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Environmental implications of the organic carbon content of soils from different landuses in Kollam District, Kerala

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ABSTRACT

This study focuses on the variations of Soil Organic Carbon (SOC) contents in soils of different land uses like forests, agricultural lands, water bodies, built up areas and industrial areas in Kollam district of Kerala. It is to find the probable environmental implications of the variation in the content of SOC in soils of different land use types of the study area. Soil samples each from the different land uses were collected in polythene bags and the SOC and nitrogen of the soil samples were analysed using CHNS analyser. The soils in the study area are mainly sandy in type. The percentage of gravel is the lowest in the industrial area and the highest in agricultural areas. The sand percentage is minimum for agricultural land and is maximum for industrial areas. The content of fines in the soils of built up areas in the study area is minimum and that in the agricultural land is maximum. The standard deviation of fines is maximum for agricultural lands and minimum for industrial areas.The percentage of fines shows a decrease in trend from forest to built- up / industrial areas. Nitrogen content also follows similar variation. There is no correlation between gravel content and SOC. Sand content in the soil is negatively correlated with the SOC. The percentage of fines shows a positive correlation with SOC. Standard deviation of SOC is similar to standard deviation of percentage of fines. The soils of industrial and built up areas of Kollam district mainly belong to the coastal part of Kollam district. Undisturbed subsurface soils from these areas contain lot of carbonaceous clay and peat. But due to intense land use activities associated with urbanisation, the SOC in the surface layers of the soil might have been removed by soil respiration. This might have locally added CO_2 from the soil to the atmosphere. Its local implications on a global phenomenon like climate change is important. It is also interesting to note that SOC closely follows changes in the content of fines in the soil. The land use activities in industrial and built up areas do not permit the formation of fine SOC associated fraction in these soils.

Key words : *Soil organic carbon, Land use types, Soil texture and environment*

Introduction

It is estimated that the global stock of Soil Organic Carbon (SOC) is in the range of 684-724 Pg. (Pentagram=10^{15} g) to a depth of 30 cm and 1462- 1548Pg to a depth of 1m. The changes in land use definitely impact SOC pools and fluxes. Forest and pasture lands make up the potential to build up large amounts of SOC, whereas conversion of natural ecosystem to croplands results in high rate of its turnover and it leads to declined level of organic carbon (Batjes, 1996).

SOC exchange with the atmosphere through soil respiration and combustion is also an important component of the global carbon cycle and it was estimated to be approximately 80PgCyr^{-1} (Assad *et al.*, 2013). Because of thelarge quantity and the important role of SOC stored in terrestrial ecosystems, a slight change in SOC stock may influence global climate (Zhi *et al.,* 2014).

Jia-Guo *et al.* (2010) conducted a study on the village landscapes in China. As per it, SOCis very sensitive to land use changes and varies significantly with changes in land use. Long-term experimental studies have confirmed that SOC is highly sensitive to land conversions from natural ecosystems, such as forest or grassland, to agricultural land, resulting in substantial SOC loss. Another study (Dang *et al.,* 2014), was conducted on Loess Plateau in China which has the highest soil erosion rate in the world, where about billion tons of soils are annually eroded. Due to the high soil erosion rate, there was significant climate change and land use change in the region. Increasing SOC by change in landuse is one of the most economical and effective ways to alleviate the greenhouse effect (Dang *et al.,* 2014).At time scales of decades to centuries, changes in land use can exert a major influence over soil C storage (Scott *et al.,* 2002).

It is also relevant that the adoption of agricultural practices, such as no tillage and crop-livestock systems, generally lead to an increase in soil carbon stock at least at more surface depths (Zinn *et al*., 2005). The term 'carbon sequestration' is commonly used to describe any increase in SOC content caused by a change in land management, with the implication that increased soil C storage mitigates climate change (Powlson *et al*., 2011). In photosynthesis, plants take in CO_2 and give out the oxygen (O_2) to the atmosphere as a waste gas. The plants retain and use the carbon to live and grow. When the plant winters or dies, part of the carbon from the plant is preserved (stores) in the soil (Lal, 2004). The application of technologies for carbon sequestration not only helps in climate change mitigation but also increases the crop productivity and thus enhances food security (Powlson *et al*., 2011).

