Original Research Article

Impact of Diverse Land Uses on Soil Organic Matter Fractions: A Comprehensive Evaluation

ABSTRACT

Soil organic matter (SOM) is a crucial component of soil that influences various soil properties and functions, including nutrient cycling, soil structure, water holding capacity and microbial activity. Different land uses significantly impact the quantity and quality of soil organic matter fractions.The primary constituent of SOM is humic substances, also known as humus. These are stable compounds originating from the decomposition of organic matter derived from plants, animals, and microorganisms. The soil humic fraction is categorized into humic acid (HA), fulvic acid (FA) and humin (HN) based on the solubility in acid and alkaline medium.The structural arrangement, chemical constitution andstability of the humic substances in soil are affected by various factors, including climate, parent material, altitude, vegetation, and the management practices employed in the area. In this context the present study was proposed to assess the impact of various agricultural land use systems on humic acid, fulvic acid and humin fraction soils of differentagro-ecological units (AEUs) of southern Kerala.The study focused on specific agro-ecological units (AEUs) in southern Kerala, including the southern coastal plain (AEU 1), Onattukara sandy plain (AEU 3), southern laterites (AEU 8), south central laterites (AEU 9), and southern and central foothills (AEU 12). Within each AEU, various agricultural land use categories such as, coconut,rice, uncultivated land and rubber were selected as specific focal points for this investigation.The HA, FA, and HN content in soil exhibited varying ranges across different AEUs, ranging from 0.57 to 2.06, 0.73 to 2.33, and 0.62 to 1.59 per cent respectively. Among the various land uses, rubber cultivation exhibited significantly higher levels of HA (1.72%), FA (2.01%) and HN (1.44%) compared to coconut, rice, and uncultivated land. Among the different organic matter fractions, FA (32.30-36.18 %) contributed more towards SOM than HA (29.40-32.51 %) and HN (26.43-29.25 %) .

Keywords- Soil organic matter, humic acid, fulvic acid, humin, land uses, agro-ecological units

1. INTRODUCTION

Soil organic matter (SOM) encompasses a wide array of organic compounds with diverse chemical structures, and these proportions tend to change over time. It serves as a critical component within soil, exerting influence on numerous soil properties and functions such as nutrient cycling, soil structure, water retention and the activity of soil microorganisms (Olk et al., 2019).The major component of SOM is humic substances or humus, which comprises stable compounds derived from the decayed organic matter of plant, animal and microbial origins. Humic substances represent the most extensively decomposed and stable organic compounds, accounting for 40–60 percent of SOM (Guimaraes et al., 2013). These substances possess slow turnover rates and extended residence times within soils, primarily because they aren't an efficient energy source for microbial population and exhibit resistance to degradation due to their complex molecular structures (Muscolo et al., 2013). Humic substances play vital roles in enhancing soil structure, cation exchange capacity, buffering capacity and water retention. Additionally, they have the capability to form complexes with heavy metals, thereby mitigating soil toxicity. These substances, characterized by complex structures with varying molecular orientations, are operationally classified based on their solubility in acidic and alkaline aqueous media. Humic acids dissolve in alkali solutions, while fulvic acids are soluble in both acidic and alkaline conditions and humin remains insoluble(Sun et al., 2012).

The humicsubstances present in any soil system is influenced by a multitude of factors, including its input from various sources and the subsequent loss due to decomposition.Despite their inherent resistance to biological degradation, changes in land use practices have the potential to alter the chemical composition of humic substances(Reddy et al., 2012).The structural formation, chemical composition, and stability of these humic substances are influenced by numerous variables such as climate, parent material, altitude, vegetation type, and soil management practices (Kotze et al., 2016). Changes in agricultural management practices have the potential to modify the chemical properties of soil humic substances (Moraes et al., 2011). Studies have shown a gradual decline in concentrations of humic substances within soils that underwent conversion from forested areas to arable land for farming purposes.The observed decrease is often linked to the microbial oxidation of organic materials, previously safeguarded within soil aggregates, which are subsequently disrupted due to cultivation. Alterations in the C:Nratio following landuse changes signify fluctuations in the extent of SOM decomposition(Kunlanit et al., 2019).In this context the present study was designed to assess the impact of various agricultural land uses including coconut, rice, rubber and uncultivated land on HA, FA and HN constituent of SOM across selected agro-ecological units of south Kerala.

