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Organic Carbon Depletion Impact on Future Global Climate

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ABSTRACT

Soil organic carbon (SOC) is a very important component of the global carbon cycle, and the fate of SOC will have an important impact on the future global climate. Moreover healthy soils are not only more productive from an agricultural point of view, but they also provide other key ecosystem services. Maintaining a healthy level of SOC is essential to maintain or improve soil health and is explicitly mentioned in Global environmental facility strategy documents. Two thousand five hundred ninety surface soil samples from the entire 232257 ha. area which covers fifteen soil series of Nagapattinam district, Tamilnadu, India were analyzed to know the strength and mapping of soil organic pool. The standard procedure was used for the analysis. This study showed that Kutthalam taluk soils ranged between 0.20 and 0.26% with an average value of 0.23%, Mayiladuthurai taluk soil: min 0.14% max 0.49% with the mean value of 0.29%, Kilvelur taluk soils: min 0.29% max 0.57% mean value of 0.39%, Vedaranyam taluk: ranged between 0.21 and 0.37% with an average value of 0.28%, Nagapattinam taluk: ranged from 0.16% to 0.49% mean- 0.29%. Sirkali taluk soils: from 0.23% to 0.67% mean value - 0.43%, Tharangampadi Taluk OC level was ranged between 0.30% and 4.56% with the mean value of 1.51% and Thirukkuvalai taluk was varied from 0.19% to 0.65% with the mean value of 0.36%. The area where the OC pool is low, medium and high is identified, nutrient index calculated and mapped. The results of present study about organic carbon (OC) of Nagapattinam district revealed that the range was 0.14 to 4.56 % with the mean value of 0.47%. The low content organic carbon was 100% in Kutthalam, 83.58% in Mayiladuthurai taluk, 53.70% in Kilvelur taluk, 100% in Vedaranyam taluk, 90.59% in Nagapattinam taluk, 28.72% in Sirkali, 15.71%in Tharangampadi and 62.86% in Thirukkuvalai. Out of 232257 ha. area of Nagapattinam District, 152584.5 ha area under low level, 67392.7 ha. area under medium level and 12279.8 ha area has sufficient quantity of OC. 66.9% of this district under low level of OC. The inappropriate land use and mismanagement practices including natural calamity are the reason for the depletion and the land users are urged to adapt with best land use practices to reclaim SOC pool in the soil.

Key words: Soil organic carbon, taluk, nutrient index, land use, mapping

INTRODUCTION

Atmospheric CO_2 is keep increasing due to many factors and threatening the world as in the form of Ozone layer depletion, Global Warming, etc. Soil Organic carbon (SOC) is present in soil organic matter (SOM) that is the organic constituent of the soil that is made up of decomposed animal, plant and microbial organisms. The organic C content is an index of organic matter status of the soils. Increasing SOC can improve soil health and can help to reduce atmospheric carbon di oxide. Moreover Soil organic carbon is very important to improve soil fertility as well. Particular emphasis will be placed here on the role of macronutrients [1-2]. It is now widely recognized that SOC plays an important role in soil biological (provision of substrate and nutrients for microbes), chemical (buffering and pH changes) and physical (stabilisation of soil structure) properties. In addition, it improves the properties of soil such as water holding capacity, water infiltration, plant root growth, plant nutrient uptake, nutrient cycling and availability, adsorption of pesticides, etc. Considering this wide variety of performance indicators, [3-4] pointed out that soil quality needs to be assessed with regard to what the soil is used for, as a particular soil may be of high quality for one function and may perform poorly for another. Many of which are a function of SOM content [5-6], indicated that SOM was a key indicator of soil health but further suggested that particulate organic matter (POM) could be used as an indirect measure of soil health because of its short turnover time.

Increasing enough quantity of OC in the degraded soil through good practices that improves not only its quality but also possible to mitigate climate change as soils can store large amounts of carbon, up to 50-300 tons per hectare, which is equivalent to 180-1100 tons of carbon dioxide [7]. The carbon cycle is essential for life on Earth. While photosynthesis by plants, algae and cyanobacteria is the key mechanism allowing life to capture the sun's energy, carbon dioxide (CO_2) respiration is the main mechanism through which autotrophs and heterotrophs use part of the stored energy to fuel their metabolism. Within the carbon cycle, the soil acts as a major reservoir.