When agricultural lands are abandoned and forests regrow, the net fluxes of carbon are reversed; carbon is removed from the atmosphere and accumulated again in vegetation and soils (Houghton, 2002). Eswaran *et al.* (1993) made a rough estimate of carbon in soil, considering different land use types such as forest and the impact of both natural and human interventions were taken into account. Conversion of land use to another type was found to have a variation in stored soil carbon. An average difference of 10% was attributed by land use conversion. The knowledge about organic carbon in terms of quality and productivity of soil is essential for understanding its influence on different land use types (Bhattacharya *et al*., 2000). The possibilities of SOC sequestration are found to be more effective and finite in magnitude and duration. The annual SOC sequestration potential is about 0.9 Pg C / year, it is found to improve soil quality and improve the fertility of soil. Hence, soil carbon sequestration is inevitable in maintaining a stable climatic condition (Lal, 2004).

Objectives of the present study include the estimation of SOC in the soils of different land use types in Kollam district of Kerala to study the impacts of this variation on the environment. In addition, the change in nitrogen content of the soil is also studied. The dependence of the soil texture on the SOC and nitrogen content with change in land use also is part of the present study.

Materials and Methods

Study Area

Kollam district in Kerala is located between North latitudes 8° 45′ and 9°28′ and East longitudes 76°29′ and 77°17′. It has a geographical area of 2491 sq km. Kollam has a tropical humid climate. The temperature is almost steady throughout the year. The average temperature is around 25 °C to 32 °C. The humidity varies from 76.8 to 80% and the district receives an average of about 2555 mm rainfall annually. The soil of the district is broadly classified by the soil survey department as sandy loams, laterite and forest soil. The costal belt has sandy loams and the forest soil is found in the eastern forest belt. Lateritic soil is present in the high land regions and coastal belts.

Site Selection

The district is divided into five, based on the major land uses in the district, namely agricultural land, built up areas, forest land, water bodies and industrial area. Out of the total area of the district, 2524 sq km, 933 sq km is agricultural land which constitutes about 40% of the total area. Built up areas (712 sq km) constitute about 29% and forest areas (596.48 sq km) constitute about 24%. While water bodies constitute 4.19 % with an area of 105 sq km, industrial belt with an area of 8.35 sq km constitutes about

0.33% of the total area of the district. Land use map of the Kollam district, showing the different land uses prevailing in the district, is shown in Fig 1. Five prominent locations under each land use type were selected for soil sample collection.

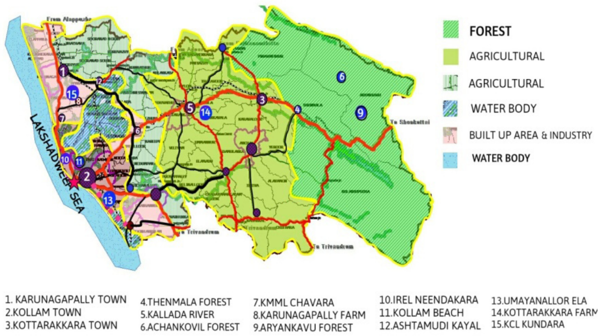

Fig. 1. Land Use Map of Kollam District. (Source: Town and Country Planning Department, Govt of Kerala)

Sample Collection

Fifteen soil samples were collected from different land use types of Kollam district. At each sampling site, areas surrounding the sample points were cleared off by removing surface debris, leaves and grass and about 2 Kg of the surface soil from a depth of about 15 cm was collected and packed in polythene bags and the samples were labelled. Then the exact locations of the samples were fixed using a hand-held global positioning system (GPS) (Table 1).

Laboratory Studies

The entire samples were oven dried for 24 hours and the samples were separated from plant materials and other impurities. The samples were then passed through 4.75 mm sieve to remove stones and other larger particles. Then about 50-60 g of soil were taken for CHNS analysis using Elementar Vario EL III CHNS analyser in the Sophisticated Instrumentation Centre, Cochin University of Science and Technology, Kochi, and the percentage of Carbon, Nitrogen, Hydrogen and Sulphur in the samples were estimated. Although, the thrust of the study is on the carbon content of the soils in each land use types, the elemental variations of nitrogen were also studied to find out its responses with respect to changes in land use types. The sulphur content in most of the analysed samples being below the level of detection, it was neglected.

The grain size analysis of the samples was carried out in the Geotechnical Engineering Laboratory. Using the data from the analysis, grain size distribution curves were drawn from which the effective size, coefficient of gradation, uniformity coefficient, percentage of gravel, percentage of sand and percentage of fines were calculated for determining the texture of the soil samples.