2.METHODOLOGY

Agro-ecological units (AEUs) serve as broad spatial divisions that take into account variations in climate, landforms, and soils. These delineations, introduced by the FAO, highlight similar agro-climatic conditions to pinpoint regions that are agriculturally favorable, indicating their suitability for specific crops or combinations of crops. This helps in identifying and optimizing areas with the potential for particular agricultural activities.The study focused on selected AEUs in South Kerala, including the southern coastal plain (AEU 1), Onattukara sandy plain (AEU 3), southern laterites (AEU 8), south central laterites (AEU 9), and southern and central foothills (AEU 12). Within each AEU, various agricultural land use categories such as coconut,rice, rubber and uncultivated land werealso selected for the investigation.

A survey was conducted within these selected AEUs and land uses, identifying specific sites for soil sampling. Surface soil samples (0-25 cm depth) were collected from a total of 60 locations across the selected AEUs for the study.The soil samples were shade dried, powdered, sieved through a 2 mm sieve and stored in a moisture free environment for further analysis. The soil samples after processing were analyzed for electro-chemical properties such as soil pH, electrical conductivity

(EC), and cation exchange capacity (CEC) following the methodology described by Jackson (1973).Fulvic acid and humic acids were isolated by sequential extraction in alkaline and acidic solutions while humin was determined in the soil residue (after fulvic acid and humic acid extraction) by mineral fraction digestion using a 0.1M HCl/0.3M HF mixture (Tan, 1996).The generated data underwent statistical analysis utilizing the GRAPES software (Gopinath et al., 2020). The statistical methodology employed was a two-way analysis of variance (ANOVA).

3.RESULTS AND DISCUSSION

3.1 Electro-chemical properties of soil

The pH of soil ranged between 4.77 and 5.73 in different AEUs under various agricultural land use systems (Table 1). The land use systems showed a significant impact on soil pH with the highest mean value of 5.63 recorded in uncultivated land and significantly lowest pH of 4.91 observed in rice which was on par with rubber (4.94). In all the AEUs, the highest pH was observed in uncultivated land and the lowest pH was observed in rubber (AEU 1 and 3) and rice (AEUs 8, 9 and 12) land uses..This may be attributed to the impact of parent material, topographic position, leaching of basic cations due heavy rainfall, high organic matter content and management practices carried out in the locality (Zhang et al., 2019).

The results of electrical conductivity (EC) of soil ranged between 0.06 to 0.44 dS m^{-1} in different AEUs under various land use systems (Fig.2). The EC was found to be less than 1dS m^{-1} in all the AEUs. It is considered as normal range with no salinity hazards. This can be attributed to the leaching of soluble salts from soil due to high rainfall (Krishna murthy, 2023).

Cation exchange capacity (CEC) of soils of different AEUs under various agricultural land use systems is shown in figure 6. The CEC of soil varied between 2.60 to 6.69 c mol(p+)kg^{-1}. Among the different AEUs, the highest CEC of 4.68 c mol(p+)kg^{-1} was recorded in AEU 12 which was found to be significantly different from other AEUs and the lowest was observed in AEU 1 (3.79 c mol(p+)kg^{-1}). Land uses also exerts significant impact on CEC of soil. Among the land uses rubber registered greater CEC of 6.09 c mol(p+)kg^{-1} and uncultivated land showed lower CEC (2.89 c mol(p+)kg^{-1}). This might be attributed to the difference in organic matter addition to the soil from different land uses (Papini, 2011). This evident from the positive correlation of CEC (r=0.92*) with SOM.

Table 1. Effect of agricultural land uses on pH of soil

AEUs(A)	LAND USE (L)				Mean
	Coconut	Rice	Rubber	Uncultivated land	
AEU 1	5.30	4.96	4.95	5.47	5.17^{ab}

AEU 3	5.44	5.01	4.90	5.60	5.24[a]
AEU 8	5.36	4.87	5.06	5.73	5.26[a]
AEU 9	5.25	4.77	4.83	5.59	5.11[b]
AEU 12	5.47	4.93	4.96	5.73	5.27[a]
Mean	5.37[b]	4.91[c]	4.94[c]	5.63[a]	
	A	L	A x L		
S.E(m)	0.041	0.037	0.082		
CD (0.05)	0.117	0.105	NS		