The soil organic carbon pool is more than twice the size of the atmospheric carbon pool (ca. 800 Pg) and that it contains about three times the amount of carbon in vegetation [8-9]. Nagapattinam is the one of the district of Tamilnadu and quite often affected by natural disaster such as cyclones, heavy rain and water runoff, etc. OC in the soil series of this district is depleted much and degraded by natural processes and inappropriate land management practices. The amount of soil organic carbon could be increased such a way to convert atmospheric carbon.

Study Area and Location

The location of experiment site was Nagapattinam district, Tamil Nadu that lies on the shores of the Bay of Bengal between Northern Latitude 10.10' and 11.20' East Longitude 79.15' and 79.50'. This is peninsular delta district surrounded by Bay of Bengal on the East, Palk Strait on the South and land on the West and Northern Side. This District is predominantly, a coastal district having a large coast line of 141 kilometres. This district is having an area of 232257 ha in its fold. This district is enveloping 8 taluks and 518 revenue villages. The Reconnaissance soil survey of Nagapattinam district has indicated 18 soil series along with Sand, Swamp and Reserve forest.

METHODS AND MATERIALS

The process made with the help of Lab manual- 2011, [10] -Soil testing, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India. A visual survey of the field was made for sampling randomly [11]. The soil colour, texture, management and cropping pattern was considered for preparing sampling unit. A 'V' - shape cut was made with a spade to remove 1 to 2 cm slice of soil. The surface soil samples were collected from 0-15 cm depth by spade and put in a clean bucket. The soil samples poured out from the bucket on a piece of clean paper and mixed thoroughly. Then spread the soil evenly and divided it into 4 quarters. Two opposite quarters were rejected and mixed the rest of the soil again. Repeated the process till left with about half kg of the soil, collected it and put in a clean polythene bag which was properly marked to identify the sample. Details of the samples was written in the information sheet, one copy was put in the bag and tied well. The packed soil samples were taken to the laboratory for air dried. Such samples were ground with a wooden pestle and mortar so that the soil aggregate are crushed but the soil particles do not break down.

After grinding, the soil was screened through a 2 mm sieve. The practice of passing only a portion of the ground sample through the sieve and discarding the remainder is erroneous. This introduces positive bias in the sample as the rejected part may include soil elements with differential fertility. The entire sample should, therefore, was passed through the sieve except for concretions and pebbles of more than 2 mm. The coarse portion on the sieve should be returned to the mortar for further grinding. Repeated sieving and grinding was done till all aggregate particles were fine enough to pass the sieve and only pebbles, organic residues and concretions remain out. After the sample was passed through the sieve, it was again mixed thoroughly. The soil samples should be stored in cardboard boxes. These boxes should be numbered and arranged in the soil sample room for further soil quality analysis, by which soil chemical parameter OC is made known by the using Chromic acid digestion method [12].

RESULTS

Kutthalam Taluk (Fig. 1): The organic carbon (OC) status of Kutthalam taluk soils were analyzed and ranged between 0.20 and 0.26% with an average value of 0.23%. The low value (0.20%) was observed from Kodimangalam, Kokkur, Nallavoor, Sengudi and Thozhulangudi villages. Whereas the highest value (0.26%) was recorded from Thiruvaduthurai and Thulasenthirapuram villages. Considering the soils having <0.4% as low, 0.4 – 0.75% as medium and >0.75% as high in organic carbon status [13], the distribution of soil samples under these categories was 100% low. None of the samples show values in medium and in high status. Nutrient index [14] value is 1 and it shows that low status while compared with nutrient index class considering < 1.5, 1.5 to 2.5, > 2.5 were low, medium and high respectively.

