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Dynamics of Soil Organic Carbon and Their Fractions Under Different Cropping Systems in Hill Zone Acid Soils of Karnataka

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Soil organic carbon (SOC) and its different labile fractions are important in minimizing negative environmental impacts and improving soil quality. Thus it is very important to understand the fractions of soil organic carbon and their distribution in different cropping systems. Soil characterization revealed that soils were slightly acidic to moderately acidic in range with low soluble salts. Soil under coffee and areca system recorded significantly higher SOC, TOC and TN content compared to paddy system. The SMB-C, SMB-N, LFC and DOC were higher in coffee and areca cropping systems compared to paddy system. The correlation between SOC with TOC, TN, LFC, DOC, MBC and MBN was positive and significant. Light fraction organic carbon showed positive and significant correlation with DOC, MBC and MBN. Regression analysis suggests that SOC and LFC could explain 85% (R^2=0.853) and 44% (R^2=0.448*) variation respectively in surface TOC concentration.**

Key words: Cropping system, SOC, DOC, LFC, MBC and MBN

Changes in total soil organic carbon (SOC) with change in land use and management can be partly explained by the way C is allocated in different fractions of soil organic matter (SOM). These fractions exhibit different rates of biochemical and microbial degradation as well as different accessibility and interactions. Soil organic carbon (SOC) is closely associated with a wide range of physical, chemical, and biological properties of soil, and thus plays a critical role in soil processes and functioning. The change in land use has significantly affected the carbon cycles both regionally and globally. Soil total organic carbon (TOC) might not be sensitive to changes in soil quality resulting from soil management practices. However, accumulating evidence suggests that certain fractions of soil organic carbon are more important in maintaining soil fertility and are, therefore, more sensitive indicators of the effects of management practices compared with the soil TOC.

SOC contains fractions with a rapid turnover rate as well as fractions with slower turnover rate.The labile fractions of organic C, such as microbial biomass C (MBC) and dissolved organic C (DOC), can respond rapidly to changes in C supply. These components have therefore been suggested as sensitive indicators of the effects of land use on SOM (Gregorich *et al*., 1994) and as important indicators of soil quality. Dissolved organic matter is an important labile fraction since it is the main energy source for soil microorganisms, a primary source of mineralizable N, P, and S and it influences the availability of metal ions in the soil by forming soluble complexes (Stevenson, 1994).

Several forms of soil carbon such as light fraction carbon (LFC), dissolved organic carbon (DOC), soil microbial biomass carbon (SMBC) and soil microbial biomass nitrogen (SMB-N), could be considered as indices of labile carbon in the soil (Gregorich *et al* ., 1994). Changes in total organic carbon are very slow in the soil. However, changes in labile forms of organic carbon are more rapid. Thus the dynamics of soil organic carbon in different cropping systems could be understood by evaluating the different carbon fractions.

Material and Methods

Study area

Chikmagalur and Hassan districts are located on the eastern sides of the Western Ghats, in the southern part of Karnataka state (zone-9). Chikmagalur and Hassan districts have total geographical area of 7201 km^2 and 6826.15 km^2, respectively. Chikmagalur district spans across the latitudinal parallels of 12° 54' 42''and 13° 53' 53'' north and the longitudinal meridians of 75° 04' 46''and 76° 21' 50'' east and Hassan district lies between 12° 13' and 13° 33' North Latitudes and 75° 33' and 76º 38' East Longitude(Figure 1).

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Hassan and Chikmagalur districts are exposed for an equitable climate and receive on an average annual rainfall of 1000-3000 mm. The western parts of the districts receive high rainfall and it decreases towards the eastern part. A major portion of the rain is received during May to August through southwest monsoon period. Northwest rains are also received during October to November. The rainfall exceeds potential evapo-transpiration for about 120 days in a year. The mean maximum temperature is 21-35 $_0$C and mean minimum temperature is 14-31 $_0$ C. April is generally hottest month and December is the coldest month.

