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Soil Organic Matter and Soil Organic Carbon in Barito Delta

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Abstract

Soil organic matter and soil organic carbon is essential indication of soil carbon stock in terrestrial ecosystem particularly in peatland. Spatial distribution of soil organic carbon and soil organic matter is primary assessment to predict future soil condition under climate change traits. Barito Delta is one of peatland areas in Kalimantan Island that experiences urban expansion. It is necessary to assess distribution of soil organic carbon and soil organic matter to define the potential traits of urbanization and climate change to carbon stock condition in this delta. Therefore, the aim of this research is to analyze the distribution of soil organic matter and soil organic carbon in Barito Delta. Fieldwork measurement is performed to take sample of soil organic matter for each layer within 5 m soil depth. Inverse distance weighting interpolation is used to determine the spatial distribution of soil organic matter (SOM) and soil organic carbon (SOC) applying in R software.

The value of SOM and SOC decrease along the increase of soil depth so that the largest percentage of SOM and SOC is in the first layer. Large value of SOM and SOC are mostly in the southern part of Barito Delta since it is bordered with sea water and downstream of rivers. The maximum value of SOM is ~12 % in the first layer, while 8.3 % of SOC in the first layer. Nevertheless, the value of SOC decrease in the near future, it is as indication Barito Delta contribute to carbon stock loss realizing to atmosphere that can rise greenhouse gasses and climate change.

Keywords:
soil organic matter, soil organic carbon, Barito Delta

Introduction

Background

Soil organic matter is sensitive to temperature because an increase of temperature can effect soil organic matter degradation (Paré, Laganière, Larocque, & Boutin, 2022). Climate change is reflecting by warmer temperature that is expected to impact the decrease of soil carbon stock (Plante & Conant, 2014). Small loss of carbon stock will impact on future atmosphere carbon dioxide concentration (Smith, Fang, Dawson, & Moncrieff, 2008). In fact, the addition of soil organic matter into soil is one of the ways to combat climate change (Navarro-Pedreño, Almendro-Candel, & Zorpas, 2021). Therefore, soil organic matter data is necessary to be assessed since soil organic matter can be used to assess changes of soil organic carbon stocks in peatland (Klingenfuß, Roßkopf, Walter, Heller, & Zeitz, 2014).

Approximately about 50 to 70 % of global wetlands is represented by peatlands (Negassa, Acksel, Eckhardt, Regier, & Leinweber, 2019). Under anaerobic condition, soil organic matter accumulates in peatlands (Leifeld, Klein, & Wüst-Galley, 2020). The future existing of peatland depends on soil organic matter (Worrall, Moody, Clay, Burt, & Rose, 2017). Land use conversion and climate change contribute to further increase potential damage of peatland (Negassa et al., 2019). Soil organic matter is important peat properties to detect effect of climate change and land use change in peatlands (Girkin et al., 2019).

Barito delta is one of peatland in Kalimantan Island that is densely populated area. Intensive land use conversion from peatland into built-up area can be a potential threat to soil organic matter degradation. This degradation probably will faster due to warmer temperature of climate change effect. Assessment of soil organic matter in Barito Delta is benefit to detect potential threat climate change to soil organic matter.

One of strategies to mitigate climate change and enhance the soil health is by increasing soil organic carbon (Herzfeld, Heinke, Rolinski, & Müller, 2021). Accounting on soil organic carbon is necessary for carbon inventory, and carbon conservation from

the point of view of climate change science (Lourenco, Fitchett, & Woodborne, 2022). Soil organic carbon can be estimated from soil organic matter using conventional method (Pribyl, 2010). It is much easier and straight forward compared to laboratory measurement to be applied in remote and complicated study area as peatland.

