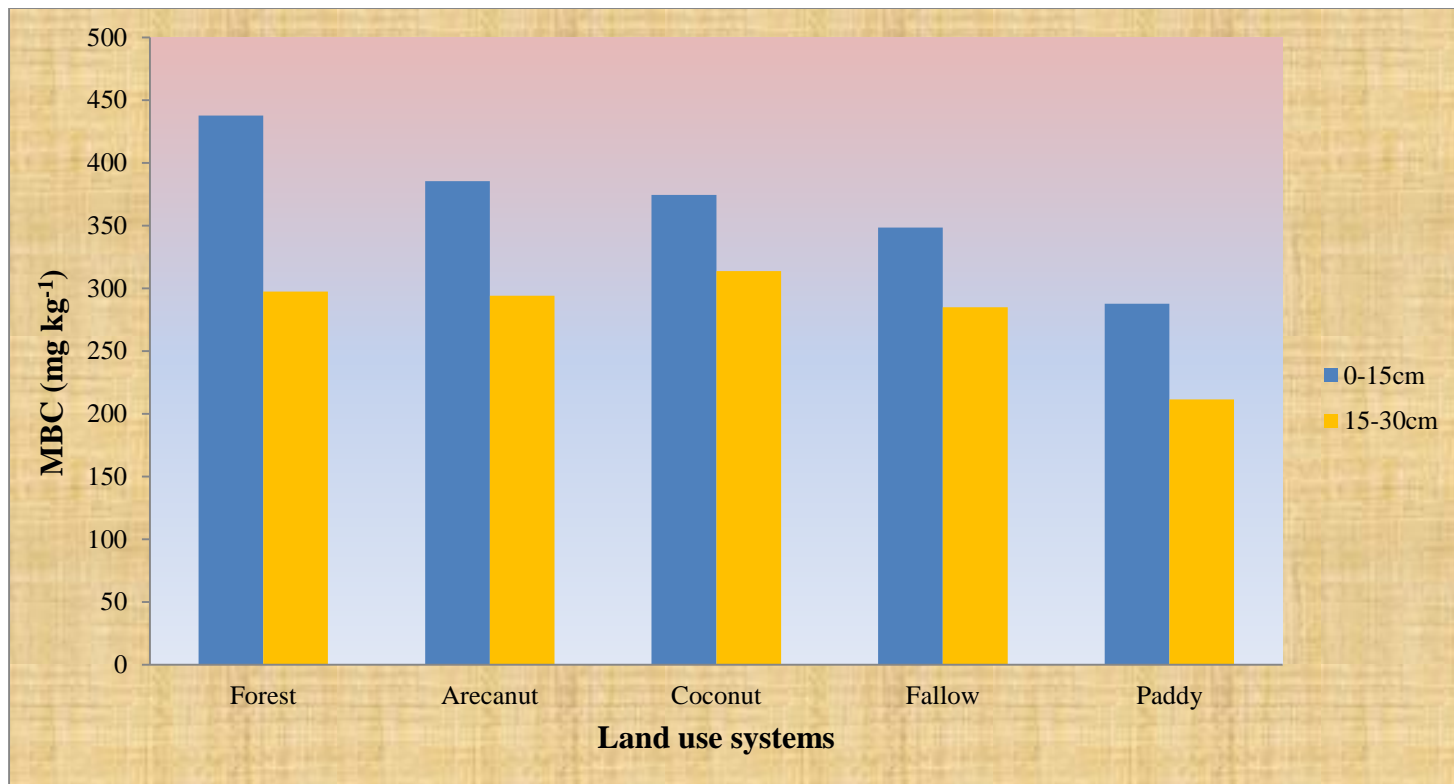
systems (arecanut, coconut) as compared to cultivated land (paddy) in all depths. Among different land use systems, forest land use recorded significantly higher cold water extractable organic carbon ( $43.3 \text{ mg kg}^{-1}$  and  $36.5 \text{ mg kg}^{-1}$ ) and the lower mean cold water extractable organic carbon was observed under paddy ( $21.3 \text{ mg kg}^{-1}$  and  $16.2 \text{ mg kg}^{-1}$ ) at surface and sub surface depths respectively (Fig 14). This might be due to higher build up of soil organic carbon, water soluble carbon and labile carbon on surface soil depth under the forest might be attributed to the accumulation of litter fall of tree species on soil surface. The subsequent decomposition and incorporation of litter into the soil would have helped in raising the soil organic carbon pool status of soil (Gill *et al.*, 1987 and Singh and Sharma, 2012).