Data Analysis

The data analysis was carried out to find out the textural type of soil, variations of carbon and other selected elements in the soil with respect to different land use types, correlations between elemental

Table 1. Locations of soil samples

Land use type	Sample location	Sample position
Forest	Achenkoil Forest area	$8^0$54′31″N $77^0$3′17″E
	Aryankavu Forest area	$8^0$58′18″N $77^0$8′55″E
	Thenmala Forest area	$8^0$57′58″N $77^0$4′5″E
Agricultural land	Karunagapally Farm	$9^0$5′23″N 76030′12′′E
	Kottarakara Farm	$9^0$4′15″N $76^0$53′19″E
	Umayanallor	$8^0$58′57″N $76^0$55′24″E
Water bodies	Ashtamudi Lake side	$8^0$54′21.37″N $76^0$34′50.1′′E
	Kallada River side	$8^0$59′51″N $76^0$56′58″E
	Kollam Beach	$8^0$52′22.06″N $76^0$35′39.42″E
Built-Up areas	Kottarakara Town	$9^0$1′5″N $76^0$55′39″E
	Kollam urban area	$8^0$53′7.7″N $76^0$32′2″E
	Karunagapally Town	$9^0$3′21″N $76^0$32′2″E
Industrial areas	Neendakara	$8^0$58′52″N $76^0$31′34″E
	Kundara	$8^0$58′7″N $76^0$39′46″E
	Chavara	$9^0$0′7″N $76^0$31′55″E

variations and land use type changes and dependence of carbon content on grain size and implications of these variations on environment. Coefficient of correlation between each element (C and N) was determined to understand the linear relationship between the variations of these elements. Also, correlation coefficient between carbon and the texture of the soil was determined to understand the dependence of SOC on the texture of the soils. Standard deviation of each percentage of fines among the three samples under each land use type was determined. Standard deviation of carbon and nitrogen contents in the soils in each land use type was also calculated.

Results and Discussion

Textural Variation of Soils in Different Land Uses

Soil texture is the relative proportion of sand, silt or clay in a soil and is determined by the size and type of particles that make up the soil. Texture of the soil determines the physical and chemical properties of the soil and it varies largely with land use. In the present study, the soil texture is expressed with respect to the percentage of gravel, sand and fines present in the samples (Table 2).

It can be seen that the percentage of sand is above 88 in all the fifteen samples analysed. The gravel percentage varies from 0.5 to 10.5. The variation of fines is from 0 to 9 percent. The effective size of soil samples varies from 0.096 to 0.42. The uniformity coefficient (Cu) and coefficient of gradation (Cc) vary from 1.53 to 9.52 and 0.393 to 1.387 respectively. It has been found that the soil samples collected from built-up areas are coarser with the calculated average of effective size (0.266 mm) and thus soil from the built-up area has the highest percentage of gravel (8.17) and lowest percentage of fines (1.5). In the soils of industrial areas, percentage of sand predominate (97.67 %). The agricultural land soil has the highest percentage of fines (4%) with a mean effective size of 0.182 mm.

The soils of the built-up areas are the coarsest and the soils from the agricultural land have the finest particles and the industrial area soils have highest percentage of sand. The soils of forest and water bodies have sizes ranging in between the size of soil particles of built-up areas and agricultural lands. The average of gravel, sand and fines content of the soil samples in different land uses were calculated (Table 3).

The percentage of gravel is maximum (7.17) in the agricultural lands and minimum (1.50) in industrial areas. The percentage of sand is maximum (97.67) in industrial areas and minimum (88.80) in agricultural lands. The percentage of fines is maximum (4.00) in agricultural lands and minimum (1.50) in industrial areas. All the samples belong predominantly to the sandy types.

The mean, median, standard deviation, minimum and maximum values of percentage of fines in the different land use types in the study area were calculated (Table 4). Previous studies (Zinn *et al.*, 2005) indicate that there is close correlation between SOC and the clay percentage in the soil. Table 4 in-

Table 2. Variation of texture of soil in each soil sample

Land Use type	Sample Location	Effective Size	Cu	Cc	% Gravel	% Sand	% Fines
Forest	Achenkovil Forest	0.17	5.05	0.393	5.5	89.5	5
	Aryankavu Forest	0.18	8.33	0.889	6	91	3
	Thenmala Forest	0.17	5.88	0.565	4.1	92.9	3
Agricultural Land	Karunagapally Farm	0.096	7.708	0.62	3	88	9
	Kottarakkara Farm	0.24	3.254	1.387	10	88.5	1.5
	UmayanalloorEla	0.21	7.14	0.793	8.5	90	1.5
Water Bodies	Ashtamudi Lake	0.16	3.25	0.692	2.7	93.6	3.7
	Kallada River	0.18	1.72	0.948	0.5	97.5	2
	Kollam Beach	0.18	3.67	0.862	1.5	97	1.5
Built-up Areas	Kottarakkara Town	0.21	9.52	0.857	2.5	96	1.5
	Kollam Town	0.42	5.95	0.952	10.5	89.5	0
	Karunagapally Town	0.17	7.058	1.082	4	93	3
Industrial Areas	IREL, Neendakara	0.17	2.82	0.766	0.5	98	1.5
	KCL, Kundra	0.17	2.235	0.891	0.5	97.5	2
	KMML, Chavara	0.17	1.53	0.997	0.5	97.5	2

