International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Soil Organic Carbon (Soc) Content of Sugarcane Agricultural Land in Western Viti Levu, Fiji

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Abstract: ***The objective of the study was to determine the soil organic carbon (SOC) content of soil samples collected, from a depth of 20 cm, from the sugarcane farmers' fields in western Viti Levu, Fiji. In total, 215 soil samples were analyzed for SOC using the Walkley and Black method. Carbon analysis revealed that most of the sugarcane agriculture soils were deficient in organic carbon, with contents ranging between 0.3% and 4.3%, with a mean value of 1.7% and a median value of 1.5%. Further data collation and classification revealed that soils from the Lautoka mill area had higher average SOC contents than those in the Rarawai mill area. This research has shown that soil organic carbon content is overwhelmingly low or very low in the agricultural sugarcane lands of western Viti Levu. An approach that incorporates green manuring may serve to increase SOC in these soils, together with legume intercropping practices, trash blanketing and usage of bio-fertilizers. Soil organic carbon plays a very significant role in controlling the availability of the nutrients in the soil.***

Keywords: soil organic carbon, sugarcane, soil samples, mill, sector

1. Introduction

Soil organic carbon (SOC) is believed to play a crucial role for many soil functions and ecosystem services (Schjønning et al., 2018). Recently, an increasing number of authors have stressed the crucial role of healthy soils, with soil carbon being the most important indicator for food security and resilience against climate change (FAO, 2017). Nearly one third of the global soil organic carbon (SOC) stocks are located in forested areas, which underscores the important role of forests, (and in particular tropical forests), in carbon sequestration and accumulation (Vargas *et al*., 2018).

Soils are the largest terrestrial reservoir of organic carbon, yet great uncertainty remains in estimates of soil organic carbon (SOC) at global, continental, regional and local scales (Chaudhari and Biswas, 2017). Globally, the terrestrial soil carbon pool in the top 2 m of soil is estimated at 2,500 Gt. Of this, the SOC pool comprises 1,550 Gt (Batjes 1996).

Soil carbon sequestration (SCS) is an important part of the terrestrial ecosystem. Soil carbon sequestration is the process of taking atmospheric carbon dioxide and store in the soil in other forms, mainly soil organic carbon. Plants, trees, and some other organisms naturally sequester carbon in the soil. These natural processes are already responsible for sequestering 80 percent of all terrestrial carbon into the soil (CNBC-TV18)

Agricultural soils have the most potential to store a large pool of carbon and depending on the farming techniques applied, can either effectively store carbon belowground, or release further carboninto the atmosphere as CO_2 gas (Chen *et al*., 2017).

Farmers may benefit financially by sequestering carbon in their soils, however the price paid to them varies around the world. A report by Marshall (2019) stated that the price paid for sequestering soil organic carbon was around \$30/t in Europe, whilst in Australia it was only around \$14/t, with indications that it would rise to between \$22–25/t within the next six years. Currently, few Australian farmers are registering their farms as a "soil carbon project" where they can sell their increased soil organic carbon as a commodity like any other agricultural commodity (Marshall, 2019).But so far, only a single farmer in West Gippsland, has earned any carbon credits for his soil (Mannix and Foley, 2023).

Short-term climatic variations affect SOC through changes in temperature and moisture, which affects vegetation growth and soil decomposition rates. In a new study, Endsley *et al*. (Endsley *et al*., 2020)used remote sensing to study surface SOC dynamics globally, drawing data from NASA's Soil Moisture Active Passive (SMAP) satellite(Shultz, 2021).

Sugarcane is a very important agricultural crop, not only in Fiji, but around the world. About 20% of Fiji's population relies either directly or indirectly on the country's sugarcane farming industry (MoSI annual report, 2018-2019). Declining soil fertility and SOC in cane areas of Fiji, due to decades of monocropping and management practices, is a major concern for the sustainability of Fiji's sugar industry (SRIF annual report, 2019).Changes in SOC are strongly influenced by anthropogenic factors, such as land-use change and management practices that affect the productive potential of the soil. SOC content is therefore a responsive metric that reflects progress in sustainable land management and restoration/rehabilitation interventions designed to provide multiple soil health benefits (Orr and Cowie, 2017), andwhich can be correlated to soil pH and the sugarcane yields.