Microbial biomass carbon refers to the labile fraction of soil organic matter that constitutes living microorganisms smaller than  $5$  to  $10 \mu\text{m}^3$ . MBC content of soil serve as an indication of microbial community (Biederbeck *et al.*, 1984) and as also an estimate of mass of potential plant nutrients contained in them (Scow *et al.*, 2002). Further, microbial activity is closely related to soil organic matter.

The microbial biomass carbon content differed significantly under different land use systems, and it decreased significantly with increase in depth. The microbial biomass carbon content was more under the forest and horticulture systems (arecanut, coconut) as compared to cultivated land (paddy) in all depths. Among different land use systems, forest land use recorded significantly higher microbial biomass carbon ( $437.75 \text{ mg kg}^{-1}$  and  $297.4 \text{ mg kg}^{-1}$ ) and the lowest mean microbial biomass carbon content was noticed in paddy land use system ( $287.7 \text{ mg kg}^{-1}$  and  $211.2 \text{ mg kg}^{-1}$ ) in surface and sub surface depths respectively (Fig 15). The variations in soil microbial biomass carbon among different land use systems may be attributed to variation in soil organic matter content consequently the microbial activity. Further the variation in soil organic matter may be attributed to variation in residue return to soil and addition of manure. The addition of manure had positive effect on soil organic matter content which in turn decides the SMB-C (Collins *et al.*, 1992). Similar results have been reported by (Geo Jose., 2006) in the FYM applied plots of long term manurial trial in Alfisol under rice pulse cropping systems.



**Fig 14: Cold water extractable carbon (CWEC) (mg kg<sup>-1</sup>) in soils under different land use systems at surface and subsurface depths**



**Fig 15: Microbial biomass carbon (mg kg<sup>-1</sup>) in soils under different land use system at surface and subsurface depths**

### 5.3.1 SOC stock in soils under different land use systems at Thirthahalli taluk

The variations in SOC stock were noticed among the different different land use systems. Forest land use system accounted for highest SOC stock (37.89 and 34.21 t C ha<sup>-1</sup>) whereas, soil under paddy accounted for lowest SOC (21.8 and 17.31 t C ha<sup>-1</sup>) (Fig 16) , indicating higher organic carbon turnover through decomposition of leaf litter. Roy *et al.* (2010) also found increase in organic carbon status with addition of organic matter through leaf litter in forest land use system.