Table 3. Average content of gravel, sand and fines in the soil

Land Use Types	Average % Gravel	Average % Sand	Average % Fines
Forest	5.20	91.33	3.67
Agricultural Lands	7.17	88.80	4.00
Water Bodies	1.57	96.03	2.40
Built- up Areas	5.66	92.80	1.50
Industrial Areas	1.50	97.67	1.83

Table 4. Descriptive statistics of percentage fines in soils of different land uses

	Fines Content in Forest	Fines Content in Agricultural land	Fines content in Water bodies	Fines content in Built -up Areas	Fines content in Industrial Areas
Min Value	3	1.5	1.5	0	1.5
Max Value	5	9	3.7	3	2
Mean	3.67	4	2.4	1.5	1.83
Median	3	1.5	2	1.5	2
SD	0.94	3.53	0.94	1.22	0.235

dicates that the standard deviation of fines is maximum (3.53) in the agricultural land followed by built up area (1.22), forest and water bodies(0.94) and industrial areas(0.235). The median is maximum for the forest (3%) followed by water bodies and industrial areas (2) and agricultural land and built up areas (1.5).

The land use types versus gravel percentage in soils was plotted (Fig 2) to find out the variation of gravel from forests (least affected by human intervention) to the industrial/ built up areas (most affected by human intervention). It is seen that the gravel content is minimum in industrial areas and maximum in agricultural lands.

The variation of percentage of sand in soil samples with land use (Fig. 2) indicates that sand content in the soils increases in the order agricultural land<forests < built-up areas< water bodies < industrial areas.

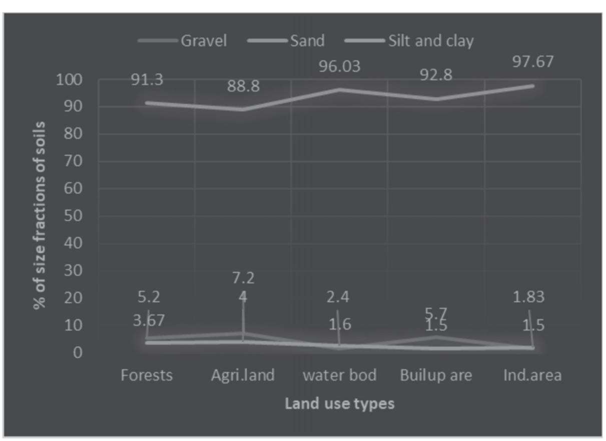

Fig. 2. Variation of soil texture with land use types

The variation of percentage of fines (silt and clay) with respect to different land use types (Fig. 2) is in the order, built-up areas<industrial areas< water bodies< forests<agricultural areas. This may be due to the fact that the fines fraction in the land uses least affected by human intervention like forests is enriched in natural fine materials like humus. It is also known that the humus content of soils decreases with intensive land use activities as that in built-up and industrial areas. This has special relevance with respect to the SOC also.

The soils of the study area belong to the sandy types. The standard deviation of fines is found to be maximum in soils of agricultural lands and minimum in built up areas. The percentage of fines shows a decrease in trend from the forest to the built up/ industrial areas. This has relevance to the SOC content variation in the soils also

Carbon Stock of Soil in Different Land Uses

The SOC content of the soil varies largely with change in land uses. The important factors that control carbon present in the soil are climate, hydrology, parent material, soil fertility, biological activity, vegetation patterns, human intervention, elevated CO_2, O_3 pollution, N fertilizers etc. Carbon is a measure of the health of the soil. Since nitrogen is a close associate of carbon in carbon pools of soils, percentage of nitrogen variation also is studied along with the variation in the carbon stock of soils

The present study reveals that the carbon stock of soils varies from 0.08% in the industrial area to 2.91% in farm areas. Similarly, Nitrogen in soil varies from 0.02% industrial area to 0.26% the Agricultural land. The percentage of carbon and nitrogen in the 15 samples considered for the study is shown in Table 5.