Selection of cropping systems: Soil samples from two depths (0-15 and 15-30 cm) were collected from paddy, areca nut and coffee cropping systems in Hassan and Chikmagalur districts, Karnataka state. The crops in each of the systems are paddy, areca nut and coffee, in these later two are perennial crops and in paddy system only one crop is taken per year. Soil samples were collected in 20 locations from each cropping system. At each location sample was collected from 8-10 spots and pooled to get one composite sample for each depth. In all, 120 soil samples (60 from 0-15 cm and 60 from 15-30 cm depth) were analyzed for characterizing the acid soils. Out of 120 samples 3 samples from each depth per land use systems per districts were selected based on pH (<6) for assessing soil organic carbon and their fractions in different cropping systems.

Soil chemical analysis: Collected soil samples were analyzed for pH and electrical conductivity (Sarma *et al*., 1987). Further these samples were analyzed for Soil Organic Carbon (Total carbon, Light Fraction carbon(LFC) and Dissolved Organic Carbon (DOC) by wet oxidation method (Jackson, 1973).

Total carbon: The total carbon content was determined by using CHN analyzer (CHNS, LECO). 100 ìg of the sample mixed with an oxidizer [vanadium pentoxide (V_2O_5)] in a tin capsule, which was then combusted in a reactor at 1000°C. The combustion products CO_2 and NO_2 were carried by a constant flow of carrier gas (helium) that passes through a glass column packed with an oxidation catalyst of tungsten trioxide (WO_3) and a copper reducer, both kept at 1000°C. At this temperature, the nitrogen oxide was reduced to N_2. The CO_2 and N_2 were then transported by the helium and separated by, a 2-m-long packed column (Poropak Q/S 50/80 mesh) and quantified with a TCD (set at 290°C).

Light Fraction Carbon (LFC): Light fraction carbon was separated from soil samples using densitometry technique (Janzen *et al.,* 1992) by dispersing approximately 10 g of soil in 40 ml NaI solution (Specific gravity = 1.7 ± 0.02 kg L_{-1}) for 30 seconds using a homogenizer. The suspension was then equilibrated for 48 hours at room temperature. The suspended materials were removed by filtering using a vacuum pump and the materials in the filter paper(light fraction) was then washed thrice with 0.01M $CaCl_2$ and distilled water. The filter paper with residues was dried for 17 hours at 70_o C, the light fraction was then scraped from the filter paper and carbon was estimated by CHNS analyzer.

Dissolved organic Carbon (DOC): Dissolved organic carbon was extracted by centrifuging 1:2 ratio of soil and distilled water for 30 minutes at 10,000 rpm. The supernatant liquid was filtered. Five ml of this extract was used for estimating organic carbon by Walkley and Black (1934) wet oxidation method using 0.07N $K_2Cr_2O_7$ (Mc Gill *et al.,* 1986).

Microbial biomass C and N: Soil microbial biomass (SMB) was estimated by fumigation - extraction method as detailed by Carter (1991). Ninhydrin-reactive N, as a measure of microbial biomass released during soil fumigation, was determined by the ninhydrin reagent.

Statistical analysis

The data obtained were subjected to statistical tests using split plot design. Correlation and regression analysis were carried out to assess the soil relationships with pH and other different fractions of soil organic carbon (Sundarraj *et al.,* 1972).

Results and Discussion

Soil reaction (pH) and electrical conductivity (EC)

Soil pH is an important property which helps in understanding processes and speciation of chemical element in soil. The soil pH did not differ

Table 1. Soil reaction (pH) and electrical conductivity (EC) of acid soils of hill zone under different cropping systems

Cropping system	pH (1:2.5)			EC (dS m_{-1}) (1:2.5)		
	Depth			Depth		
	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean
Paddy	5.26 ± 0.60	5.19 ± 0.71	5.22 ± 0.65	0.10 ± 0.03	0.08 ± 0.03	0.08 ± 0.02
Areca	5.66 ± 0.46	5.49 ± 0.37	5.57 ± 0.41	0.11 ± 0.03	0.07 ± 0.02	0.09 ± 0.02
Coffee	5.46 ± 0.54	5.26 ± 0.48	5.30 ± 0.50	0.10 ± 0.03	0.07 ± 0.03	0.08 ± 0.02
Mean	5.46 ± 0.55	5.32 ± 0.54	-	0.10 ± 0.03	0.076 ± 0.02	-
	Crop (C)	Depth (D)	C×D	Crop (C)	Depth (D)	C×D
SEm ±	0.09	0.73	0.10	0.005	0.0039	0.0055
CD at 5%	0.25	NS	NS	NS	0.010	NS

significantly with depth. But the pH value of surface soil was (5.46 ± 0.55) slightly higher than subsurface layer (5.32 ± 0.54). However, the pH in soils under arecanut cropping system was significantly higher than (5.57 ± 0.41) that recorded for coffee (5.30 ± 0.5) and paddy (5.22 ± 0.65). Further, the interaction was non significant (Table 1).