**Values represented by same lower case superscript letters are not significantly different*
**NS- Non significant*

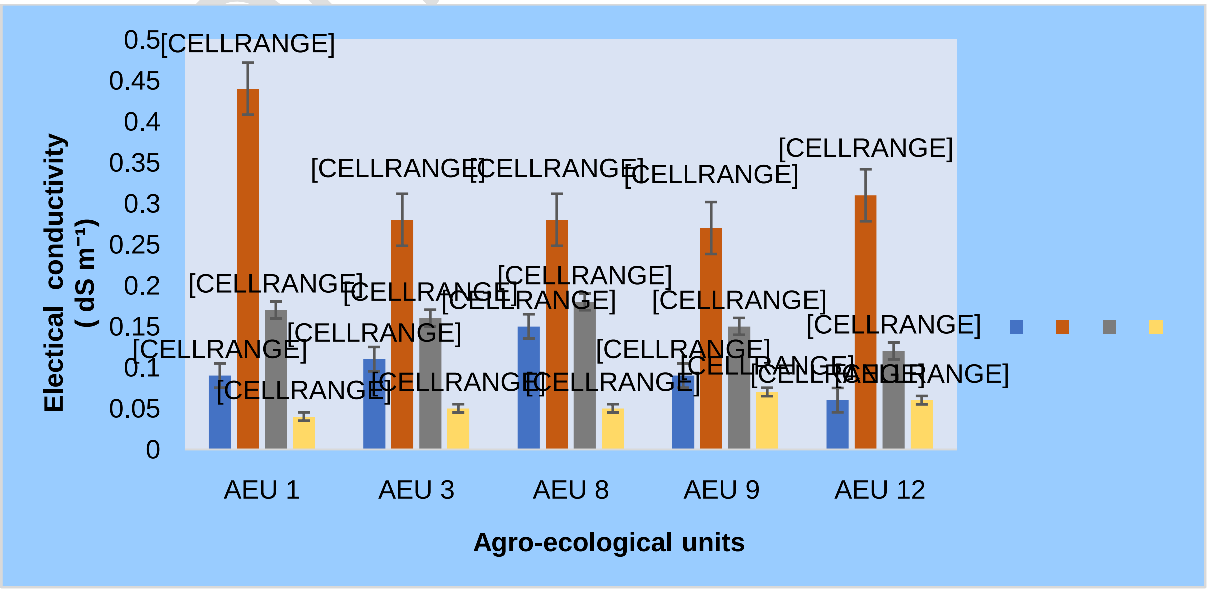

Fig. 1 Effect of agricultural land uses on electrical conductivity of soil

**Values represented by same lower case superscript letters are not significantly different*

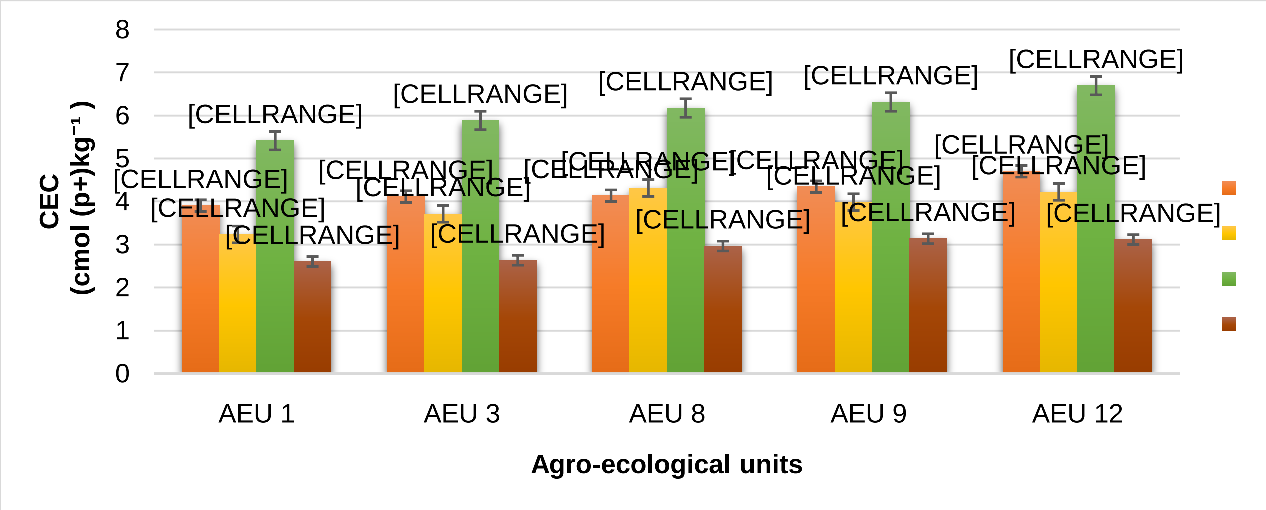

Fig. 2 Effect of agricultural land uses on cation exchange capacity of soil

**Values represented by same lower case superscript letters are not significantly different*

3.2 Soil organic matter fractions

The results shown in table2 revealed that the soil organic matter (SOM) in soil varied between 2.67 and 5.47 per cent in different AEUs under various agricultural land use systems. The highest value was obtained for rubber land use (5.47 %) and lowest for uncultivated land (2.60 %). Among the AEUs the highest value was recorded for AEU 12 (4.35 %) followed by AEU 9 (4.23 %), AEU 8 (4.22 %), AEU 8 (3.85 %) and AEU 1 (3.60 %). The differences observed in land uses and AEUs can be attributed to the difference in microclimate, vegetation canopy, litter input (Guimares et al. 2013).

Humic acid content varied from 0.57 to 2.06 per cent, fulvic acid ranged between 0.73 and 2.33 per cent and humin ranged from 0.62 to 1.59 per cent across different AEUs under various land uses (Fig. 3). Among the different AEUs higher concentration of fulvic acid and humin was were observed in AEU 12 whereas humic acid in AEU 9. The higher concentration of fulvic acid compared to humic acid in all AEUs, regardless of land use, can be attributed to the regular incorporation