Mayiladuthurai Taluk (Fig. 2): The 335 soil samples taken from Mayiladuthurai were investigated and ranged from 0.14% to 0.49% with the mean value of 0.29%. The results were showed (Table 4.1.2) that 83.58% soil samples under low category (< 0.4 % as critical limit given in Table 3.4) and 16.42 % samples under between 0.4 and 0.49% (medium level). The lowest OC value 0.14% was observed from Kozhaiyur village and highest OC value 0.49% was noted from Ivanullur village. The nutrient index class was deficient (1.16) as its nutrient Index value was < 1.5, (table1)

Kivelur Taluk (Fig. 3): The organic carbon status of Kilvelur taluk soils was ranged from 0.29% to 0.57% with the mean value of 0.39%. The 53.7% soil samples under low category and 46.3% samples between 0.4 to 0.57% that is medium level. The lowest OC value was 0.29% observed from Radha Mangalam and Karungannii village and highest OC value was 0.57% noted from Satiya Kudi village. The nutrient index class was deficient (1.46) as its nutrient Index value was <1.5, (table1).

Vedaranyam Taluk (Fig. 4): In Vedaranyam taluk, all the samples were under low category. It ranged between 0.21 and 0.37% with an average value of 0.28%. The low value (0.21%) was observed from Vedaranyapuram village and the highest value (0.37%) was recorded from Ayakaran Pulam 1 St Sethi village. The nutrient index value is 1 and it shows low status (table 1).