The acidic soil reaction was attributed to leaching of basic cations as the soils are collected from hill zone which receives an average annual rainfall of 1000- 3000 mm. The variation in pH among soils under different cropping systems may be attributed to variation in rain fall within the zone, topographic position and management practices (Ananth narayana and Ravi, 1997).Further, as these soils are derived from granite and granite gneiss which are silica saturated igneous and metamorphic rocks, as a result the soils show acidic reaction.

The EC, which is a measure of total soluble salt content in soil, was in general low in these soils (Table 1). The EC value in the surface soil was (0.10 ± 0.03 dS m^{-1}), which was significantly higher than that recorded in lower soil depth (15-30 cm).

The EC value under different cropping system and interaction between soil depth and cropping system was non significant. The low EC indicate that the soluble salts were leached out of soil under high rainfall area; consequently there was no salt accumulation in these soils (Rao, 1992).

Soil organic carbon and total nitrogen

The soil organic carbon content differed significantly with depth. The soil organic carbon content of surface soil was significantly higher (28.0 ± 3.34 g kg^{-1}) than subsurface soil (23.33 ± 3.87 g kg^{-1}). SOC content decreased significantly with depth in all the cropping systems (Table 2) with a maximum value of 29.0 ± 5.4 g kg^{-1} in surface soil layer of coffee. The accumulation of soil organic matter is a function of the amount of plant, animal and microbial inputs received by soil in the past (Brady and Weill, 1996) and the rate at which the biomass input decays. It is also directly related to the amount of organic residues added to the soils, manure and fertilizer application (Banger *et al*., 2008).

Further, the interaction between cropping system and depth was nonsignificant (Table 2). The lower organic carbon content in sub surface layer might be attributed to lower vertical mixing of soils as the soils under coffee and areca are not disturbed by tillage operation.

Table 2. Soil organic carbon, total carbon and total nitrogen content in acid soils of hill zone under different cropping systems

Cropping system	SOC (g kg^{-1})			TOC (g kg^{-1})			TN (g kg^{-1})		
	Depth			Depth			Depth		
	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean
Paddy	25.67 ± 6.35	19.83 ± 7.11	22.75 ± 4.1	26.76 ± 6.57	21.49 ± 7.24	24.13 ± 3.72	2.35 ± O.77	2.23± 0.73	2.29± 0.08
Areca	26.50 ± 6.75	22.67 ± 5.43	24.58 ± 2.7	27.70 ± 6.62	23.99 ± 5.58	25.85 ± 2.62	2.74 ± 0.59	2.22 ± 0.58	2.48 ± 0.36
Coffee	31.83 ± 3.43	27.50 ± 6.12	29.67 ± 3.1	32.79 ± 3.75	29.68 ± 6.66	31.24 ± 2.19	2.86 ± 0.30	2.82 ± 0.75	2.84 ± 0.02
Mean	28.0 ± 3.34	23.33 ± 3.87	-	29.08 ± 3.24	25.05 ± 4.19	-	2.65 ± 0.26	2.42 ± 0.34	-
	Crop (C)	Depth (D)	C×D	Crop (C)	Depth (D)	C×D	Crop (C)	Depth (D)	C×D
SEm ±	1.27	2.20	1.87	1.28	2.34	1.95	0.14	0.25	0.21
CD at 5%	3.77	NS	NS	3.78	NS	NS	0.41	NS	NS

The TOC content in surface soil layer was 29.08 ± 3.24 g kg^{-1} which decreased significantly to 25.05 ± 4.19 g kg^{-1} at 15-30 cm depth and similar trend was observed in case of total N (Table 9). These results suggest that the leaf litters derived from crop and other vegetation are accumulated in the surface soil layer itself and there is very little vertical movement due to less disturbance by tillage operations (Marriott and Wander 2006).