The minimum, intermediate, maximum, average and standard deviation of carbon and nitrogen in different land uses were calculated (Table 6). The minimum content of carbon varies from industrial area (0.08%) to forest area (1.49%) and the corresponding nitrogen percentage varies from agricultural land (0%) to forest area (0.14). The intermediate carbon content varies from 0.15% in the industrial area to 2.26% in the agricultural land and the corresponding nitrogen content varies from 0.02% in the industrial area to 0.26% in agricultural land.

The maximum value of carbon content varies from 0.41% in the industrial area to 2.91% in the agricultural land and the corresponding nitrogen content varies from 0.04% in the industrial area to 0.3% in the agricultural land. The average value of carbon content varies from industrial area (0.213%) to forest area (2.1%) and the corresponding nitrogen content varies from industrial areas (0.0267%) to agricultural land (0.213%). The standard deviation (SD) of carbon content varies from 0% in industrial area to 0.127% in agricultural land and the corresponding nitrogen content varies from 0.01% in industrial area to 0.117% in agricultural land.

The lowest values of carbon and nitrogen are always minimum in the case of industrial areas and the highest content of carbon and nitrogen is maximum either in forest or in the agricultural land.

Fig. 3 also supports the above observation that minimum, intermediate, maximum and average values of carbon content in the study area decreases from the forest/ agricultural land to the industrial area.

The soil collected from the industrial area genetically is not devoid of organic carbon, because carbonaceous clay and peat are common content of the coastal soils of Kollam district. Land use activities in the form of construction and industrial operations might have caused aeration and loss of carbon by soil respiration. Fig. 4 shows the variation of nitrogen and it is similar to that of the SOC. This is be-

Table 5. Percentage of C and N in soil samples

Land Use type	Sample Location	C%	N%
Forest	Achenkovil Forest area	2.69	0.25
	Aryankavu Forest area	2.12	0.2
	Thenmala Forest area	1.49	0.14
Agricultural Land	Karunagapally Farm	2.91	0.3
	Kottarakkara Farm	1.01	0.08
	Umayanalloor	2.26	0.26
Water Bodies	Ashtamudi Lake area	1.43	0.13
	Kallada River side	0.87	0.12
	Kollam Beach	0.49	0.06
Built-up Areas	Kottarakkara Town	0.69	0.07
	Kollam urban area	0.17	0.02
	Karunagapally Town	2.02	0.17
Industrial Areas	Neendakara	0.08	0.02
	Kundara	0.41	0.04
	Chavara	0.15	0.02

Table 6. Descriptive statistics of C and N in different land uses

	Forest		Agricultural land		Water Bodies		Built up areas		Industrial Areas	
	C	N	C	N	C	N	C	N	C	N
Min Value	1.49	0.14	1.01	0	0.49	0.06	0.17	0.02	0.08	0.02
Intrmdte Value	2.12	0.2	2.26	0.26	0.87	0.12	0.69	0.07	0.15	0.02
Max Value	2.69	0.25	2.91	0.3	1.43	0.13	2.02	0.17	0.41	0.04
Avg Value	2.1	0.197	2.06	0.213	0.93	0.103	0.96	0.0867	0.2133	0.0267
SD	0.043	0.054	0.127	0.117	0.042	0.037	0.035	0.07	0	0.01

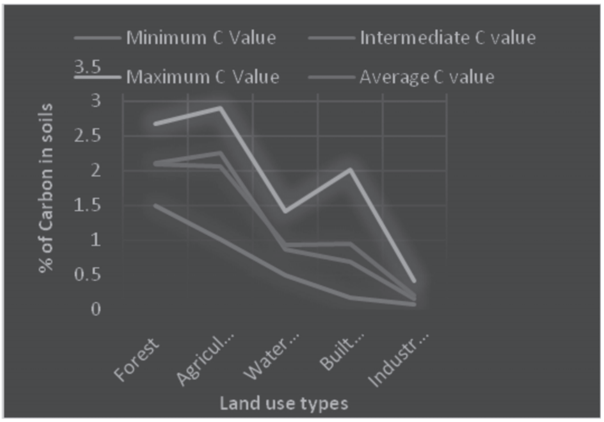

Fig. 3. Variation of SOC in different land use types

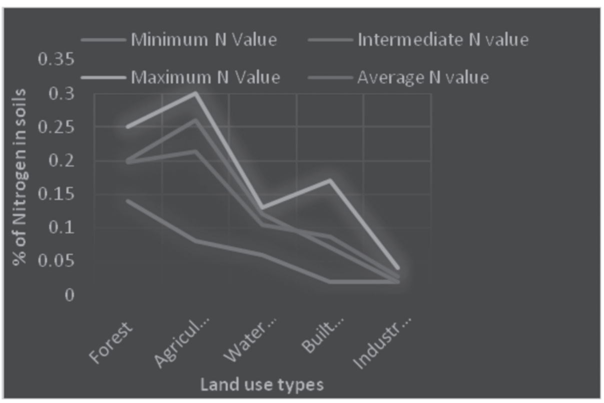

Fig. 4. Variation of N in different land use types

cause in the elemental cycles in the soils, nitrogen is a close associate of carbon pool.