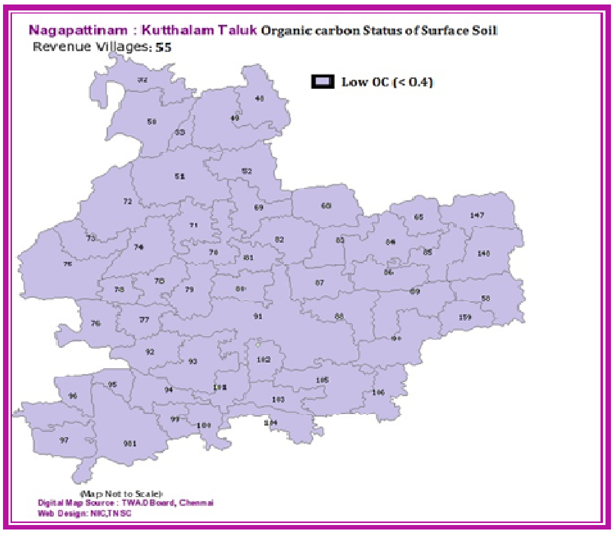

Fig.1 OC status of Kutthalaum Taluk

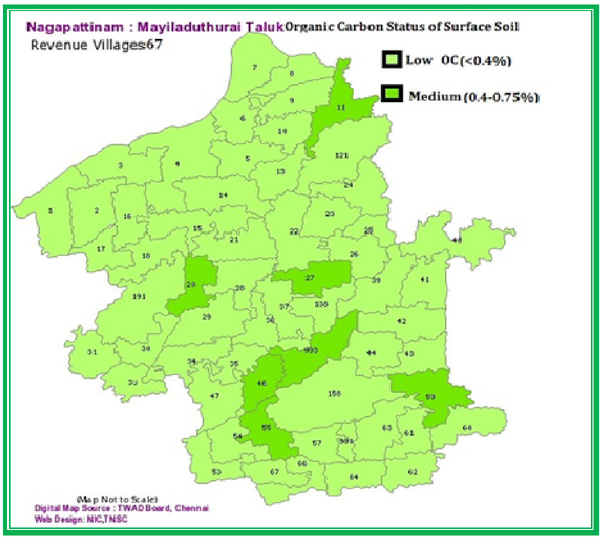

Fig.2 OC status of Mayiladuthurai Taluk

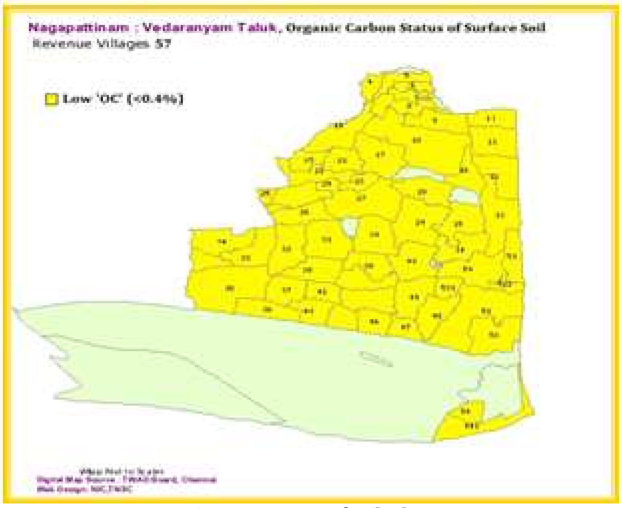

Fig.3 OC status of Kilvelur

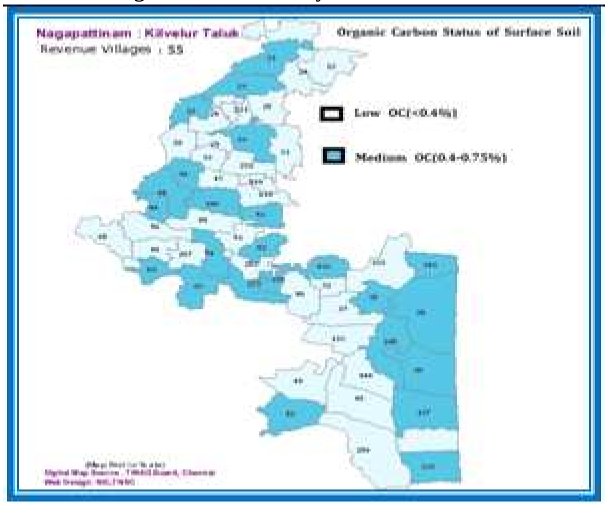

Fig. 4 OC status of Vedaranyam Taluk

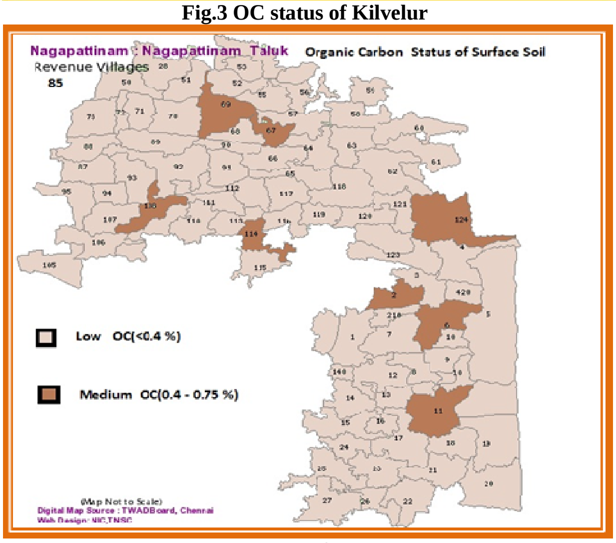

Fig.5 OC status of Nagai Taluk

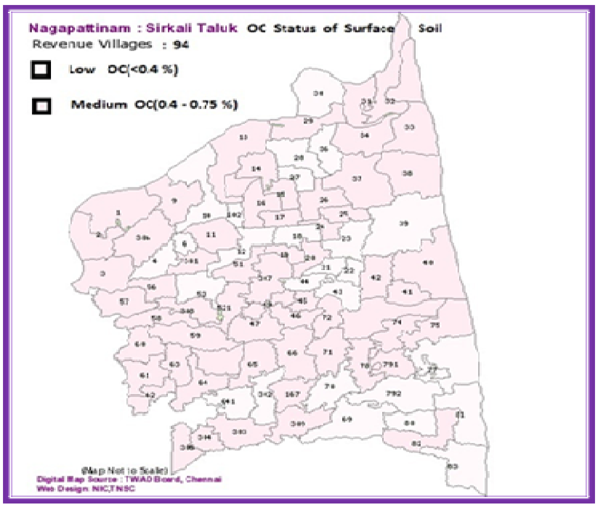

Fig.6 OC status of Sirkali Taluk

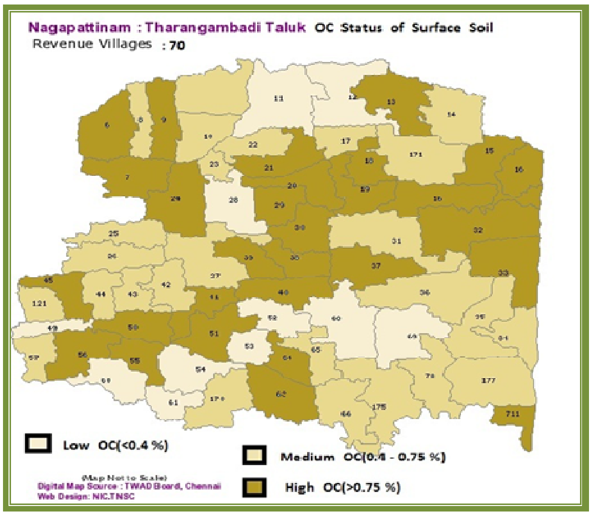

Fig.7 OC status of Tharangam badi

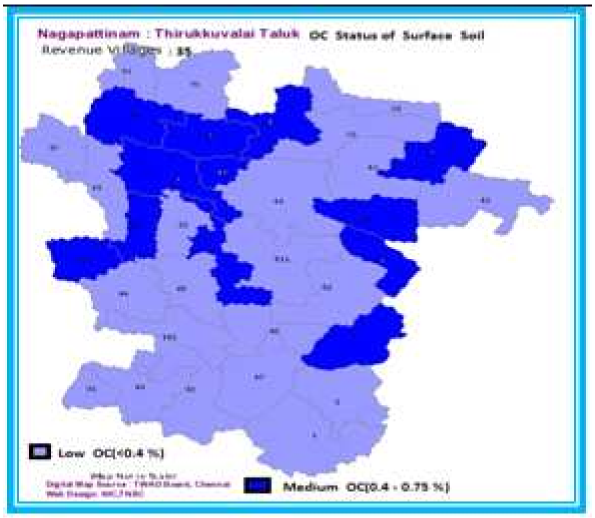

Fig.8 OC status of Thirukkuvalai

Nagapattinam Taluk (Fig. 5): The OC status of Nagapattinam taluk was ranged from 0.16% to 0.49% with the mean value of 0.29%. Maximum number of (90.59%) soil samples were recorded in low category i.e. < 0.4 % as critical limit given in Table 3.4 and 9.41% samples had EC between 0.4 to 0.49% that is medium level (Table 4.1.5) when compared with critical value 0.4 to 0.75%. The lowest OC value 0.16% was observed from Thirupugalur and highest OC value 0.49% was noted from Pappakoil village. The nutrient index class was deficient (1.09) as its nutrient Index value was <1.5 (table1).

Sirkali Taluk (Fig. 6): The organic carbon strength of Sirkali taluk soils was ranged from 0.23% to 0.67% with the mean value of 0.43%. Considerable number of (28.73%) soil samples were recorded in low category and maximum number of (71.28%) soil samples had EC between 0.4 to 0.67% (medium level). The lowest OC value 0.23% was observed from Pachai Peruma Nallur village and highest OC value 0.67% was recorded from Thennam Pattinam and Mahendra Palli villages (Table 3.8) (Table 4.1.6). The nutrient index class was medium (1.68) as its nutrient Index value between >1.5 and < 2.5(table1).

Tharangampadi Taluk (Fig. 7): Tharangampadi Taluk OC level was ranged between 0.30% and 4.56% with the mean value of 1.51%. Considerable number of (15.71%) soil samples were recorded in low category (< 0.4 %). 40% soil samples had OC between 0.4 and 0.75%. 44.49% soil samples recorded above 0.75%. The lowest OC value 0.30% was observed from Vilaham and highest OC value 4.56% was noted from Parasalur villages (Table 3.8) (Table 4.1.7). The nutrient index class was medium (2.29) as its nutrient Index value was between >1.5 and < 2.5(table1).