Ai Daniah, *et al.,* (2008) observed the recovery of total nitrogen under coffee plantations because of nitrogen fertilization as well as recycling of leaf litter derived from both shade trees and coffee plants.

Table 3. Percent contribution of SOC and MBC to TOC and C:N ratios in acid soils of hill zone under different cropping systems

Cropping system	Contribution of SOC to TOC (%)		Contribution of MBC to TOC (%)		C:N ratio	
	Depth		Depth		Depth	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Paddy	95.50	91.74	6.53	7.13	10.56 ± 0.34	10.82 ± 0.26
Areca	94.30	92.97	9.43	8.04	10.41 ± 0.34	10.53 ± 0.55
Coffee	96.08	92.66	9.17	6.31	11.75 ± 0.35	10.69 ± 0.32

Among cropping systems, soils under paddy cropping systems had significantly least TOC (24.13 ± 3.72 g kg^{-1}) than soil under areca (25.85 ± 2.62 g kg^{-1}) and coffee (31.24 ± 2.19 g kg^{-1}). The contribution of SOC to the Total-C in surface soils under coffee cropping system was higher (96.08%) compared to paddy (95.5%) and areca (94.30%).

Table 4. Light fraction carbon and dissolved organic carbon content in acid soils of hill zone under different cropping systems

Cropping system	LFC ($g\ kg^{-1}$)			DOC ($g\ kg^{-1}$)		
	Depth			Depth		
	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean
Paddy	13.29 ± 1.23	11.83 ± 1.31	12.71 ± 1.2	0.15± 0.02	0.15 ± 0.03	0.15 ± 0.02
Areca	18.47 ± 2.93	16.17 ± 2.45	17.32 ± 1.6	0.18± 0.02	0.17 ± 0.04	0.17 ± 0.03
Coffee	24. 55 ± 4.54	22.17 ± 2.84	23.34 ± 1.7	0.20 ± 0.03	0.19 ± 0.04	0.20 ± 0.04
Mean	18.87 ± 5.40	16.71 ± 5.11	-	0.18± 0.02	0.17 ± 0.02	-
	Crop (C)	Depth (D)	C×D	Crop (C)	Depth (D)	C×D
SEm ±	0.685	0.08	0.64	0.01	0.01	0.01
CD at 5%	2.02	0.29	NS	0.02	NS	NS

The TOC content in soils under agriculture land cover was generally lower than total C values of grass land (Don Axel *et al.,* 2007). The lower TOC content under present study suggest that the disturbance may favour decomposition of residues as against the accumulation under undisturbed cropping systems (Seul *et al*., 2009).

Table 5. Percent contribution of LFC and DOC to TOC in acid soils of hill zone under different cropping systems

Cropping system	Contribution of LFC to TOC (%)		Contribution of DOC to TOC (%)	
	Depth		Depth	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Paddy	53.2	50.4	0.59	0.65
Areca	63.2	60.4	0.67	0.66
Coffee	74.5	71.5	0.75	0.64

In the cropping system under investigation, C:N ratio of soil varied from 10.41 to 11.75. However, significantly higher C:N ratio was observed under coffee cropping system (11.75) compared to paddy (10.56) and areca (10.41). This result suggests that C:N ratio is most stabilized because of formation of most resistant end products of organic matter decomposition. Further variations could also be attributed to rate of decomposition as different C:N ratio biomass (leaf, litter etc) materials are added in different cropping systems (Marriott and Wander, 2006). Improved aeration due to tillage and increased temperature that enhances mineralization of organic carbon could probably be the cause for lower C:N ratio (Achalu Chimdi *et al.,* 2012) in paddy and areca field.

Light fraction organic carbon

The LFC content did not differ significantly with depth. But the LFC content of surface soil was slightly higher (18.87 ± 5.4 $g\ kg^{-1}$) than subsurface soil (16.71 ± 5.11 $g\ kg^{-1}$). The lower LFC content in subsurface soil layer suggest that no fresh materials are added to subsurface layer. Among different cropping systems paddy systems was recorded lower (24.13 ± 3.72 $g\ kg^{-1}$) LFC content compared to areca (25.85 ± 2.62 $g\ kg^{-1}$) and coffee (31.24 ± 2.19 $g\ kg^{-1}$) systems (Table 4). These results suggest that under coffee and areca cropping system more and more fresh leaf litter is being added to soil.