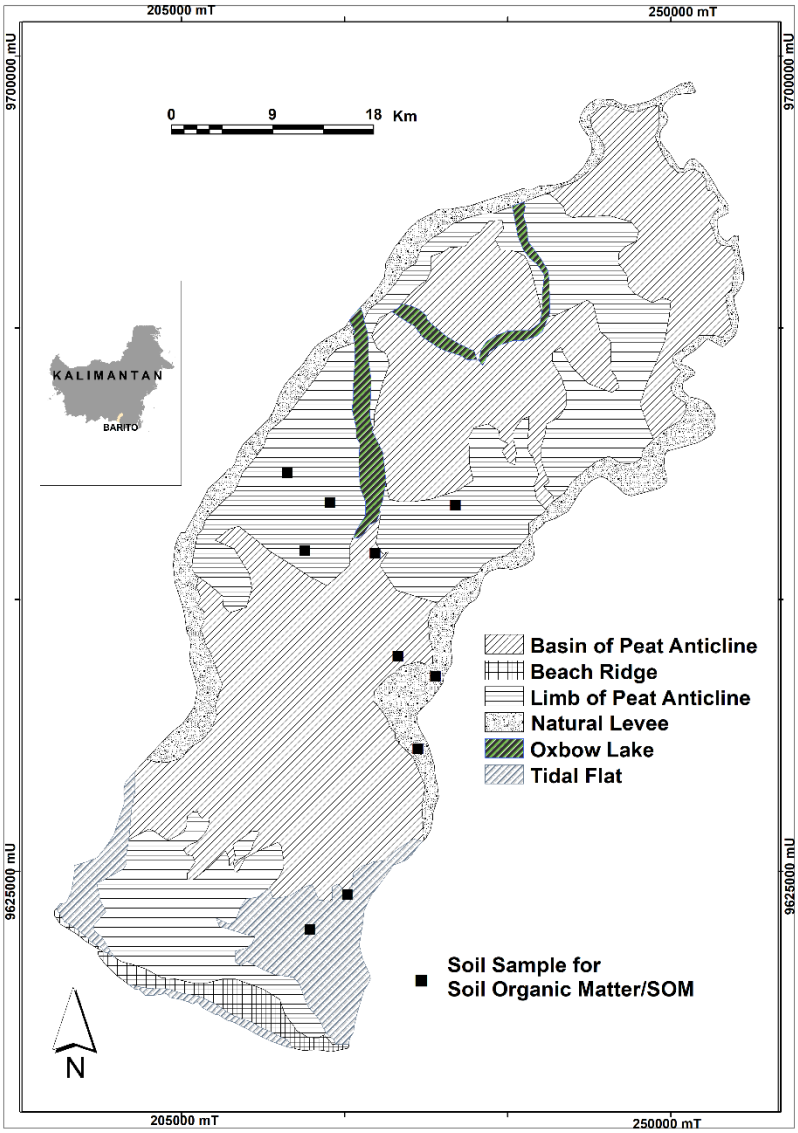
Soil organic matter and soil organic carbon mapping are essential to identify one of the key component affecting global changes of carbon stock due to climate change (Siewert, 2018). It is essential to map soil organic matter and soil organic carbon as a prior identification impact of climate change. Inverse distance weighting can be used to draw soil organic assessment in each soil layer. Inverse distance weighting is widely used for spatial data interpolation (Liu et al., 2021). It is one of frequent spatial interpolation methods used since it is fast, easy and straight forward technique to be interpreted (Lu & Wong, 2008).

Therefore, the purposes of this article are: a) to assess soil organic matter for each soil layer in Barito Delta, b) to analyze soil organic matter content in each soil layer in Barito Delta

Study Area

Barito Delta is located in the south east part of Kalimantan Island. It is administratively in the area of South East Kalimantan province. Barito Delta consists of six landforms that are Basin of Peat Anticline, Beach Ridge, Limb of Peat Anticline, Natural Levee, Oxbow Lake, and Tidal Flood Figure 1). Basin of Peat Anticline is the most vast area in the landform of Barito Delta that is 1,014 km^2. Beach Ridge has the smallest area occupying Barito Delta that is only 4 km^2. It is because Beach Ridge only occupies in south area of Barito Delta where sea water body as the south border to Barito Delta.

