Model Assessment of Soil Organic Matter Content by Remote Sensing in Bayah, Indonesia

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Abstract. Bayah is an area that is well known to have the composition of the soil of mostly limestone which may influence the organic matter content. The land use and slope gradient also influence the organic matter content of the soil. This study aims to determine the distribution of organic matter content by using Landsat 8 and linear regression of statistical analysis which is associated with land use, type of soil, rock type, and slope as the factors that are influencing it. This study uses the normalized difference soil index (NDSI) algorithm to see the soil organic matter content and also using Landsat 8 OLI as a reference for the determination of soil sampling. Spatial analysis and descriptive analysis will be done by creating classifications of soil organic matter content, using the methods of multi-criteria analysis (MCA). Overall the organic matter content in Bayah soil is comparatively low. The distribution of the soil organic matter with the classification of medium and low there was almost total throughout in Bayah and dominated by land use mixed plantation and paddy fields that were located on a slope of 15-25% and 25-40%.

Keywords: Landsat 8 OLI, Linear Regression, NDSI algorithm, Organic Soil Matter Content, Remote Sensing.

INTRODUCTION

Change in soil organic matter (SOM) stocks over time is a critical issue for soil fertility, soil development (pedogenesis) and the global carbon (C) cycle [1]. SOM content, which is typically measured in the form of soil organic carbon (SOC) content, is commonly regarded as a key indicator of soil quality and utilization. The presence of SOM has been proved to be beneficial for soil productivity, water holding capacity, and carbon sequestration [2]. The diversity of different SOM compounds and their molecular characteristics is a function of the organic source material [3]. The spatial variability in SOM content is generally controlled by environmental variables, such as land use types (farmland, grassland, forestland, and scrubland) [4]. Soil organic carbon (SOC) storage at a location is controlled by various environmental factors including climate, vegetation, relief, parent material, soil texture, and land use [5]. Soil parent material can have a major impact on the ecosystem’s (vegetation and soil) functioning, and therefore deeply influence SOM stock. Soil parent material has been observed to be an important driver of SOC stocks at the regional scale [6]. Bayah layer is the clastic material comes from a southern land mass, now under the Indian Ocean, consisting of schists and granites. Bayah layers sediments age Older Eocene in Southern (paralic); quartz sandstones and conglomerates, black clay shale, tuff layers and allochthonous coal seams. At least 1,500 m thick, in Northern (neritic): clays, marls, quartz sandstones and foramina feral limestone. Fossils in Bayah layers are Assilina, Pellatispira Discocyclina, Camerina [7]. Bayah is an area that is well known to have the composition of the soil of mostly limestone, which may influence the organic matter content. This study aims to determine the distribution of organic matter content by using Landsat 8 and linear regression of statistical analysis which is associated with land use, type of soil, rock type, and slope as the factors that are influencing it.
METHODS

This study will use two types of data, primary data, and secondary data. Primary data were obtained from field observation and soil sampling in the field, and Landsat 8 OLI/TIRS image data obtained from USGS website. Secondary data obtained from government agencies related to the data provider and processing of primary data. Secondary data to be used are data of district administration boundary, lithology, slopes, land use, type of soil, and soil organic matter content.

Normalized Difference Soil Index (NDSI)

Normalized difference soil index (NDSI) was proposed using the combination of bands 7 and 2 of Landsat Thematic Mapper Image [8]. This study uses the normalized difference soil index (NDSI) algorithm to see the soil organic matter content using Landsat 8 OLI as a reference for the determination of soil sampling. The combination of bands in this study used a combination of bands 5 and 4 on Landsat 8 OLI.

Linear Regression

Simple linear regression aims to see the correlation/relationship between the dependent variable of soil organic matter (%) with the free variable that is the pixel value of the image of NDSI result. The results of the linear regression statistical test will be used to determine how the distribution of soil organic matter content.

Multi-Criteria Analysis (MCA)

Multi-Criteria Decision Analysis (MCDA) is a general term for systematic approaches that can be used to support the analysis of multiple alternatives in complex problems involving multiple criteria. The process typically consists of the divergent and convergent phases [9]. Spatial analysis and descriptive analysis will be done by creating the classification of soil organic matter content, and combining with the result of the distribution of soil organic matter with physical condition (lithology, slope, type of soil, and land use), using the methods of multi-criteria analysis (MCA), and draw a line cross section transverse (cross-section) to determine the relationship of soil organic matter content in land use, soil type, rock type and slope. The conceptual framework is shown in Fig. 1.