of fresh organic residues. This is particularly noticeable in AEU 12 and rubber land use, where there is an elevated fulvic acid content, indicating a greater input of fresh organic residues. The higher concentration of humic acid was obtained from AEU 9 might be due to the climate and moisture content prevailing in the area which have resulted in more favourable condition for humic acid formation. In all the AEUs, a higher concentration of organic matter fractions, including fulvic acid, humic acid, and humin, was observed in soils from rubber plantations that received larger quantities of fresh biomass. This is primarily attributed to the high plant density and dense vegetation canopy in rubber plantations, contributing to the elevated levels of these organic matter fractions. The SOM content tends to be higher in tree-based land use systems which in turn contributes to the increased concentration of SOM fractions(Reddy et al. 2012). This is confirmed from the positive correlation obtained between SOM and its fractions such as humic acid (r= 0.97***), fulvic acid (r = 0.97***) and humin (0.96***).

Table 2. Effect of agricultural land uses on humic acid (%) in soil

AEUs (A)	LAND USE (L)				Mean
	Coconut	Rice	Rubber	Uncultivated land	
AEU 1	1.30^{g}	1.02^{i}	1.39^{ef}	0.57^{k}	1.07^{d}
AEU 3	1.40^{ef}	1.03^{i}	1.47^{de}	0.87^{j}	1.19^{c}
AEU 8	1.49^{d}	1.20^{h}	1.87^{b}	0.83^{j}	1.34^{b}
AEU 9	1.67^{c}	1.16^{h}	1.81^{b}	0.90^{j}	1.38^{a}
AEU 12	1.32^{fg}	1.15^{h}	2.06^{a}	0.83^{j}	1.34^{b}
Mean	1.44^{b}	1.11^{c}	1.72^{a}	0.80^{d}	
	A	L	A x L		
S.E(m)	0.014	0.013	0.029		
CD (0.05)	0.041	0.037	0.083		