Figure 1. Study area location and soil sample location based on landform



Methodology

Soil organic matter is mostly taken each every 1 meter depth for 5 meters soil depth based on landforms (Figure 1). The sample is taken less than 5 meter depth in case it is found fine sand material of ancient sedimentation. Soil sample for soil organic matter is taken using cylindrical ring with the diameter of the ring is 5 cm. Percentage of soil organic matter for each soil layer is defined from laboratory test. Soil organic Carbon is estimated from soil organic matter formula in Equation 1 following. Distribution of soil organic matter and soil organic carbon in each layer is interpolated applying inverse

distance weighting in R Package. Inverse distance weighting formula is shown in Equation 2 and 3 following (Chen & Liu, 2012; Maleika, 2020). The quality of inverse distance weighting interpolation is assessed applying cross validation of mean error (ME) and root mean square error (RMSE) in Equations 4 and 5 (Kambhammettu, Allena, & King, 2011; Munyati & Sinthumule, 2021; Oliver & Webster, 2014).

$$SOM_x = \sum_{i=1}^{N} w_i \, SOM_i \qquad \text{Equation 2}$$

$$w_i = \frac{d_i^{\alpha}}{\sum_{i=1}^{N} d_i^{\alpha}} \qquad \text{Equation 3}$$

where SOM_x is the unknown soil organic matter content in x location (%), SOM_i is soil organic matter content from sample observation in i location (%), N is the number of points, w_i is the weighting for each soil layer, d_i is the distance from each soil organic matter sample to the calculated grid note, α is a power and as control parameter that generally the value is set to be two.

ME and RMSE are quantified as in Equation 3 and 4

$$ME = \frac{1}{n}\sum_{i=1}^{n}\left(z_{(x_i)} - \check{z}_{(x_i)}\right) \qquad \text{Equation 4}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i}^{n}\left(z_{(x_i)} - \check{z}_{(x_i)}\right)^2} \qquad \text{Equation 5}$$

where n is the number of point data, $z_{(xi)}$ is the observed value of SOM at location xi, $\check{z}_{(xi)}$ is the estimated value of SOM at location xi

The conversion formula of SOM into Soil Organic Carbon (SOC) is following USDA Natural Resources Conservation Service as the formula in Equation 6 (Arisanty, Rahmawati, & Rosadi, 2022).

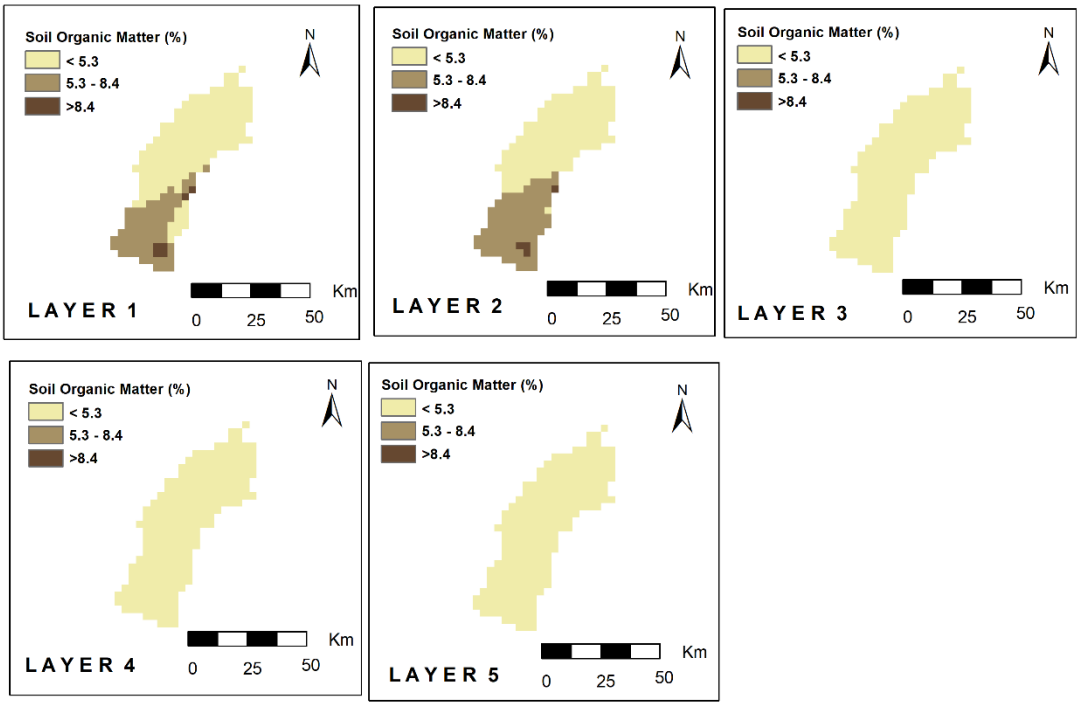
$$SOC = 0.58 * SOM \qquad \text{Equation 6}$$