This paper examines the SOC contents of the sugarcane lands in the western side of Viti Levu, along the country's sugarcane belt.

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2. Materials and Methods

***Study area*:** The study area comprises the agricultural land of sugarcane growers across the sugarcane belt areas from Sigatoka to Rakiraki, on the western side of Viti Levu, Fiji Islands.

***Soil sampling procedure*:** At each site the Fiji Sugar Corporation (FSC) extension team collected about 10 core soil samples to a depth of 20 cm. Core samples were thoroughly mixed and 1 composite sample was taken to represent the entire field and provided to the SRIF laboratory.

***Soil analysis procedure*:** Soil organic carbon was determined by the Walkley and Black wet oxidation method (Walkley and Black, 1934). Firstly, 0.2 g (±0.005 g on a 4 decimal place balance) of air-dry soil was placed in a conical flask. Next, 10 mL of 1N potassium dichromate solution ($K_2Cr_2O_7$) was added to the flask. Carefully, 20 mL of concentrated sulfuric acid was added and immediately swirled vigorously for 15s to ensure complete mixing. After the mixture was allowed to stand for 30 mins, 200mL of distilled water was added to the flask to quench the reaction. Finally, 10 mL of concentrated phosphoric acidand5 drops of diphenylamine indicator were added to the flask and a colorimetric titration was carried out with 1 N ferrous sulfate solution ($FeSO_4.7H_2O$). The end-point volume was noted when solution flashed from dark blue to brilliant green. Chemical reaction is as follows;

$$2Cr_2O_7^{2-} + 3C^0 + 16H^+ \rightarrow 4Cr^{3+} + 3CO_2 + 8H_2O \quad \text{(Eqn 1)}$$
$$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O \quad \text{(Eqn 2)}$$

2 blank samples and a reference sample was included during the analysis, with every 20th sample being duplicated. These techniques were taken as quality control for this research. %OC was calculated with the calculation given below and reported as oven-dry basis with two (2) decimal places.

$$\%OC = (V_{blank} - V_{sample}) \times N_{Fe^{2+}} \times 0.003 \times f \times mcf \times \frac{100}{W} \quad \text{(Eqn 3)}$$

where:
V_{blank} = volume of titrant in blank, mL
V_{sample} = volume of titrant in sample, mL
$N_{Fe^{2+}}$ = concentration of standardized $FeSO_4$
0.003 = weight of 1 milli equivalent carbon (g)
f = correlation factor, 1.3
W = weight of soil, g
mcf = moisture correction factor

Tools and techniques –A statistical analysis was made of the soil samples measured SOC data, whereby the mean, minimum, maximum, standard deviation (SD) and coefficient of variance (CV) was calculated.

