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To cite this article: B H Kusumo *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **830** 032079

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Soil organic matter in various land uses and management, and its accuracy measurement using near infrared technology

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Abstract. The aim of this study is to investigate the soil organic matter (SOM) status in various land uses and management in Kayangan Sub-District, North Lombok, and its accuracy measurement using near infrared spectroscopy (NIRS). A total of 100 soil samples (0-10 cm depth) were collected from several land uses and management (rain-fed areas, irrigated areas, areas planted 1-3 times with seasonal crops, areas planted with 1-3 perennial plants) in the study area, which were dried, ground and sieved, then analyzed using Walkley and Black method and scanned using near infrared spectroscopy (NIRS). Partial least square regression (PLSR) was used to create SOM prediction models. The results showed that the SOM content varied from very low to moderate with most of them were low. The content of SOM was significantly higher in the irrigated areas compared to that of in the rain-fed areas, and also higher in the areas planted with seasonal crops 3 times a year compared to the areas planted 1-2 times a year. SOM content was higher in areas planted with 2-3 types of perennial plants, compared to with 1 type of perennial plant. NIRS technology was moderately accurate in measuring SOM, which can be used to monitor spatially changes in SOM.

1. Introduction

Soil organic matter (SOM) is one of the key factors in determining soil fertility and productivity. It can influence the physical, chemical and biological properties of soil, which then determines the ability of soil to support plant growth [1]. Improving soil structure and water holding capacity, enhancing the amount of plant nutrients, increasing cation exchange capacity (CEC) and amplifying the number and activities of soil organisms, those are some of the identified functions of SOM [1,2]. In contrast, soils with low SOM was reported poor in aggregation, easily to erode, more prone to dry [3], low availability of plant nutrients [2], and low in microbial biomass [4]. As SOM has crucial function in soil quality, functionality and health, its amount in soil should be maintained above the critical level.

In soil, the amount of SOM can vary greatly, ranging from very low to very high, depending on the land use, the accumulation of plant residue, and the organic matter addition [5]. For agricultural land that is intensively planted and produces a lot of biomass [6], the accumulation of organic matter in soil



can be through plant litter and roots [7,8]. As reported by Calvalho et al [9], roots and plant residue remain one of the biggest contributors to the addition of organic matter in soil. Other than intensity of planting, the amount of SOM accumulated in soil is also influenced by water irrigation [10]. Dong et al [10] reported greater amount of SOM accumulation in the area with long-term availability of water irrigation compared to the non-irrigated soils. The availability of water increases the planting intensity and then increases the amount of SOM accumulated in soil.

However, in order to know the amount of SOM in soil, it is required tedious procedure with high cost and energy, if conventional analysis is used [11]. Soil samples must be collected, dried, sieved and analyzed in a laboratory, which requires long time procedure [12]. Rapid technology (near infrared spectroscopy – NIRS) in measuring the SOM content has been found in recent years, as it utilizes soil reflectance and it does not require chemical reagents on its operational process [12]. The technology catches the vibration of the covalent bonds of small atoms (such as C-H, N-H and O-H) which are associated to the SOM content [13]. This technology has been reported able to measure soil organic carbon (SOC) content [14,15], and other soil chemicals and physical properties [16-19], with the level of accuracy varies from low to high, depending on the robustness of the developed calibration model.

The aim of this study is to investigate the SOM content in various land uses and management in Kayangan Sub-District, North Lombok Indonesia, and to test whether the measurement can be sped up using NIRS by testing the accuracy of its measurement. The information is useful for monitoring the SOM status in the study area which then determines further decisions in terms of SOM management.

2. Materials and method

The method used in this research was a quantitative method by collecting 100 soil samples (0-10 cm depth) from several land uses and management (i.e. rain-fed areas, irrigated areas, areas planted 1-3 times with seasonal crops, areas planted with 1-3 types of perennial plants) in Kayangan Sub-District, North Lombok, Indonesia, from July to October 2019. On the areas planted 3 times a year, it was usually applied by farmers the cropping system of rice – corn – and then other crops such as chili, tomato or snake bean. On the areas planted 2 times, the cropping system was corn – peanut (or other crops such as chili, tomato, and snake bean) – fallow. For the rain-fed areas with 1-time planting, the cropping system was corn or peanut – fallow – fallow. While the common perennial plants grown were mango, cashew and coconut. The soil samples were determined by grid method by considering the land use and types of irrigation. The samples were dried, ground and sieved with 0.2 mm sieve, then were divided into 2 parts; some parts were analyzed using Walkley and Black method, and the other parts were scanned using NIRS (NIRFlex N500, manufactured by BÜCHI Labortechnik AG, Switzerland). The spectral data were then pre-processed using ParLeS [20] for several steps such as to transformation to $\log(1/R) - R$, wavelet detrending, Savitzky-Golay smoothing, first derivative, and mean centering [21].