Thirukkuvalai Taluk (Fig. 8): OC status in Thirukkuvalai taluk was varied from 0.19% to 0.65% with the mean value of 0.36%. Low level was 62.86%. Medium status was 37.14%. The lowest OC value 0.19% was observed (table 4.1.8) from Panangadi and highest OC value 0.65% was noticed from Kodiyalathur village. The nutrient index class was medium (1.37) and nutrient Index was between >1.5 and < 2.5, (table1).

Table -1 Spatial Distribution of Organic Carbon

Taluks	Minimum (%)	Maximum (%)	Mean (%)	% of samples In Low	% of Samples in Medium	% of samples In High	Nutrient Index	Nutrient Index Class
Kutthalam	0.20	0.26	0.23	100	Nil	Nil	1	low
Mayiladuthurai	0.14	0.49	0.29	83.58	16.42	Nil	1.16	Low
Kilvelur	0.29	0.57	0.39	53.70	46.30	Nil	1.46	low
Vedaranyam	0.21	0.37	0.28	100	Nil	Nil	1	Low
Nagapattinam	0.16	0.49	0.29	90.59	9.41	Nil	1.09	Low
Sirkali	0.23	0.67	0.43	28.72	71.28	Nil	1.68	Medium
Tharangambadi	0.30	4.56	1.51	15.71	40.0	44.29	2.29	Medium
Thirukkuvalai	0.19	0.65	0.36	62.86	37.14	Nil	1.37	Low

DISCUSSION

Particulate organic matter [15] regarded as the 'organic fertilizer' property of SOM. In general, increases in SOM are seen as desirable by many farmers as higher levels are viewed as being directly related to better plant nutrition, ease of cultivation, penetration and seedbed preparation, greater aggregate stability, reduced bulk density, improved water holding capacity, enhanced porosity and earlier warming in spring [16-18]. It is [18] noted that 'SOC' is the most important indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical and biological indicators of soil quality'. Even though few soil type found in the Nagapattinam soils, Researcher studied that the irrespective of soil type it appears that if SOC contents are below 1%, it may not be possible to obtain good potential yields from crops [19].

The results of present study about organic carbon (OC) of Nagapattinam district revealed that the range was 0.14 to 4.56 % with the mean value of 0.47%. The low content organic carbon was 100%, 83.58%, 53.70%, 100%, 90.59%, 28.72%, 15.71% and 62.86% were Kutthalam, Mayiladuthurai, Kilvelur, Vedaranyam, Nagapattinam, Sirkali, Tharangampadi and Thirukkuvali taluks respectively (Fig. 9). The lowest OC value 0.14% was observed from Kozhaiyur village Mayiladuthurai taluk and highest OC value 4.56% was noted from Parasalur.

It was found from the result that 17087 ha. in Kutthalam taluk, 20464.6 ha. in Mayiladuthurai taluk, 14748.0 ha. in Kilvelur taluk, 47029 ha. Vedaranyam taluk, 27386.3 ha. in Nagapattinam taluk, 12698.3ha area in Sirkali taluk, 4355.8 ha in Tharangampadi taluk and 8825.5 ha area in Trirukkuvalai taluk were low content of organic carbon (Table 2) that compared with the critical limit (<0.4 %) suggested by Muhr et al., [20], Biswas and Mukherjee [21] and also guideline was given in the lab. manuel, Dept. of agriculture, India. Similar study was taken by Sharma K.P et al [22]. There were 152584.5 hectare area (65.7%) of this Nagapattinam district has low level of OC (<0.4% compare to critical limit), 67392.7 ha area i.e. 29% in medium level (0.4-0.75 %) and 12279.8 ha area 5% only in sufficient level of OC (>0.75%) out of 232257 ha area of Nagapattinam district. This results indicate that majority of soils were found to contain low level organic carbon, which in turn reflects on the low fertile and degraded status of Nagapattinam district that enhancing climate change of the world. Hence this soil should be treated as its nutrient value was 1.39 as the limit given [22].