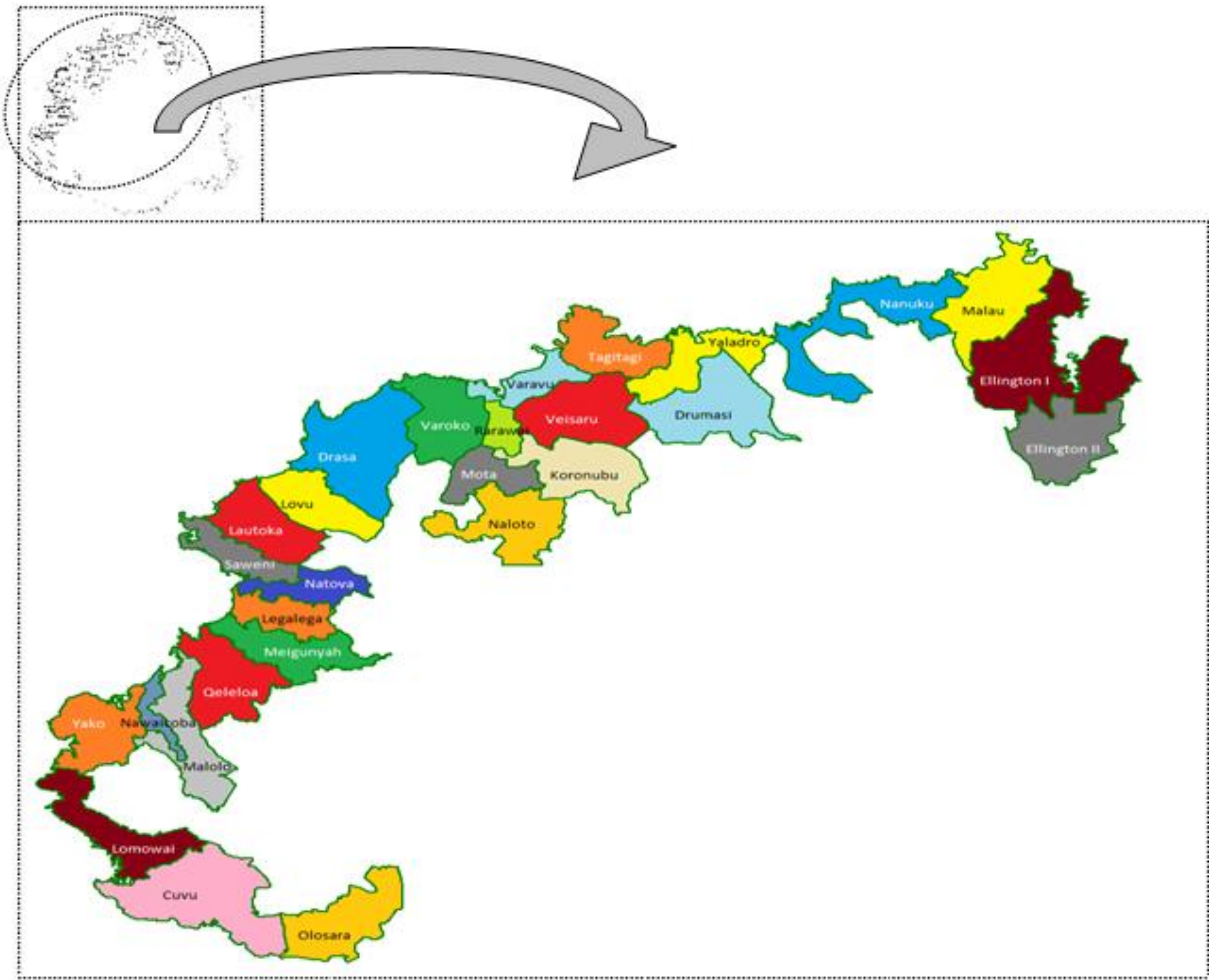

Figure 1: Sector map of the study site, Fiji Islands.

3. Results and Discussion

A total of 215 soil samples were taken for the study of the soil organic carbon (SOC) content across the sugarcane belt areas from Sigatoka to Rakiraki. Each mill area contains 12 sectors within its perimeter. The different sectors are illustrated in Figure 1.Table 1 is a summary of the statistics of the soil analysis, including the total number of soil samples received from each sector in the western Viti Levu. Of the 215samples, 45%were taken from the Lautoka mill area, whilst 55% came from Rarawai mill area.

The soil organic carbon varied between 0.3% and 4.3%, with an average SOC value of 1.7% (Table 1). Values less than 2% are categorized as very low, values within the range 2–4% are categorized as low, whilst values within the range 4–10% are considered as medium. The average SOC content of the 215 soils across this study was 1.7%, meaning that overall the sugarcane agriculture lands in the western side of Viti Levu would be categorized as very low in SOC, which has potential implications for soil fertility and crop production.

The average SOC content for Lautoka mill soils was 2.0%, whilst for Rarawai mill it was 1.6%.The lowest SOC value was found in the Drasa sector, with a value of 0.3%. Figure 2demonstrates the minimum SOC values for each sector, between the corridors of Sigatoka district to Penang district. The highest SOC content was found in the Yako sector, with a value of 4.3%. Figure 3showsthe maximum SOC values for each sector, between the corridors of Sigatoka district to Penang district.