Table 6. Soil microbial biomass C and N content in acid soils of hill zone under different cropping systems

Cropping system	MBC ($mg\ kg^{-1}$ soil)			MBN ($mg\ kg^{-1}$ soil)		
	Depth			Depth		
	0-15 cm	15-30 cm	Mean	0-15 cm	15-30 cm	Mean
Paddy	179 ± 79	140 ± 46	160 ± 27	20.9 ± 9.2	16.3 ± 5.4	18.0 ± 3.2
Areca	301 ± 70	203 ± 63	252 ± 69	35.2 ± 8.2	23.7 ± 7.4	29.4 ± 8.1
Coffee	300 ± 38	185 ± 17	242 ± 81	35.0 ± 4.5	21.6 ± 1.9	28.3 ± 9.4
Mean	260 ± 70	176 ± 32		30.4 ± 8.1	20.5 ± 3.7	
	Crop (C)	Depth (D)	C×D	Crop (C)	Depth (D)	C×D
SEm ±	13	14	15	1.5	1.7	1.7
CD at 5%	39	54	NS	4.6	6.3	NS

Further, the interaction between cropping system and depth was nonsignificant. These differences in light fraction carbon are mainly attributed to the residue inputs, moisture and temperature of the soil. The reason for relatively low LFC content of paddy soil might be attributed to slow rate of decomposition of organic matter under anaerobic condition. The lower content of LFC in sub surface soil might be attributed to the minimum soil disturbance under coffee and areca cropping systems (Tan *et al*. 2007).

Berry *et al*., (2002) reported an increase in LFC which was strongly correlated to soil respiration rates, suggesting that the light fraction may be an important C and energy source for soil microorganisms. This fraction of carbon is not protected by clay minerals or other mechanisms, and hence it is readily accessible to microbial and enzyme attack. The contribution of light fraction

Table 7. Correlation between different organic carbon fractions in surface soil

	pH	SOC	TOC	TN	LFC	DOC	MBC	MBN
pH	1							
SOC	-0.279	1						
TOC	-O.539	0.922**	1					
TN	-0.277	0.736**	0.767**	1				
LFC	0.074	0.589**	0.514*	0.061	1			
DOC	0.217	0.591**	0.421	0.341	0.722**	1		
MBC	0.241	0.516*	0.463	0.358	0.683**	0.731**	1	
MBN	0.230	0.527*	0.319	0.373	0.747**	0.732**	0.926**	1

Note: SOC - Soil organic carbon, **TOC** - Total organic carbon, **TN** - Total nitrogen, **LFC** - Light fraction carbon, **DOC -**Dissolved organic carbon, **MBC** -Microbial biomass carbon, **MBN -**Microbial biomass nitrogen, ***** - significant @ 5% ,****** - significant @ 1%

carbon to the total-C in surface soils under coffee cropping system was higher (74.5%) compared to paddy (53.2%) and areca (63.2%)**.**

Dissolved organic carbon

Dissolved organic carbon was in the range of 0.15 ± 0.003 to 0.20 ± 0.007 g kg^{-1} under different cropping systems**.** Coffee cropping system had significantly higher DOC (0.20 ± 0.007 g kg^{-1}) compared to areca (0.17 ± 0.001 g kg^{-1}) and paddy (0.15 ± 0.003 g kg^{-1}) cropping system(Table 4).

Fig. 1: Map depicting the study area of Hassan and Chikmagalur districts

The DOC content did not differ significantly with depth, however surface soil had slightly higher (0.18 ± 0.02 g kg^{-1}) DOC content than lower (0.17 ± 0.02 g kg^{-1}) layer soil (Table 4). In the sub surface soil, the DOC content was greatest among all the SOC fractions, which may result from the mobility of the DOC compared to other fractions (Banger *et al.,* 2008). Further coffee cropping system (0.20 ± 0.04 g kg^{-1}) showed higher DOC content in sub surface soils when compared with areca (0.17± 0.03 g kg^{-1})and paddy(0.15 ± 0.02 g kg^{-1}) cropping system.