Table - 2 Mapping of Nagapttinam District in Terms of OC level

Sl. No	Taluks of Nagapattinam District	No. Of Villages	Area (ha) of OC content		
			L	M	H
1	Kutthalam	55	17087	-	-
2	Mayiladuthurai	67	20464.6	4020.4	-
3	Kilvelur	55	14738.0	12707.0	-
4	Vedaranyam	57	47029.0	-	-
5	Nagapattinam	85	27386.3	2844.7	-
6	Sirkali	94	12698.3	31515.7	-
7	Tharangambadi	70	4355.8	11090.4	12279.8
8	Thirukkuvalai	35	8825.5	5214.5	-
	Total	**518**	**152584.5**	**67392.7**	**12279.8**

FACTORS INFLUENCING LOSS OF OC

However, historic loss of SOC due to inappropriate land use and mismanagement practices has caused a decline in soil quality and emission of C into the atmosphere. Agricultural practices have contributed to the depletion of the SOC pool through deforestation and biomass burning, drainage of wetlands, ploughing, and removal of crop residues, summer fallowing and cultivation.

The loss of SOC was attributed to three main processes: 1) oxidation and mineralization due to the breakdown of aggregates leading to exposure of carbon, 2) leaching and translocation as OC and 3) accelerated erosion by runoff [23-24]. Soil degradation leads to the depletion of the SOC pool and emission of greenhouse gases from soil to the atmosphere. Physical, chemical and biological degradation lead to a reduction in biomass production and the amount returned to the soil, decline in soil quality and emission of trace gases to the atmosphere.

Moderate to severe soil degradation through erosion [25] compaction, leaching and loss of biodiversity, structure, and tilth continues and around the world [26] due to previously unrecognized consequences of traditional soil and crop management practices (e.g., intensive tillage, excessive nutrient and pesticide applications, and over-consumption of fossil fuels). Reports on the state of our land suggest that soil (deposited off-site as sediment or dust), nutrients, and organic matter have been lost at rates far exceeding a sustainable level, [27] . The result is that traditional agricultural practices have had enormous direct and indirect consequences on productivity, profitability, and environmental quality throughout the country.

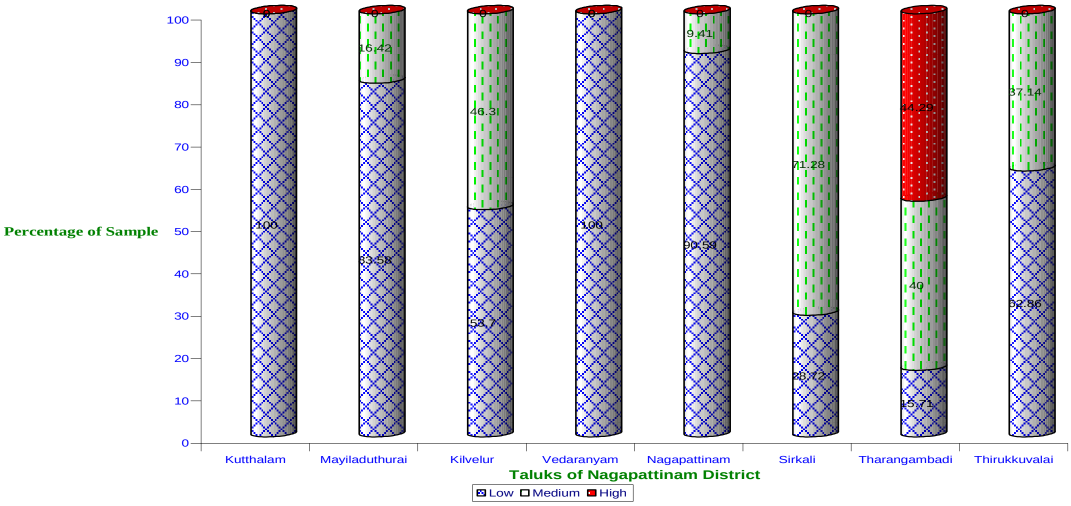

Fig. 9 Deficiency and sufficiency status of OC of Nagapattinam District

RECLAIMING PROCESSES OF ORGANIC CARBON

The main factors employed in the loss of OC in Nagapattinam soils were decomposition and leaching processes. To effectively increase SOC, the rate of input must exceed the rate of loss from decomposition and leaching processes. In most agricultural cases, this is achieved by stubble retention, rotating crops, or the addition of organic residues such as animal manure, litter or sewage sludge. In the study he [28] showed that SOC of a sandy soil could be increased from 0.7 to 0.9% over 6 years by return of crop residues, which was associated with a consistent increase in arable crop and sugar beet yields.