To test the accuracy of NIRS in measuring SOM content, it was developed a Partial Least Square Regression (PLSR) models using a software (ParLeS) [20] from SOM data measured by conventional analysis and spectral data scanned by NIRS. The models were then used to predict SOM from the spectral data. The best model for SOM prediction was chosen from the model that produces the lowest root mean square error (RMSE), the highest coefficient determination (R^2), and the highest RPD (ratio of prediction to deviation; SD/RMSE [22,23]).

3. Results and discussion

3.1. Soil organic matter content in the research location

Soil organic matter (SOM) content in the study area is depicted at Table 1. The SOM content varies from very low to moderate with 85% of samples are very low. This is probably related to the low amount of organic matter produced in the land and/or low amount of organic matter left after harvesting. In the area with less intensively planted, the low SOM content was found. In contrast to the areas with high cropping intensity, it was found higher content of SOM, which is in line with what Novelli et al. [6]

reported. In some areas with no irrigation facilities which are planted once a year, it was found also low SOM content. This is similar to the phenomenon reported by Dong et al [10].

Table 1. Soil organic matter content in the various land uses of the study area.

Soil organic matter (%)	Range		Median	Mean	Standard deviation	Variance
	Min.	Max.				
All land uses	0.67	3.93	1.76	1.78	0.52	0.27
Rain-fed areas planted with seasonal crops	0.67	3.33	1.48	1.59	0.53	0.28
Irrigated areas planted with seasonal crops	0.95	3.93	1.85	1.91	0.56	0.31
Areas planted with seasonal crops 1-3 times per year	0.67	3.93	1.70	1.77	0.56	0.32
Areas planted with perennial plants (1-3 species)	0.88	3.55	1.80	1.80	0.44	0.20
1 time planting (seasonal crops)	0.67	3.33	1.47	1.55	0.53	0.28
2 times planting (seasonal crops)	0.74	3.33	1.55	1.64	0.58	0.34
3 times planting (seasonal crops)	0.95	3.93	1.80	1.87	0.55	0.30
1 type perennial plant	0.88	2.56	1.68	1.70	0.40	0.15
2 types perennial plants	1.32	3.26	1.87	1.89	0.40	0.16
3 types perennial plants	1.05	3.55	1.83	1.88	0.58	0.33

3.2. Organic matter in rain-fed and irrigated land planted with seasonal crops

The SOM content in both rain-fed and irrigated areas planted with seasonal crops can be seen at Figure 1. The SOM content in the rain-fed areas is lower than that of in the irrigated areas. The difference in SOM content under the two conditions seems significant, although the average of SOM in both irrigation conditions is still classified into low content. The accumulation of organic matter derived from roots and debris of the standing crops and or plants is considered to be the cause of the SOM difference [6]. Higher SOM found in the irrigated areas is probably due to the higher intensity of planting in the area which then leaves higher amount of plant residues [24]; farmers planted the irrigated areas 3 times a year with seasonal crops, while in the rain-fed areas, it can be planted only one time. This is comparable to what Kusumo et al [21] found that higher SOM content was in the irrigated areas of rice paddy fields of Lombok Island compared to the non-irrigated areas. Similarly, Dong et al [10] reported larger amount of SOM content in the area with long-term availability of water irrigation compared to the non-irrigated soils.

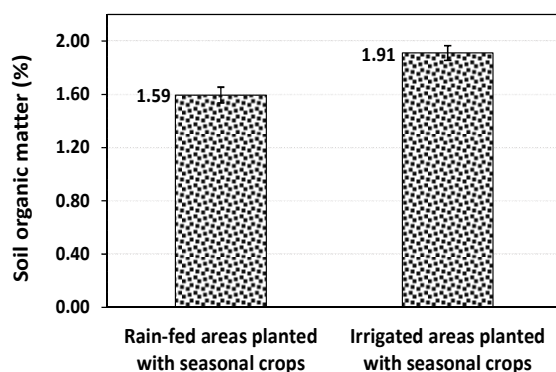


Figure 1. The SOM content of areas planted with seasonal crops in the rain-fed and irrigated areas.

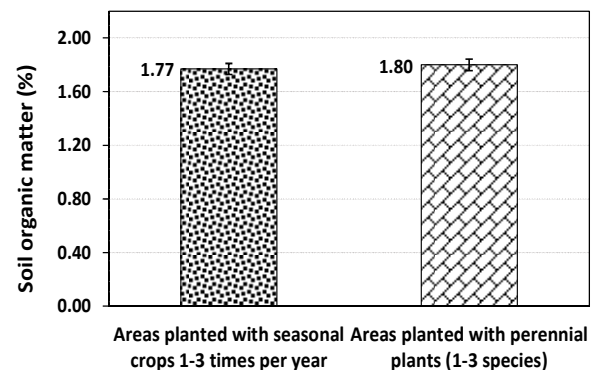


Figure 2. Soil organic matter on areas planted with seasonal crops and perennial plants.