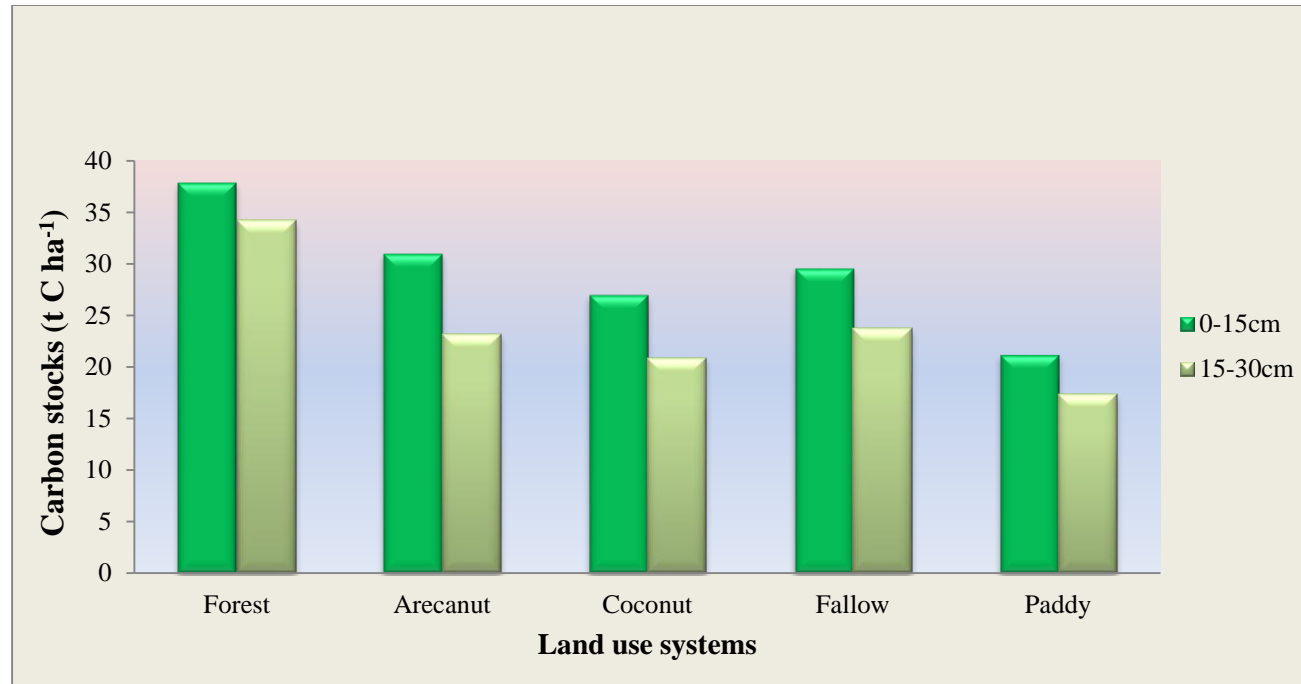
### 5.4. Correlation coefficient values among the different carbon fractions with soil properties

Correlation between soil carbon fractions and soil physical and chemical properties under different land use systems are discussed here.

Nitrogen showed positive and significant correlation with OC, PPOC, CWEC, MBC HA, FA ( $r = 0.84$ ,  $r = 0.63$ ,  $r = 0.85$ ,  $r = 0.75$ ,  $r = 0.20$  and  $r = 0.37$  respectively). Phosphorus showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.61$ ,  $r = 0.37$ ,  $r = 0.58$  and  $r = 0.49$  respectively). Potassium showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.59$ ,  $r = 0.62$ ,  $r = 0.81$  and  $r = 0.64$  respectively) irrespective of land use cover. This is might be because of with increase in organic carbon and CEC of the soil, microbial activity increased significantly, as evidenced from very high positive values of correlation coefficients (Pal *et al.*, 2013).

Soil BD showed negative and non significant correlation with clay, pH, OC, CaCO<sub>3</sub> PPOC and CWEC ( $r = -0.05$ ,  $r = -0.26$ ,  $r = -0.58$ ,  $r = -0.29$ ,  $r = -0.41$  and  $r = -0.63$  respectively). Soil BD showed negative and significant correlation with MBC, HA and FA ( $r = -0.51$ ,  $r = -0.078$ ,  $r = -0.230$  irrespective of land use cover (Vikas *et al.*, 2014).

Soil pH showed negative significant correlation with OC, PPOC, CWEC, and MBC ( $r = -0.11$ ,  $r = 0.35$ ,  $r = 0.40$ ,  $r = 0.13$ , respectively) irrespective of land use cover. Soil pH showed negative and nonsignificant correlation with BD and clay ( $r = -0.05$ ,  $r = -0.26$ , respectively) irrespective of land use cover (Vikas *et al.*, 2014).