In the Lautoka mill area, the lowest average SOC occurred in the Lomawai sector (1.0%), whilst in the Rarawai mill area the lowest average SOC value was found in the Drumasi sector (0.8%).

Of the 215 soils analyzed, 155 had SOC contents of <2% (very low), 59 had values between 2% and4% (low), whilst only one soil sample had a SOC content between 4%–10%—a level categorized as medium.

Table 1: Summary of SOC (%) results (mean, minimum, maximum, SD and CV values) of soil samples collected from farmers' fields in the various sectors in the western Viti Levu.

Sector	N	%C Mean	%C Minimum	%C Maximum	SD	CV
Lautoka Mill						
Drasa	28	1.9	0.3	3.4	0.88	47
Lautoka	2	2.3	1.8	2.9	0.80	34
Natova	2	1.9	1.8	1.9	0.04	1.9
Drasa Estate	14	1.7	0.8	2.5	0.52	31
Legalega	4	2.0	1.9	2.1	0.09	4.6
Meigunyah	6	2.3	0.7	3.1	0.85	37
Yako	7	2.8	2.2	4.3	0.79	28
Malolo	1	1.9	1.9	1.9	M	M
Nawaicoba	5	2.1	1.0	2.7	0.68	32
Waqadra Estate	2	2.4	2.3	2.4	0.13	5.4
Lomawai	12	1.0	0.4	1.6	0.38	36
Cuvu	12	1.9	0.7	3.3	0.78	41
Rarawai Mill						
Varoko	17	1.6	0.7	3.7	0.82	51
Mota	14	1.3	0.3	2.3	0.60	47
Koronubu	9	1.6	1.0	2.3	0.42	27
Rarawai	18	1.7	0.6	3.0	0.69	41
Veisaru	25	1.3	0.5	3.0	0.52	39
Varavu	10	1.4	0.8	2.1	0.38	26
Naloto	5	2.0	1.2	3.3	0.90	46
Rarawai Estate	2	2.4	1.9	2.9	0.71	30
Tagitagi	1	1.5	1.5	1.5	M	M
Drumasi	7	0.8	0.5	1.1	0.20	24
Yaladro	9	1.7	1.3	2.4	0.33	19
Nanuku	3	1.6	1.0	1.9	0.46	30
Grand Total	**215**	**1.7**	**0.3**	**4.3**		

Note, M stands for insufficient samples taken to calculate the statistics. Malolo and Tagitagi sectors had very few samples taken, making it difficult to draw firm conclusions based on the data set.