One of the principal on site functions of the SOC pool is that it works as a source and sink of principal plant nutrient including nitrogen (Lal, 2004). Carbon and nitrogen in each soil sample varies linearly. An increase in carbon content in soil sample indicates an increase in nitrogen content. The variation of nitrogen with carbon is shown in the (Fig 5). Carbon and nitrogen are positively correlated with a coefficient of determination of 0.9623. This value indicates that they are strongly correlated.

The above facts further add to the validity of the co-variation of C and N through soils of different land use types. The maximum carbon content in the forest area of the district is mainly due to the fact that the forest is concentrated on the mountains in the eastern part of the district. The soil carbon stock increases with altitude which is due to the high precipitation and low temperature associated with increasing altitude. Lower temperature retards the

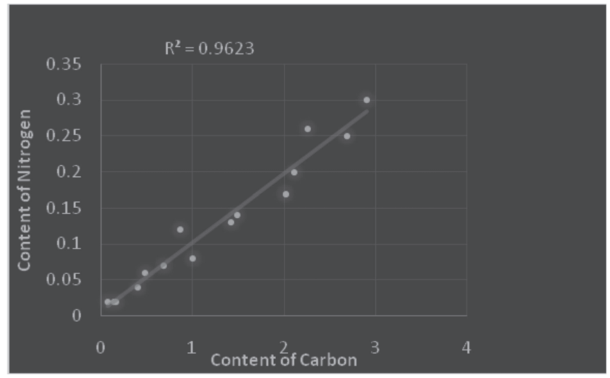

Fig. 5. Variation of Nitrogen with Carbon in soils of Kollam district

decomposition rate of organic matter which results in greater amount of SOC stock at higher elevation (Jabbogy and Jackson, 2000). This in turn causes higher SOC stock in forest area of the district. Moreover, among the three forests, Thenmala forest has the least carbon content. Due to high erosion, the surface soil which is rich in carbon stock is carried away due to which the carbon content decreases.

Due to the conversion of natural vegetation or forest to agricultural land, there is a decrease in carbon stock of soil (Assad *et al.*, 2013). Carbon stock of soil is higher in agricultural land than that in built up areas and industrial areas and is primarily due to the biochemical process (photosynthesis) carried out by the plants, in which the carbon is taken from the atmosphere and transferred to the soil. The soil collected from Karunagapally farm has more carbon content when compared with other soils from agricultural land and this is because of the very high clay content of soil collected from the farm.

The carbon content is found to be least in the industrial areas and this can be attributed to the extensive human intervention in the area. Built-up areas were found to have less amount of carbon content in soil. This is due to the unscientific activities prevailing in the area and also due to the mismanagement of the soil.

Dependence of Carbon Content on Texture of Soil

SOC is usually said to be well correlated with soil texture (Razamfimbelo, 2013). Relation between SOC and soil texture has been attributed to a chemical stabilization of SOC by physicochemical adsorption of SOC on clay mineral surface (Feller and Beare, 1997). This relation showed that clayey soils have more potential for SOC storage than sandy soils. Therefore, the percentage of clay content is a good predictor of SOC.

Macro-aggregates increase with increase in clay content and become more stable when the clay content is high. Macro-aggregates protect the SOC from the attack of the microbes, which will lead to the release of SOC in the form of CO_2, by isolating them. The protected C inside macro-aggregates is defined as the physically protected C pool. Aggregates physically protect SOC by forming physical barriers between microbial enzymes and their substrates and by controlling O_2 and consequently influencing microbial turnover. Table 7 shows the variation of C content with soil grain size.

Fig. 6 indicates that there is no correlation between the gravel content in the soils and the SOC. The coefficient of determination in this case is 0.0807 which is insignificant.