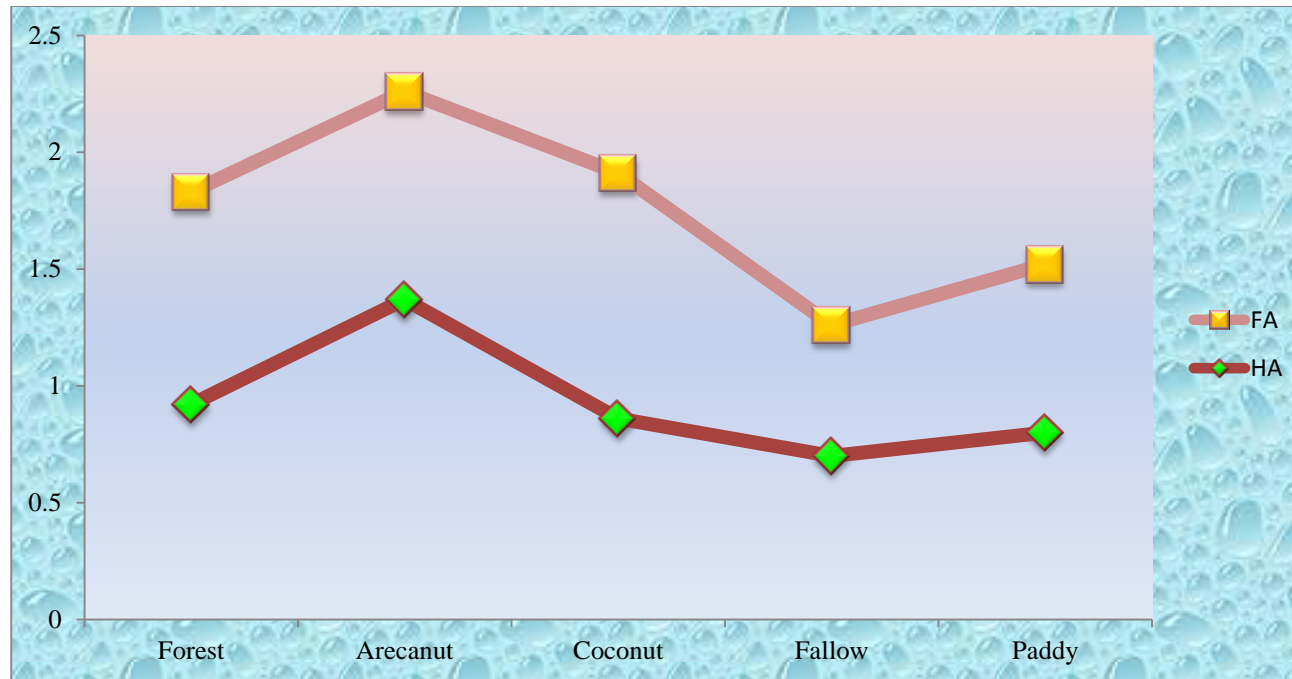


**Fig: 16 Carbon stocks under different land use systems at surface and subsurface depths**

## **5.5 Aliphaticity and aromaticity of humic acid and fulvic acid fractions in soils under different land use systems.**

The ratio between humic and fulvic acids (HA/FA) reflects the mobility of soil organic carbon. HA/FA ratio near to 1 is indicative of good quality organic material that could enhance soil physical properties and improve plant growth. HA/FA ratio  $>1$  indicates loss of the more labile FA fraction, a situation very common in sandy soils. The mean values of E4/E6 ratios of fulvic acids were higher (5.53 and 4.00) in forest land use system as compared to other land use systems, and it was lowest in fallow land use system (3.28 and 2.40) at surface and subsurface depths respectively. The mean values of E4/E6 ratios of humic acid were higher (5.12 and 3.65) in forest land use system as compared to other land use systems, and it was lowest in fallow land use system (3.28 and 2.40) at surface and subsurface depths respectively (Fig 17). Narrower FA: HA ratios less than one in all the land use systems suggest that the fulvic acid was relatively more than humic acid. These results suggest that the HA: FA ratios are regulated by quality of organic matter added. Least variations in the proportional values were observed in all land use systems. This suggests that the proportional amount of each soil organic matter fraction is likely to be determined by the management practices adopted in the land use system and not the quantity of soil organic carbon (Reddy *et al.*, 2012).