**Values represented by same lower case superscript letters are not significantly different*

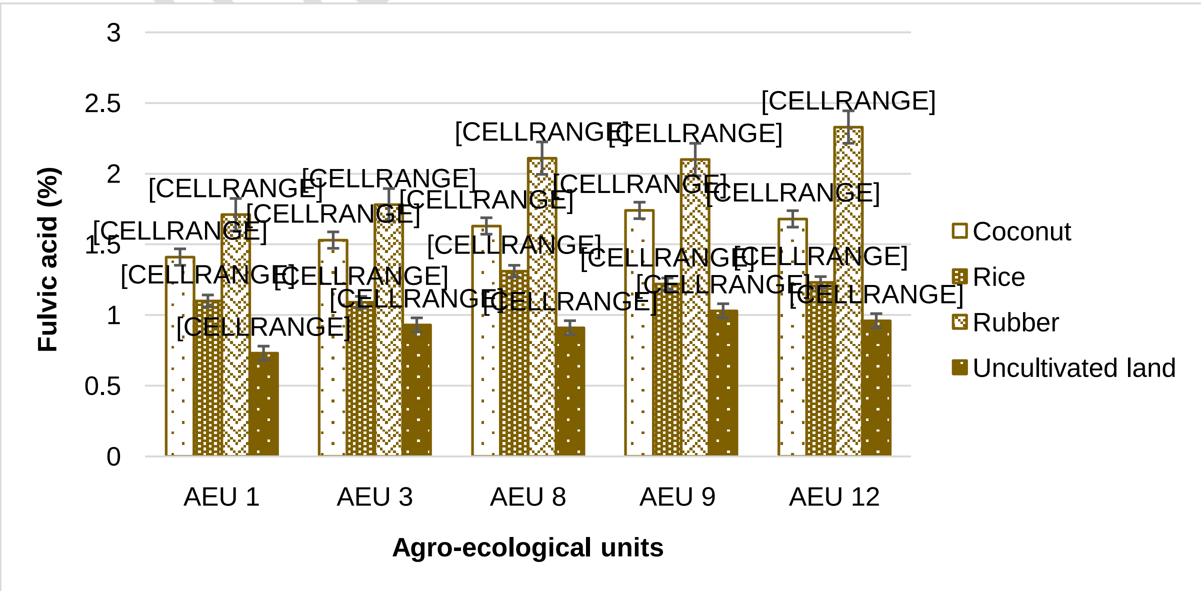

Fig. 3 Effect of agricultural land uses on fulvic acid in soil

**Values represented by same lower case superscript letters are not significantly different*

Table 3. Effect of agricultural land uses on humin (%) in soil

AEUs (A)	LAND USE (L)				Mean
	Coconut	Rice	Rubber	Uncultivated land	
AEU 1	1.17^{cde}	1.01^{fg}	1.43^{b}	0.62^{j}	1.06^{bc}
AEU 3	1.21^{cd}	0.99^{g}	1.25^{c}	0.70^{hij}	1.04^{c}
AEU 8	1.20^{cd}	1.10^{ef}	1.44^{b}	0.68^{ij}	1.11^{ab}
AEU 9	1.15^{de}	1.09^{efg}	1.48^{b}	0.78^{h}	1.12^{a}
AEU 12	1.15^{de}	1.07^{efg}	1.59^{a}	0.75^{hi}	1.14^{a}
Mean	1.18^{b}	1.06^{c}	1.44^{a}	0.71^{d}	
	A	L	A x L		
S.E(m)	0.017	0.016	0.035		
CD (0.05)	0.050	0.044	0.099		

**Values represented by same lower case superscript letters are not significantly different*

Percentage contribution of humic acid, fulvic acid and humin to total organic matter ranged from 29.40 to 32.51, 32.30 to 36.42 and 26 to 29.25 per cent respectively (Fig.4). Among the OM fractions fulvic acid contributed more towards total SOM content than humic acid and humin irrespective of AEUs and land uses. Fulvic acids are typically more soluble and have a lower molecular weight compared to humic acid and humin, making them more mobile and, as a result, making them more prevalent in soil solutions. In terms of proportion of different OM fractions to SOM in different land uses, higher proportion of humic acid to SOM was higher in coconut land use while fulvic acid to SOM was higher in rubber land use and humin to SOM was higher in rice land use. Higher proportion of fulvic acid to SOM in rubber land use might be attributed to the fresh biomass addition compared to other land uses. The higher percent contribution of humic acid to SOM in coconut land use could be due to the relatively slower decomposition compared to rice land use. The humin proportion in rice land use is higher than other land use indicating the occurrence of more decomposition process in rice soils. The results are in conformity with the findings of Seddaiu et al. (2013).