Subsequent regular applications of farmyard manure (FYM) increased SOC from 1% to 3.4% whereas long-term application of fertilizer N had no measurable effect on SOC levels. Similarly, [29] showed in a 30-year-long field trial that biannual additions of various organic carbon residues (straw, sawdust, green manure, and FYM) had positive effects on soil C levels. The highest accumulations occurred with sawdust plus N and manure amendments. It was suggested that the quality of the amendments was related to these trends as lignin contents were high for sawdust and FYM (30%) and low for straw (15%). This is in accordance with a study by However, he [29] also showed that green manure had only 6% lignin but had higher C accumulation compared with straw. In turn, this was related to higher crop productivity and returned inputs due to the higher N content supplied by green manure.

STATISTICAL ANALYSIS

In the case of OC, the data have been collected from the sampled villages of each taluk and using the same descriptive statistics have been computed and given. From the table 3, it is seen that for Tharangambadi taluk the average is highest next comes Sirkali taluk. It is interesting to note that the variations are very low in the case of all the taluks except Tharangambadi for which the S. D is 1.417 which is the highest. Hence it can be concluded that even though the average of OC is higher for Tharangambadi taluk, the variations between the villages with regard to the OC values is very high. From the data collected the analysis of variance has been carried out and the results are given.

Table - 3 OC Analysis of Variance and Descriptive Statistics

Taluks	Villages	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Nagapattinam	85	.29	.06532	.00708	.2823	.3104	.16	.49
Kilvelur	55	.39	.06080	.00820	.3701	.4030	.29	.57
Thirukkuvali	35	.36	.13283	.02245	.3115	.4028	.19	.65
Vedaranyam	57	.28	.05090	.00674	.2832	.3102	.21	.37
Sirkali	94	.43	.10647	.01098	.4293	.4729	.23	.67
Tharangambadi	70	1.51	1.41707	.16937	1.1483	1.8240	.30	4.56
Mayiladuthurai	67	.29	.08042	.00983	.2702	.3095	.14	.49
Kutthalam	55	.23	.01568	.00211	.2238	.2322	.20	.26
Total	518	.47	.65815	.02892	.4340	.5476	.14	4.56

Table - 4 ANOVA – OC

	Sum of Squares	df	Mean Square	F	Sig.(P)
Between Groups	82.587	7	11.798	42.567	.000
Within Groups	141.355	510	.277		
Total	223.942	517			

It is noted that from the table 4 that is F statistic value is 42.567 with corresponding P = 0. Therefore the null hypothesis of equal average OC for the different taluks is getting rejected. It implies that the average of OC differs significantly from one taluk to another.

CONCLUSION

Soils play an important part in the global carbon cycle as they contain about 1550 Pg (picogram) of organic carbon and 750 Pg of inorganic carbon (0-100 cm depth). Accordingly, the total soil carbon pool of 2300 Pg is three times that of the atmospheric and 3.8 times that of the biotic pool [17]. The CO_2 in the atmosphere can theoretically be controlled by growing trees.' [30]. The benefits of increased SOC stocks by adopting sensible land management practices extend beyond the much-discussed greenhouse gas sequestration schemes. In fact, direct benefits of increased SOC content to the landowner include increased productivity, sustainability and, above all, improved soil quality. Therefore, carbonization or greening of the terrestrial biosphere [24] can transfer some of the atmospheric CO_2 into the terrestrial C pool and also offset anthropogenic emissions. As the soils of study area has very low content of OC, more quantity of OC could be sink into the area is possible.

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