Amongst the most labile fractions, fulvic acid predominated, resulting in a HA/FA ratio  $< 1$  for most land uses. The predominance of a higher percentage of fulvic acids, as compared to humic acids, indicated either a slow rate of soil organic matter decomposition, or frequent inputs of fresh organic residues. Fulvic acid was effective in discriminating changes in land use, due to its characteristic liability (Guimaraes *et al.*, 2013).



**Fig: 17 Humic acid and fulvic acid ratio among the different land use systems**

*Summary*

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## VI. SUMMARY

The investigation was undertaken at University of Agricultural and Horticultural Sciences, Shivamogga to study the impact of land use systems on nutrient status and carbon distribution in Thirthahalli taluk, Shivamogga district. Surface and subsurface (0-15 and 15-30 cm depths) soil samples were collected from forest, areca, coconut, paddy and fallow land use systems. The soils were characterized and studied different fractions of carbon in soils under different land use systems, their distribution and relationship with soil properties and among the fractions of carbon. The significant findings of the investigation are summarized below.

The surface soils under all the land use systems, the soil texture varied from sandy loam to sandy clay loam. Bulk density showed wide variations among the different land use systems. The lowest bulk density was noticed in arecanut, and highest bulk density was observed in paddy land use system. The mean bulk density increased with depth under all land use systems. The water holding capacity (WHC) of soils varied among the different land use systems. Water holding capacity increased with increase in depth all the land use systems. The per cent WHC in soils followed the order: forest > arecanut >coconut >fallow > paddy land use systems.

Soils of different land use systems were acidic in nature, the mean pH values being ranged from 4.47 to 5.41 in surface depth and 4.86 to 5.62 in sub surface depth. Whereas, the higher EC value was recorded under coconut (0.12 dS m<sup>-1</sup> and 0.17 dS m<sup>-1</sup>) and lowest EC value was observed under fallow land use (0.03 dS m<sup>-1</sup> and 0.04 dS m<sup>-1</sup>) in surface and sub surface depths, respectively. The mean soil calcium carbonate equivalent (% CaCO<sub>3</sub>) content was higher in the forest land use system and lowest in fallow land as compared to other land use systems. The soil organic carbon status in forest system recorded significantly higher soil organic carbon content of (19.23 g kg<sup>-1</sup> and 16.51 g kg<sup>-1</sup>) and lowest soil organic carbon was recorded in paddy land use system (9.81g kg<sup>-1</sup> and 7.71 g kg<sup>-1</sup>) in surface and subsurface depths respectively.

The soils under different land use systems were low to medium in available-N and available phosphorus was medium and available potassium status was medium to high in all surface and subsurface soils studied. Similarly, the exchangeable Ca and Mg

and available S status were higher than the critical level. The content of available nutrients decreased with depth. The higher mean status of available nitrogen was observed in forest land use (372.7 kg ha<sup>-1</sup> and 323.6 kg ha<sup>-1</sup>) and lowest in paddy (232.2 kg ha<sup>-1</sup> and 209.9 kg ha<sup>-1</sup>) land use system at surface and sub surface depths respectively. Highest mean available phosphorus status was noticed in soils of forest land use (28.2 kg ha<sup>-1</sup> and 23.7 kg ha<sup>-1</sup>) and lowest were recorded in paddy (20.0 kg ha<sup>-1</sup> and 17.40 kg ha<sup>-1</sup>) land use system at surface and sub surface depths respectively. The highest mean available potassium status was recorded in soils of forest land use (382.2 kg ha<sup>-1</sup> and 338.5 kg ha<sup>-1</sup>) and lowest were recorded in paddy land use system (115.3 kg ha<sup>-1</sup> and 111.4 kg ha<sup>-1</sup>) at surface and sub surface depths respectively. The highest exchangeable calcium was noticed in soils of forest land use (4.6 and 5.0 cmol (p<sup>+</sup>) kg<sup>-1</sup>) and lowest were recorded in paddy land use system (2.8 and 3.3 cmol (p<sup>+</sup>) kg<sup>-1</sup>) at surface and sub surface depths respectively. The highest mean exchangeable magnesium status in the surface and sub surface soils were noticed in forest land use (2.5 and 2.6 cmol (p<sup>+</sup>) kg<sup>-1</sup>), and the lowest was in paddy land use (2.0 and 2.3 cmol (p<sup>+</sup>) kg<sup>-1</sup>) respectively. Highest mean available sulphur status was noticed in forest land use (25.1 mg kg<sup>-1</sup> and 22.3 mg kg<sup>-1</sup>) in surface and sub surface depths respectively.