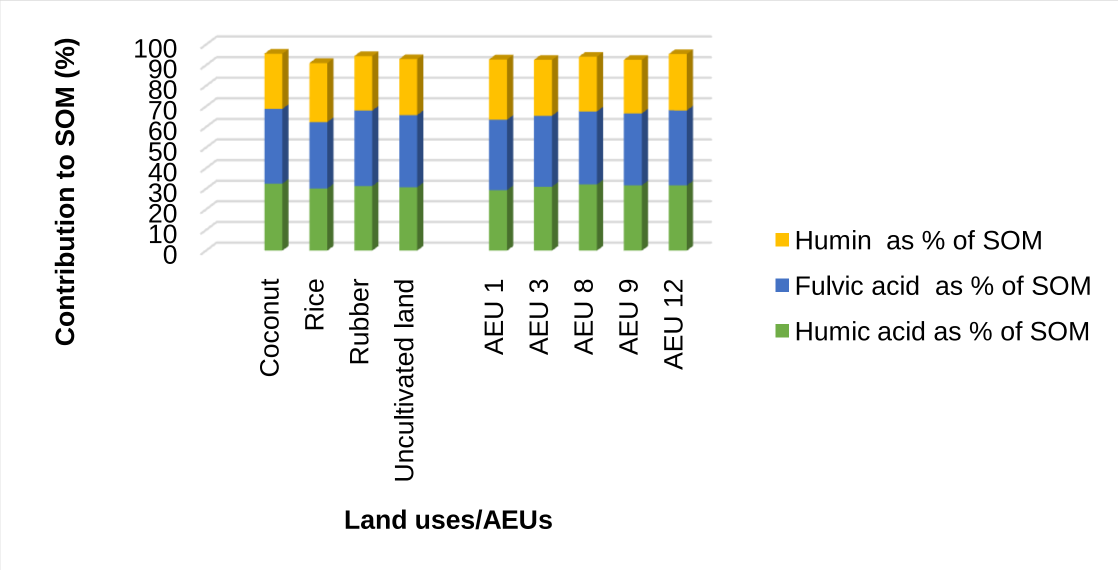

Fig. 4 Contribution of humic acid, fulvic acid and humin to SOM

The ratio of humic acid to fulvic acid reflects the mobility of organic carbon in soil. The humic acid to fulvic acid ratio ranged between 0.85 to 0.93 across various AEUs under different land uses which indicates the presence of higher fulvic content compared to humic acid and it also indicates a lower decomposition rate of organic matter or frequent addition of organic manure to the soil (Gladis et al., 2020). Humic acid to fulvic acid ratio less than 1 indicate the good quality of SOM and greater than 1 indicate the loss of labile C fractions of SOM. Dutta *et al*. (2021) proposed that differences in the ratio of humic acid to fulvic acid in various soils serve as indicators of varying levels of humification influenced by vegetation and agro-ecology.