In the case of correlation between the sand content and SOC (Fig. 7), it is seen that there exists a

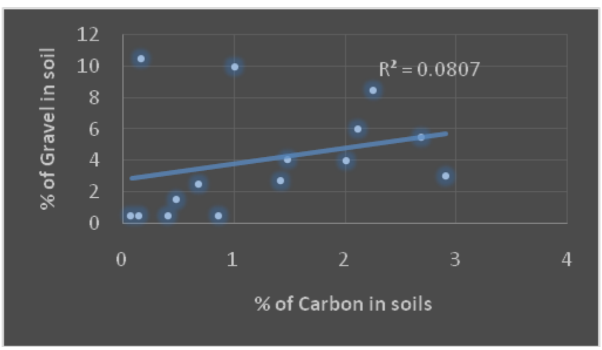

Fig. 6. Variation of percentage of gravel with carbon content

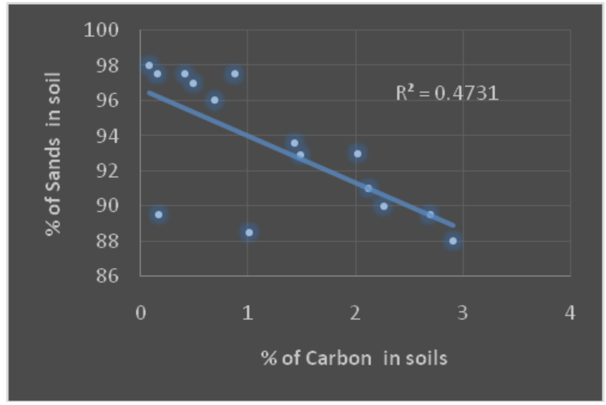

Fig. 7. Variation of percentage of sand with carbon content

significant negative correlation between the two variables. The coefficient of determination in this case is 0.4731.

But the content of fines in the soil samples is positively correlated in a significant way to the SOC (Fig. 8). The coefficient of determination in this case is 0.5587. This means that SOC is associated with the fine fraction of the soils.

Figures 9 and 10 show similar variations. This means that the standard deviation of SOC is almost similar to the standard deviation of percentage fines of soils in different land uses.

This is also supportive of the fact that these SOC content in the soils are closely following the percentage of fines in the soils.

Implications of Soc Variation on Environment

Soils are made of minerals, residues from plants and animals, water, air and living organisms. Organic

Table 7. Variation of C with soil texture

Land Use type	Sample Location	C%	% Gravel	% Sand	% Fines
Forest	Achenkovil Forest	2.69	5.5	89.5	5
	Aryankavu Forest	2.12	6	91	3
	Thenmala Forest	1.49	4.1	92.9	3
Agricultural Land	Karunagapally Farm	2.91	3	88	9
	Kottarakkara Farm	1.01	10	88.5	1.5
	UmayanalloorEla	2.26	8.5	90	1.5
Water Bodies	Ashtamudi Lake	1.43	2.7	93.6	3.7
	Kallada River	0.87	0.5	97.5	2
	Kollam Beach	0.49	1.5	97	1.5
Built-up Areas	Kottarakkara Town	0.69	2.5	96	1.5
	Kollam Town	0.17	10.5	89.5	0
	Karunagapally Town	2.02	4	93	3
Industrial Areas	IREL, Neendakara	0.08	0.5	98	1.5
	KCL, Kundra	0.41	0.5	97.5	2
	KMML, Chavara	0.15	0.5	97.5	2