So, though DOC constitutes a very low percentage of SOC the high variations in its content especially in sub surface of the soil may act as useful tools to evaluate the impact of management systems on gross C accumulation or depletion (Freixo *et al.,* 2002).

The higher DOC content in soils of coffee cropping systems may be attributed to relatively higher contents of MBC and LFC in soils of coffee cropping system. The variation may also be attributed to differences in management and nature of residue returned to soil, moisture content and microbial activity.

Among different cropping systems coffee cropping system recorded higher percent of DOC at 0-15 cm depth (0.75%) when compared with areca (0.67%) and paddy (0.59%) systems, respectively. The contribution of DOC to the total -C in surface soils under coffee cropping system was (0.75%) compared to paddy (0.59%) and areca (0.67%) systems. Further, the interaction between depth and cropping system was nonsignificant.

Soil microbial biomass C and N

The results in context of MBC and MBN in acid soils revealed that soils under coffee (242 ± 81 and 28.3 ± 9.4 mg kg^{-1}) and areca (252 ± 69 and 29.4 ± 8.1 mg kg^{-1}) system recorded higher soil MBC and MBN content respectively compared to paddy (140 ± 46 and 18 ± 3.2 mg kg^{-1}) cropping system (Table 6).

Interaction effect between soil depths and cropping systems was nonsignificant and the (%) contribution of MBC to the total- C in surface soils (Table 3) under coffee cropping system was less (9.17%) than that compared to areca system (9.43%), but in paddy cropping system it was lowest (6.53). The variations in soil MBC and MBN among different cropping system may be attributed to variation in soil organic matter content consequently the microbial activity. The addition of manure had positive effect on soil organic matter content which in turn decides the SMB-C and SMB-N (Roldan *et al*. 2005). Further, with addition of leaf litter and other biomass return in coffee and areca systems must have contributed inversely to LFC content, which

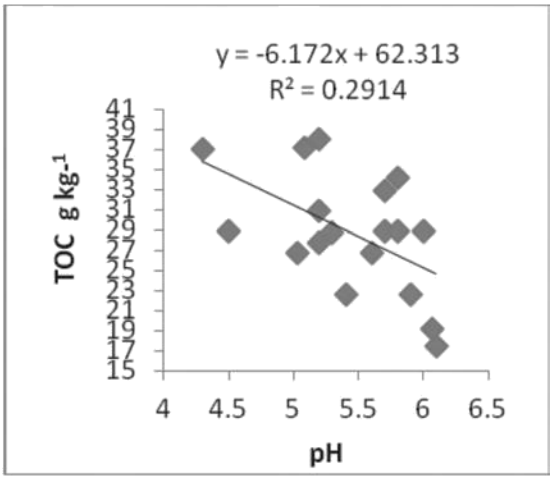

Figure -2.

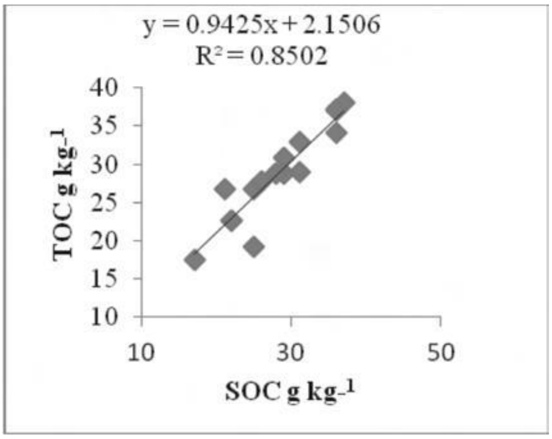

Figure -3.

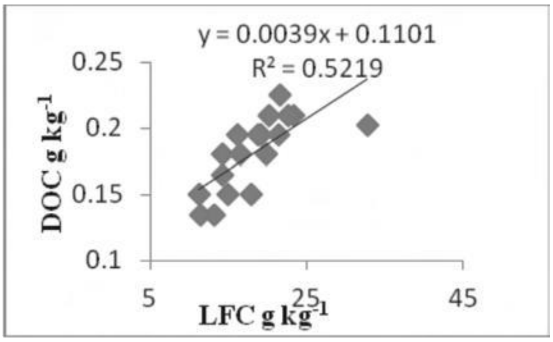

Figure -4a.