where SOC and SOM is in %.

Result and Discussion

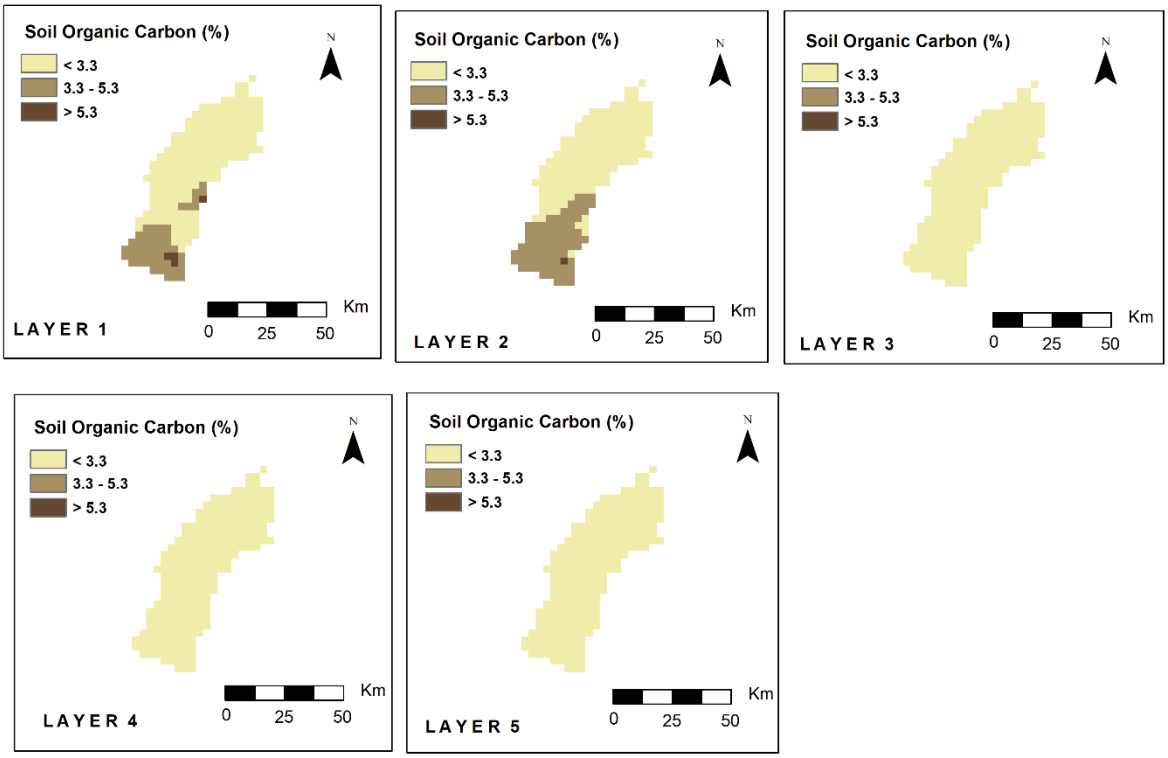
Spatial distribution of soil organic matter (SOM) for each layer in Barito Delta is shown in Figure 2. Percentage of SOM is ranging from less than 5.3 % to more than 8.4 %. The first soil layer has larger percentage of SOM compared to other layers. The value of SOM decreases along the increase depth of soil layer. In the first and second of soil layer, the percentage of SOM can be more than 8.4 % which the maximum value of SOM is 14% for first layer and 9 % for second layer. In the first and second layer, southern part of Barito Delta has larger value of SOM compared to the northern part. It is probably because the southern part is close to the sea water so that the value of SOM is high. It is related to deposition and sedimentation of material (Lawrence, Harden, Xu, Schulz, & Trumbore, 2015). The value of SOM is less than 5.3 % from third to fifth layer.