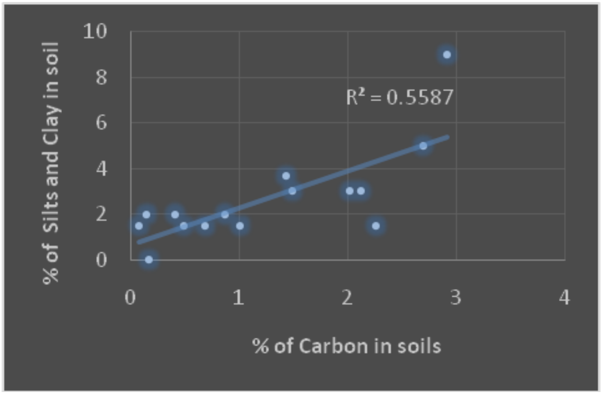

Fig. 8. Relation between carbon content and percentage fines

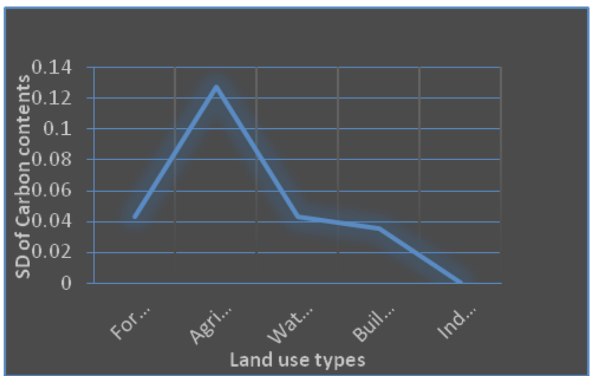

Fig. 9. Variation of standard deviation of C in different land uses

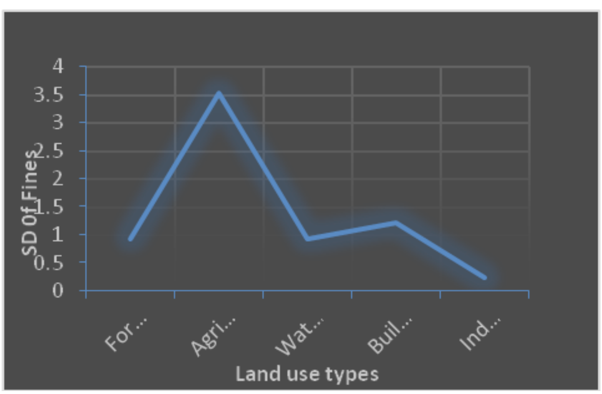

Fig. 10. Variation of standard deviation of fines in different land uses

matter is the key to healthy soil to maintain its structure, nutrient levels and improved levels of water infiltration and retention. About 60% of carbon is present in soil as organic matter. So organic matter is the crucial factor in influencing global carbon cycle. There is more carbon stored in soil than in atmosphere and vegetation combined. As part of this carbon cycle there are constant transfers of carbon between the soil and atmosphere and vice versa. Emissions of carbon dioxide from soils to atmosphere are ten times than those from fossil fuels.

Microbial breakdown of organic matter releases nutrients to the soil. At the same time carbon is released as carbon dioxide through soil respiration. These processes depend on temperature, rainfall, soil-water balance, composition of the organic matter and land use activity.

In the case of any soil there is a balance between the organic carbon added to the soil from decaying organic matter and carbon that is released to the atmosphere in the form of carbon dioxide. By any chance, if the rate of addition of organic matter into the soil exceeds rate of emission of CO_2 into the atmosphere, soil becomes enriched in carbon and vice versa.

In the present study, SOC decreases from the natural forests to industrial/ built up areas. The industrial/built up areas selected for the study are mainly the coastal belts of Kollam districts. It is well known that coastal soils of Kollam invariably contain organic matter and peat. The present study reveals that SOC in the top soil of industrial/ built up area is the minimum. This is due to the removal of SOC in the form of CO_2 to the atmosphere. The land use activities in these areas might have caused aeration of the soil followed by aerobic bacterial decomposition of SOC into CO_2. This means that compared to the forests and agricultural lands, the results of urbanisation like built up and industrial areas are promoting more release of CO_2 into the atmosphere and causes more to the greenhouse effect and climate change.

It is also seen that the percentage of fines in the soils decreases from the forest to the industrial/built up areas. This is due to the fact that components of soils like humus is mostly present in the form of fine fraction in the soil and it is dominating in the forest and agricultural lands. The scope for the generation of humus in the soils of built up and industrial areas are minimum. The SOC is closely associated with the fine fraction of the soil. This means that land use changes associated with urbanisation are directly responsible for the reduction of fine fraction in the soil and that in turn reduces the SOC and finally contributes locally to a global phenomenon like climate change.

Conclusion

The soil of the study area was found to be sandy in nature. The percentage of gravel was found to be minimum in industrial areas and maximum in agricultural areas. Agricultural land has the minimum sand percentage and industrial area has the maximum percent of sand. The percentage of fine is minimum in built up area and maximum in agricultural land. The standard deviation of fines was found to be minimum in industrial areas and maximum in agricultural lands.

The percentages of gravel and sand do not indicate any variation with change in land use but percentage of fines shows decrease in trend from forest to built-up/ industrial area. Minimum, intermediate, maximum and average values of SOC decrease from forest/agricultural land to the industrial area. Nitrogen contents in the soil also follow the same trend.

No significant correlation has been found between gravel content and SOC. Sand content is found to be negatively correlated with SOC and percentage fines has a positive correlation with SOC. Standard deviation of SOC is similar to standard deviation of percentage fines.

The soils of industrial and built up areas of Kollam district studied mainly belong to the coastal part of Kollam district. Undisturbed subsurface soils from these areas contain lot of carbonaceous clay and peat. But due to intense land use activities associated with urbanisation, the SOC in the surface layers of the soil might have been removed by soil respiration. This might have locally added CO_2 from the soil to the atmosphere. Its local implication on a global phenomenon like climate change is evident from this study. It is also interesting to note that SOC closely follows changes in the content of fines in the soil. The land use activities in industrial and built up areas do not permit the formation of fine SOC associated fraction in these soils.

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