FIGURE 1. Conceptual Frame Work
RESULTS AND DISCUSSION

Result Pixel Value of NDSI (Normalized Difference Soil Index)

NDSI can to a certain degree, separate soil with other land cover types. In particular, the values of NDSI for soil are clustered in the range of 0.1 to 0.4, while vegetation is with lower NDSI values. Therefore, with NDSI, soil information has been enhanced and could be, to some degree, separated from vegetation [8]. Based on Fig. 2, the brighter the pixel color indicates the pixel value close to 0, the darker the pixel color indicates the value of pixel value close to 1. Figure 2 shows that the pixel value close to 1 is in the southeast, west to north of Bayah, while the pixel value close to 0 is in the south and centered in the middle of the Bayah region. This means that the determination of the sample point by the NDSI method is very appropriate for the Bayah region. Determination of sample point will be taken from the value of pixel value, which ranges from ≥ 0.3. This is because the pixel value of ≥ 0.3 indicates that the vegetation cover will be more open and not a water body. The NDSI (Normalized Difference Soil Index) values that have been classified indicate that the NDSI (Normalized Difference Soil Index) value in Bayah District mostly has a value of 0-0.2 spread throughout the Bayah District.

Simple Linear Regression

The result of simple linear regression shows that the value of R, which is a symbol of the correlation coefficient value between the variable pixel value of NDSI, and the value of the soil organic matter content. Table 1 shows the correlation coefficient value is 0.845. This value can be interpreted that the relationship of NDSI variable and variable of soil organic matter content in this research is in strong category. Table 1 also shows the value of R Square or coefficient of determination, which shows the interaction between NDSI variable and variable of soil organic matter content. The coefficient of determination obtained is 71%.

This means that the NDSI pixel value variable has a contribution of 71% to the variable content of soil organic matter and another 29% influenced by other variable factors. Table 1 also shows the level of significance or linearity of the regression. The criterion can be determined based on the F test or the Significance value test (Sig.). The Sig test has provisions if the Sig Value < 0.05, then the regression model is linear, and vice versa. Sig value =
TABLE 1. Classification of Soil Organic Matter Content in Bayah

<table>
<thead>
<tr>
<th>Class</th>
<th>Interval</th>
<th>Km²</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>&gt; 5.00</td>
<td>0.52</td>
<td>0.36</td>
</tr>
<tr>
<td>High</td>
<td>3.01 - 5.00</td>
<td>4.40</td>
<td>3.03</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.01 - 3.00</td>
<td>10.06</td>
<td>6.93</td>
</tr>
<tr>
<td>Low</td>
<td>1.01 - 2.00</td>
<td>66.88</td>
<td>46.08</td>
</tr>
<tr>
<td>Very Low</td>
<td>&lt; 1.00</td>
<td>63.29</td>
<td>43.60</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>145.15</td>
<td>100</td>
</tr>
</tbody>
</table>

0.03 which means < significant criterion (0.05), thus the regression equation model based on the research data is significant and has an error on the data of 0.03. Value A, which has value -1,882, and value B, which has value 10,051. The next process is inserting into equation formula to get the map of the distribution of soil organic matter content to be processed with Band Math tool in ENVI 5.1 software. Then the formulas that will be included are:

\[ y = -1,882 + (10,051 \times B1) \]

\[ Y \] = the value of the soil organic matter content

- 1,882 = value A (constant)

10,051 = value B (Regression Coefficient)

B1 = whole band

The Result of the Distribution of Soil Organic Matter Content

The result of the distribution of soil organic matter based on Fig. 3 shows that, the class interval from the calculation result using the math band tool shows the interval value from 0.00-5.00 which will be divided into five classes into very high, high, medium, low, and very low grade. Very high class is with interval > 5.00 with wide area of 0.52 Km² and which represent 0.36% of the area of Bayah. High class is with intervals of 3.01-5.00 with wide area of 4.40 Km² and which represent 3.03% of the area of Bayah. Moderate class is with intervals of 2.01-3.00 with wide area of 10.06 Km² and which represent 6.93% of the area of Bayah. Low grade is with interval value 1.01-2.00 with the area of 66.88 Km² and which represent 46.08% of the area of Bayah. Very low is class with interval value < 1.00 has an area of 63.29 Km² and which represent 43.60% of the area of Bayah. The distribution of soil organic matter in Bayah District is dominated by low content of organic material with an area of 66.88 Km² with a percentage of area of 46.08%. Figure 3 shows the distribution of soil organic matter with very low classification is in the southeast, and northwest. The distribution of soil organic matter with medium and high classification is found in areas close to the river. This indicates that the content of soil organic matter in Bayah District is low.

Soil Organic Matter Content in Physical Conditions

Based on Table 2a and Table 2b about geological physical condition, soil organic matter content with very high classification is found in lithology, which is a member of limestone in Sareweh Formation and has characteristics of limestone and shale with Tmdl symbol. The content of soil organic materials with a high classification, that are located on the lithology of Terrigenous Clastic sedimentary rocks that are formed from the result of formation of other rocks through the process of weathering, erosion, transportation, sedimentation and deposition, and has the characteristics of alluvium, crust, gravel, sand, clay, mud and sediment with a rock type Qa symbol. The content of soil organic matter with low classification is found in lithology, which is a member of shale, which has the characteristics of limestone clay, black clay, shale and sandstone with the symbol of Tebm rock type. When viewed from the formation process, Tebm is a sedimentary rock. The content of soil organic matter with very low classification is found in lithology, which is Cimapang rock Formation, which has the characteristics of breccia or conglomerate of various materials, clay, tuff, lava, clipped wood, and rocks are converted with Tmc rock type symbol.