Figure 2. Spatial distribution of Soil Organic Matter for each layer in Barito Delta (source: primary data, 2022)



Spatial distribution of soil organic carbon is illustrated in Figure 3. The SOC percentages decrease following the depth of soil layer. The value of SOC is larger in the first layer compared to other layers. The value of SOC is only less than 3.3 % from third layer to fifth layers, while more than 3.3 % from first to second layers. The value of SOC is mostly larger in the south part of Barito Delta. It is because there is a lot of sedimentation occurs surrounding sea water body in the south so that SOC content has large percentage.

Figure 3. Spatial distribution of Soil Organic Carbon for each layer in Barito Delta (source: primary data, 2022)



The spatial distribution of soil organic matter for each layer is benefit to predict soil organic carbon stock and soil water content for future condition under climate change impact. Since soil is the largest organic carbon pool in terrestrial ecosystems, it is necessary to analyze its condition under climate stress. Maintaining or increasing the recent condition of soil organic carbon percentage is significant role to challenge impact of climate change (Fujisaki et al., 2023). It is necessary to maintain the maximum value

of SOC in first layer is 8.3 %, 5.3 % for second layer, 2.7 % for third layer, 2.3 % for forth layer and 2.2 % for fifth layer in Barito Delta. In case the value of SOC percentage decrease in the near future, it will be an indication loss of carbon stock in peatland and could be as indication of climate change stress.

Table illustrating the quality of interpolation is shown in Table 1. The value of ME is mostly very low for both SOM and SOC interpolation. Most of ME value is less than 0.02 and the largest value is -0.22. The number of positive and negative values of ME are comparable. It means that the underestimation and overestimation of SOC and SOM values are comparable in number. The value of RMSE values if also mostly very low for both SOC and SOM interpolation. It is approximately 60% of RMSE values is less than 1. It is only 40% of RMSE values are more than 1 with the largest values is 5.3. It can be concluded that the quality of interpolation is good.

Table 1. Cross validation of Inverse Distance Weighting for SOM and SOC applying R software

No	SOM (%)		SOC (%)	
	ME	RMSE	ME	RMSE
1	**-0.13**	**5.3**	**-0.008**	**3.08**
2	**-0.22**	**2.3**	**-0.13**	**1.34**
3	**-0.002**	**0.49**	**0.01**	**0.28**
4	**-0.01**	**0.54**	**-0.007**	**0.31**
5	**0.02**	**0.68**	**0.01**	**0.39**

source: primary data analysis, 2022

Conclusion

Large content of soil organic matter and soil organic carbon is mostly concentrated in upper layer such as first to third soil layer. The value of SOM and SOC decrease gradually from first layer to fifth layer. It is necessary to maintain and increase the value of SOC in the first layer into 8.3 % since it can be used as indication the healthy carbon stock condition in Barito Delta. It is recommended to perform soil organic matter and soil organic carbon assessment gradually so that it is available time series data of SOM and SOC. It is to detect in case there is an impact of climate change.

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