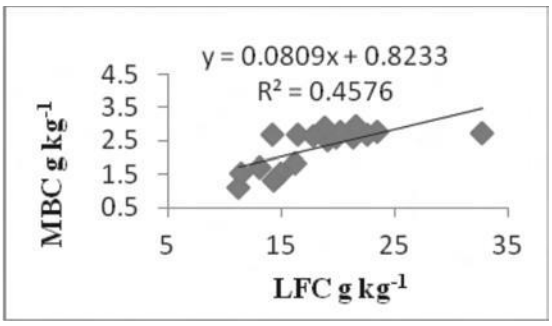

Figure -4b.

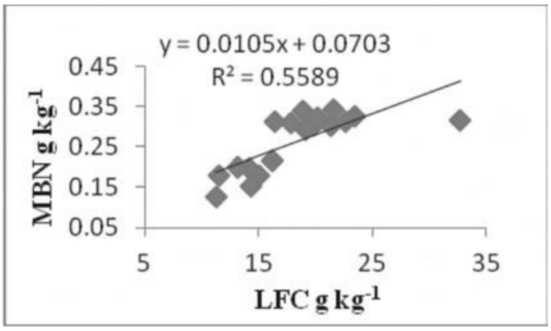

Figure -4c.

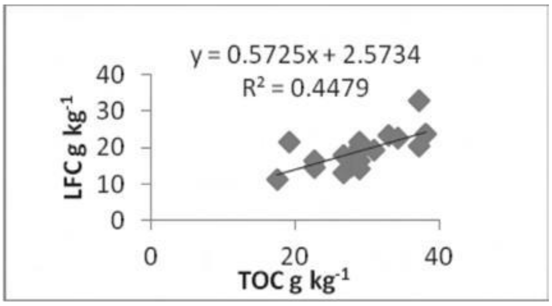

Figure -5.

Figures 2-5 : Correlation and Regression between Soil Organic Carbon and its Fraction

serves as source of energy for microorganisms (Alvarez and Alvarez, 2000).

Correlation and regression studies between soil organic carbon and its fractions

Soil pH of surface soil showed a significant negative relationship with TOC (r= -0.539*), which indicates that as pH increases TOC content decreases. This might be attributed to faster rate of decomposition and utilization of the decomposition products quickly without much stabilization (Tilahun and Asefa, 2009). As the pH increases from acidic to neutral or slightly alkaline, the population of bacteria in soil increases which play a vital role in decomposition of organic matter (Brady and Weill 1996).

The regression analysis showed that the variation in TOC can be explained to the extent of 29% (R_2=0.291) (Figure 2). However, there was no significant relationship between pH and SOC, TN, LFC and DOC. Significant and positive correlation exist between SOC and TOC (r=0.922**) . The positive relation suggests that increase in SOC content increases the TOC. This might be attributed to acidic soil reaction, in which the major component of TOC is in organic form only. The regression analysis showed that the variation in TOC can be explained to the extent of 85% (R_2=0.850**) (Figure 3) by SOC. Similarly, significant and positive relationship was observed between SOC and TN, LFC, DOC, MBC and MBN.

LFC showed positive and significant correlation with DOC (r=0.515*), MBC (r=0.745**) and MBN (r=745**). Further, regression analysis showed that the relationship between LFC and above parameter was linear and significant. Variation in LFC can be explained to the extent of 52% (R_2= 0.521), 46% (R_2=0.457), 55% and (R_2=0.558) (Figure 4 a, b and c) respectively to DOC, MBC and MBN and LFC contributes 44% of variation to surface TOC (Figure 5).

These correlation and regression results indicate that there is a strong relationship among the different forms of labile organic carbon and this may be attributed to interconversion among the forms.

Conclusion

Soil organic matter content was highest in coffee cropping system. Surface soil organic carbon concentration generally decreased with increasing depth and it is positively correlated with TOC. The DOC content is the lowest among the forms of organic carbon. Thus, the TOC concentration can be quantitatively described by the combination of SOC and LFC in the selected cropping systems under hill zone acid soils.

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