In the sloping physical condition of 0-2%, the content of soil organic matter has a very high, high, and moderate tendency, on the slope of 25-40% the content of soil organic matter has a low tendency, and on the slope of 15-25%
TABLE 2a. Soil Organic Matter Content in Physical Conditions

<table>
<thead>
<tr>
<th>Physical Conditions</th>
<th>Soil Organic Matter Content</th>
<th>Very High</th>
<th>Low</th>
<th>Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Km²</td>
<td>%</td>
<td>Name</td>
<td>Km²</td>
</tr>
<tr>
<td>Lithology</td>
<td>Tndi</td>
<td>0.02</td>
<td>3.83</td>
<td>Qa</td>
</tr>
<tr>
<td>Slope</td>
<td>0 - 2%</td>
<td>0.12</td>
<td>1.14</td>
<td>0 - 2%</td>
</tr>
<tr>
<td>Type Of Soil</td>
<td>Alluvial</td>
<td>0.04</td>
<td>0.72</td>
<td>Alluvial</td>
</tr>
<tr>
<td>Land Use</td>
<td>Irrigated Paddy Field</td>
<td>0.08</td>
<td>2.98</td>
<td>Dense Forests</td>
</tr>
</tbody>
</table>

TABLE 2b. Soil Organic Matter Content in Physical Conditions

<table>
<thead>
<tr>
<th>Physical Conditions</th>
<th>Soil Organic Matter Content</th>
<th>Low</th>
<th>Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Km²</td>
<td>%</td>
<td>Name</td>
</tr>
<tr>
<td>Lithology</td>
<td>Tebm</td>
<td>1.84</td>
<td>60.50</td>
</tr>
<tr>
<td>Slope</td>
<td>25 - 40%</td>
<td>8.15</td>
<td>52.62</td>
</tr>
<tr>
<td>Type Of Soil</td>
<td>Latosol</td>
<td>54.65</td>
<td>46.47</td>
</tr>
<tr>
<td>Land Use</td>
<td>Coconuts Plantations</td>
<td>10.26</td>
<td>61.07</td>
</tr>
</tbody>
</table>

soil organic matter content with very low classification. In the physical condition of type of soil of alluvial soil type soil organic matter has a tendency very high, high, and moderate. In the physical condition of type of soil of Latosol soil type has the content of soil organic matter with the classification of low and very low classification. In the physical condition of irrigated paddy field land use, the content of soil organic matter has a very high and moderate tendency. In the physical condition of the use of dense forests soil content of soil organic matter has a high tendency. In the physical condition of land use, coconut plantation content of soil organic matter has a low tendency.

In the physical condition of land use, oil palm plantation soil organic matter has the very low tendency. The pixel value of the NDSI algorithm close to 1 is in the southeast, west to north of Bayah, while the pixel value of the NDSI algorithm close to 0 is in the south and centered in the middle of the Bayah region. The interaction between the pixel value of the NDSI algorithm variable and variable of soil organic matter content with simple linear regression shows that the NDSI pixel value variable has a contribution of 71% to the variable content of soil organic matter and another 29% influenced by other variable factors. This means that the determination of the sample point by the NDSI algorithm method is very appropriate for the Bayah region. The distributions of the content of moderate to high soil organic matter, there is a region with slopes of 0-2%, has Alluvial soil type, with the type of rock-forming sediments from erosion of limestone weathering that has Alluvial soil type properties, and is found in the use of irrigated wetland And dense forest. Low to very low soil organic matter content is in the region having a slope of 15-25% and 25-40%, having Latosol soil type, with rock types of shale members, shale, and breccia or conglomerate, the use of coconut plantations and oil palm plantations.

CONCLUSIONS

The analyses of land use effects on SOC dynamics confirmed that paddy soils were superior to other land uses in sequestering SOC. Considering the potential rapid desalinization under submerged conditions, paddy management is thus recommended as an environmentally sustainable approach. Distribution of soil organic matter in Bayah District spread throughout the District Bayah. The tendency of soil organic matter content with very high classification which covers an area of 0.52 Km², in physical condition of land use we can find irrigated land and forests, in physical condition of type of soil we can find Alluvial soil, in physical condition of slope we can find 0-2% of slope, and in physical condition of lithology we can find a member of limestone in the Sareweh Formation, which has...
characteristics of rock types namely limestone and shale with \textit{Tmdt} symbol. The tendency of soil organic matter content with very low classification which covers an area of 63.29 \text{Km}^2, that are found in physical condition of land use we can find coconut plantation and oil palm plantation, in physical condition of type of soil we can find \textit{Latosol} soil type, in physical condition of slope we can find 15-25\% and 25-40\%, and in physical condition of lithology we can find a Cimapang Formation rock, which has the characteristics of the type of breccia or conglomerate of various materials, shale, tuff, lava, clipped wood, and rocks are converted with \textit{Tmc} rock type symbols. From the above explanation, it can be concluded that Bayah has a very low content of soil organic matter, which can be seen from the physical conditions contained in Bayah.

REFERENCES