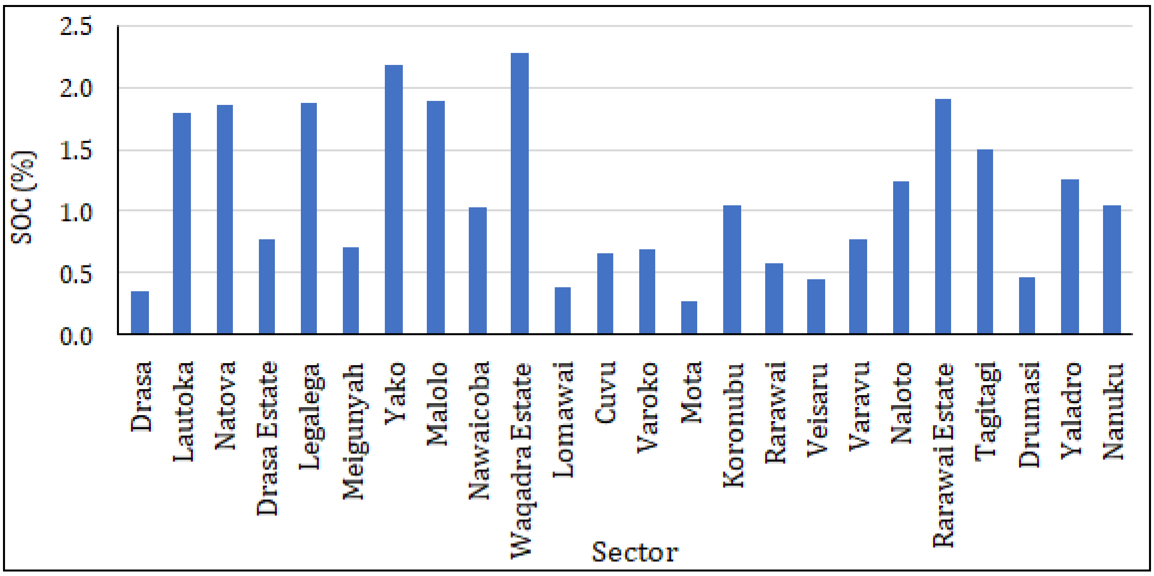

Figure 2: Refers to minimum SOC values for each sector from sugarcane agricultural land in western Viti Levu, Fiji.

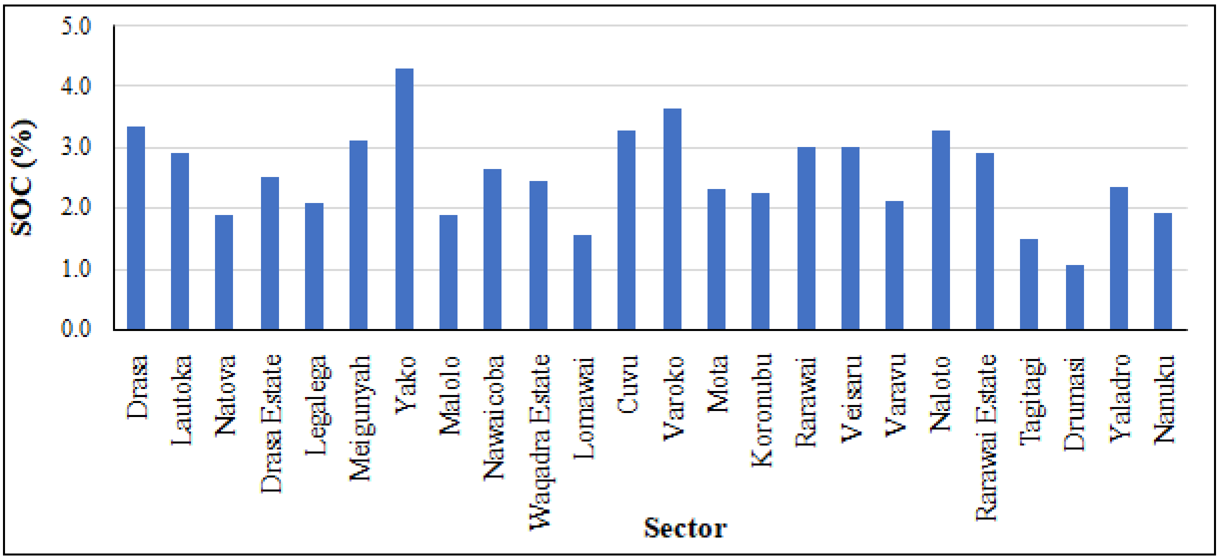

Figure 3: Refers to maximum SOC values for each sector from sugarcane agricultural land in western Viti Levu, Fiji.

4. Conclusion

Soil organic carbon plays a significant role in controlling the availability of the nutrients in the soil. The study revealed that the SOC content of soils in the study area ranged between 0.3% to 4.3%, with a mean value of 1.7%. Almost all the soils sampled were found to be deficient in organic carbon. Lautoka mill soils had a higher average SOC content compared to those of the other mill, but were still in the very low to low category. Few, very simple soil management approaches that includes; 1.) intercropping—a practice of growing 2 or more crops with sugarcane, 2.) green manuring—a process whereby leguminous plants such as pulses, lentils, peas, peanuts and mucuna (capable of 'fixing' nitrogen from the atmosphere) are incorporated in the soil, 3.) green cane trash blanketing, should be instigated to increase the carbon content of these soils.