Highest mean potassium permanganate oxidizable organic carbon content was noticed in forest land use (1182.7 mg kg<sup>-1</sup> and 802.6 mg kg<sup>-1</sup>) in surface and sub surface depths as compared to other land use systems. Highest mean cold water extractable organic carbon content was recorded in forest land use (43.3 mg kg<sup>-1</sup> and 36.5 mg kg<sup>-1</sup>) and the lowest mean cold water extractable organic carbon content was noticed in paddy land use (21.3 mg kg<sup>-1</sup> and 16.2 mg kg<sup>-1</sup>) in surface and sub surface depths respectively. Highest mean microbial biomass carbon content was recorded in forest land use (437.7 mg kg<sup>-1</sup> and 297.4 mg kg<sup>-1</sup>) in surface and sub surface depths as compared to other land use.

The mean values of E4/E6 ratios of fulvic acids were higher (5.53 and 4.00) in forest land use as compared to other land use and the mean values of E4/E6 ratios of humic acid were higher (5.12 and 3.65) in forest land use as compared to other land use systems at surface and subsurface depths respectively.

Soil organic carbon stock of soils varied widely among the different land use systems. The mean soil organic carbon stock was higher in surface (0-15 cm) soils as

compared to sub surface depths. The highest mean soil organic carbon stock was noticed in forest land (37.89 and 31.00 t C ha<sup>-1</sup>) use at surface and sub surface depths, whereas lowest SOC stock was observed in paddy land (21.18 and 17.31 t C ha<sup>-1</sup>) use at surface and subsurface depths respectively.

Soil bulk density showed negative and significant correlation with MBC, HA and FA ( $r = -0.51^{**}$ ,  $r = -0.078^{**}$ ,  $r = -0.230^{**}$ ) irrespective of land use systems. Clay showed positive and significant correlation with OC ( $r = 0.38^{**}$ ) and positive non significant correlation with PPOC, CWEC, MBC ( $r = 0.03$ ,  $r = 0.11$ ,  $r = 0.02$ ) respectively. CaCO<sub>3</sub> showed positive and significant correlation with PPOC, CWEC, MBC ( $r = 0.45^{**}$ ,  $r = 0.43^{**}$ ,  $R = 0.30^{**}$  respectively). Soil pH showed negative significant correlation with OC, PPOC, CWEC and MBC ( $r = -0.11^*$ ,  $r = -0.35^{**}$ ,  $r = -0.40^{**}$ ,  $r = -0.13^*$ , respectively).

Available nitrogen showed positive and significant correlation with OC, PPOC, CWEC, MBC HA, FA ( $r = 0.84^{**}$ ,  $r = 0.63^{**}$ ,  $r = 0.85^{**}$ ,  $r = 0.75^{**}$ ,  $r = 0.20^*$  and  $r = 0.37^*$ ) respectively. Available phosphorus showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.61^{**}$ ,  $r = 0.37^{**}$ ,  $r = 0.58^{**}$  and  $r = 0.49^{**}$  respectively). Available Potassium showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.59^{**}$ ,  $r = 0.62^{**}$ ,  $r = 0.81^{**}$  and  $r = 0.64^{**}$  respectively) irrespective of land use systems.

Exchangeable calcium showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.36^{**}$ ,  $r = 0.50^{**}$ ,  $r = 0.48^{**}$  and  $r = 0.37^{**}$ ) respectively. Available sulfur showed positive and significant correlation with OC, PPOC, CWEC, MBC ( $r = 0.67^{**}$ ,  $r = 0.42^{**}$ ,  $r = 0.54^{**}$  and  $r = 0.66^{**}$  respectively) irrespective of land use systems.

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\* Originals not seen