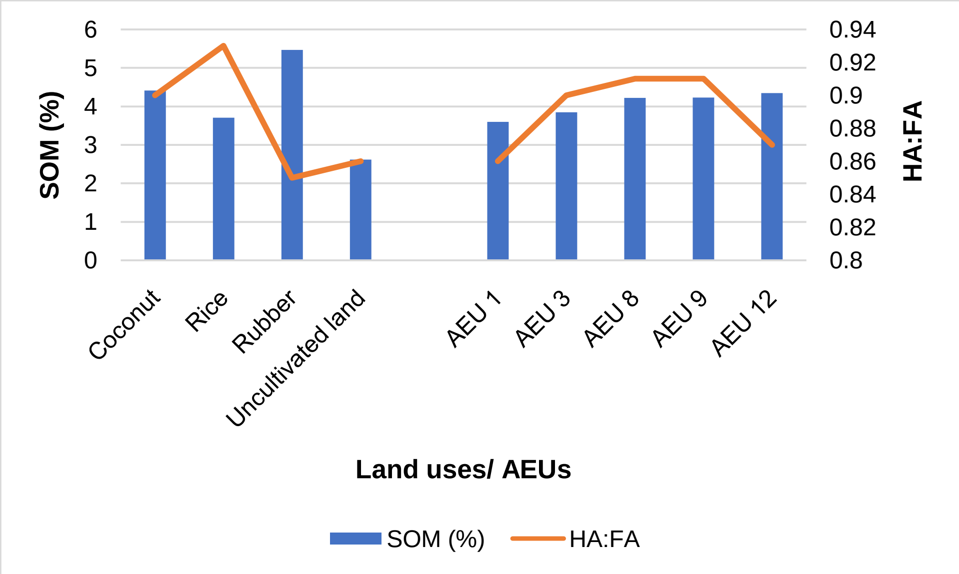

Fig. 5 SOM and HA:FA ratio as influenced by different agricultural land uses

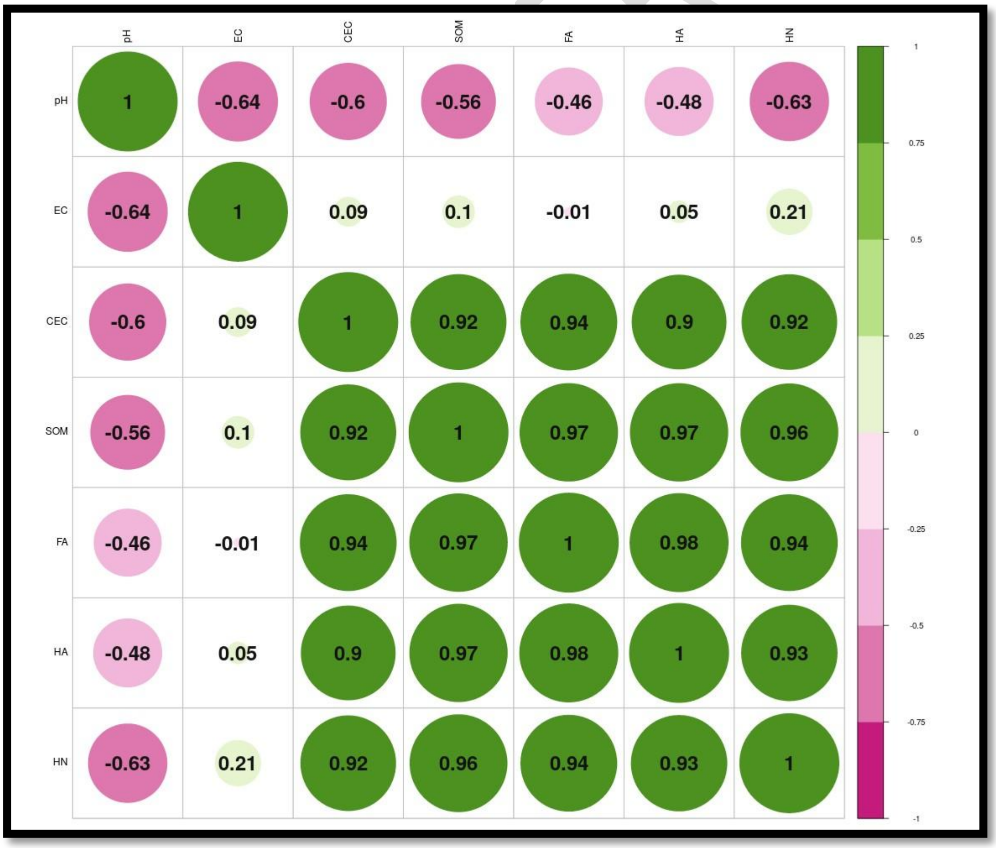

Fig.6 Correlogram showing Pearson's correlation between various soil properties and SOM fractions.

*Green and pink represents positive and negative correlations respectively. The size of the circle indicate the strength of correlation (r)(p=0.05)

4. CONCLUSION

In all the land use systems observed, the fulvic acid fraction demonstrated a higher prominence compared to both the humic acid and humin fractions.This led to an HA/FA ratio below 1 across most land uses. The prevalence of a higher proportion of fulvic acids in comparison to humic acids suggested either a slow decomposition rate of SOM or frequent influxes of fresh organic residues to the soil. Land uses exerted a tenacious impact on both quantity and quality of SOM. Among the land uses higher organic matter accumulation was observed in rubber land use followed by coconut and rice and the lowest was registered from uncultivated land. With respect to different AEUs, AEU 12 exhibited a favourable condition for accumulation of organic matter in soil.

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