Acknowledgement

The authors are grateful to the staff and support staff of the Sugar Research Institute of Fiji. Thanks to Dr. Angus McElnea, Senior Scientist, Department of Environment and Science, Australia and Mr. Prem Naidu, Deputy Chief Executive Officer, Sugar Research Institute of Fiji for editing this paper.

References

[1] Schjønning, P., Jensen, J. L., Bruun, S., Jensen, L. S., Christensen, B. T., Munkholm, L. J., Oelofse, M., Baby, S. and Knudsen, L. (2018). *Chapter Two - The Role of Soil Organic Matter for Maintaining Crop Yields: Evidence for a Renewed Conceptual Basis.* Advances in Agronomy, Science Direct, Volume 150, Pages 35-79.

[2] FAO. (2017). *Global Soil Organic Carbon Map – Technical report.*Food and Agriculture Organization of the United Nations, Rome, Italy, 2017.

[3] Vargas, R., Yigini, Y., Federico Olmedo, G., Viatkin, K. and Guevara Santamarıa, M., (2018). *Global Soil Organic Carbon Map Technical report.*

[4] Chaudhari, S. and Biswas, P., (2017). *Assessment, Monitoring and Managing Soil Organic Carbon (SOC) for Climate Change Mitigation and Adaptation: An Indian Perspective.*

[5] Batjes N. H. (1996). "*Total Carbon and Nitrogen in the Soils of the World.*" European Journal of Soil Science 47: 151–163.

[6] CNBC-TV18 (2021) *What is soil carbon sequestration and how it helps mitigate climate change.* Available at https://www.cnbctv18.com/environment/what-is-soil-carbon-sequestration-and-how-it-helps-mitigate-climate-change-9928531.htm(Accessed: 23 January 2023)

[7] Chen, J., Dercon, G., Heiling, M., Slaets, J., Resch, C., Weltin, G., Mayr, L., Gruber, R., Zaman, M., Adu-Gyamfi, J. and Heng, L., (2017). *Integrated Monitoring of Carbon Storage and Loss Through Emerging Isotope Technology*. Proceedings of the Global Symposium on Soil Organic Carbon, 2017, Rome, Italy, 21–23 March, 2017 pp. 49–52.

[8] Marshall, N. (2019) *What Is the Economic Value of Soil Organic Carbon and How Can You Increase It?* rep. Australian Soil Management, Australia.

[9] Mannix, L. and Foley, M. *Carbon farmers are raring to go, but experts say the soil carbon method is flawed.* Available at https://www.smh.com.au/national/carbon-farmers-are-raring-to-go-but-experts-say-the-soil-carbon-method-is-flawed-20230112-p5cbzi.html(Accessed: 24 January 2023)

[10] Endsley, A. K., Kimball, J. S., Reichle, R. H. and Watts, J. D., (2020). *Satellite Monitoring of Global Surface Soil Organic Carbon Dynamics Using the SMAP Level 4 Carbon Product.* Journal of Geophysical Research: Biogeosciences, Volume 125, Issue 12.

[11] Shultz, D. (2021), *A Global Look at Surface Soil Organic Carbon*, Eos. Published on 01 February 2021.

[12] Ministry of Sugar Industry (2018–2019) *Annual Report 2018 - 2019*. rep. Lautoka, Fiji, p. 3.

[13] Sugar Research Institute of Fiji (2019) *Annual Report 2019*. rep. Lautoka, Fiji, p. 88.

[14] Orr, B.J. and Cowie, A.L. (2017) "*SOC As Indicator of Progress Towards Achieving Land Degradation Neutrality (LDN)*," Proceedings of the Global

Symposium on Soil Organic Carbon 2017, Rome, Italy, 21–23 March, 2017 pp. 20–25.

[15] Walkley, A. and Black, I.A. (1934). *An examination of the Degtjareff method of determining organic matter and a proposed modification of the chronic acid titration method*. Soil Science 37: p. 29-30.