3.3. Organic matter on land planted with seasonal crops and perennial plants

The SOM content in the areas planted with seasonal crops and those planted with perennial plants can be seen at Figure 2. There is no significant difference between the SOM content in both land uses, although there is a slightly higher SOM in the land planted with perennial plants. This shows that there is no significant effect of plant species in determining the amount of SOM in the research area of Kayangan Sub-District, North Lombok, Indonesia.

3.4. Soil organic matter on areas planted with seasonal crops and perennial plants

The SOM content in the areas planted with seasonal crops (with 1-3 times of planting) and perennial plants (with 1-3 types of plants) can be seen at Figure 3. There is a tendency of higher SOM content accumulated in the areas planted 3 times a year with seasonal crops, compared to the areas planted with seasonal crops 1-2 times a year. In this case, more crops residue left on the areas with 3 times cropping a year are considered to be the cause of this phenomenon [24]. Halvorson et al. [24] reported that total crop residue tended to be higher on the land with higher cropping intensity, with was also in line with the findings of Ortega et al [25] that more cultivated agricultural land produces higher SOM. They reported that agricultural land planted with wheat (*Triticum aestivum* L.) – fallow produced organic C soil 6.6 g kg^{-1} , while agricultural land planted with wheat – corn (*Zea mays* L.) or sorghum [*Sorghum bicolor* (L.) Moench] – proso millet (*Panicum miliaceum* L.) – fallow produced 7.5 g kg^{-1} C.

Organic matter also tends to be higher in the areas planted with 2-3 perennial plants (the SOM mean 1.88-1.89%) compared to the areas planted with 1 type of perennial plant (the SOM mean 1.70%) (Figure 3). In this case, plant residue was more accumulated in the areas planted with 2-3 types of perennial plants compared to the areas planted with only 1 type of perennial plant. This is in line with the findings reported by Saha et al [26] that there was more carbon stock in the yard (homegarden) which has more species. Yard that has more plant species has a carbon stock of 119.3 Mg ha^{-1} , while in the yard with fewer species has a carbon stock of 108.2 Mg ha^{-1} [26].

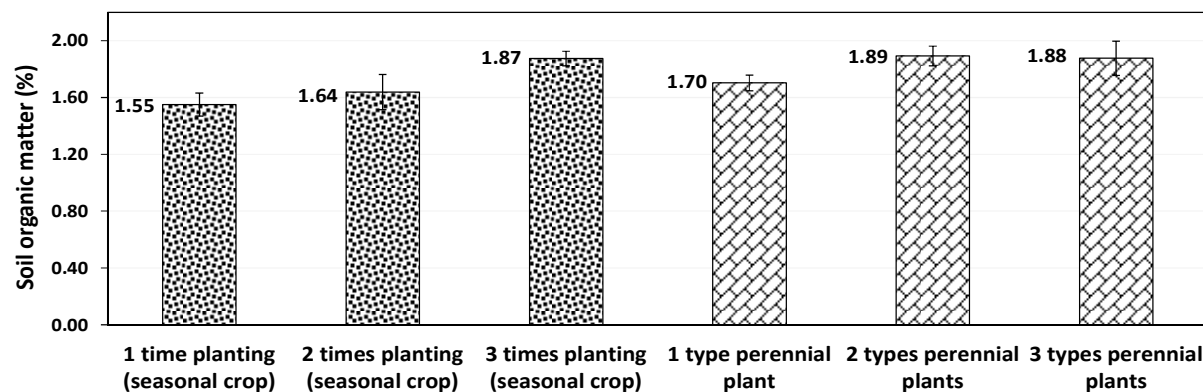


Figure 3. Soil organic matter on the areas planted by farmers with seasonal crops (with 1-3 times of planting) and perennial plants (with 1-3 plant species).

3.5. NIRS accuracy in measuring SOM

The accuracy of near infrared spectroscopy (NIRS) in measuring SOM can be seen at Figure 4. The SOM measured using the Walkley and Black method in X axis which are plotted against the SOM predicted using the NIRS method in Y axis shows quite strong coefficient of determination ($R^2 = 0.76$). Besides, the ratio of prediction to deviation (RPD = 2.01) also shows relatively good value in showing the accuracy of NIR measurement. With the $R^2 = 0.76$ and RPD = 2.01, these show that the NIRS technology is considered moderately accurate compared to the Walkley and Black method. Chang et al. [19] classified accuracy into moderately accurate if R^2 between 0.5 and 0.8 and RPD between 1.4 and 2.0. While Malley et. al [27] classify moderate accuracy levels if R^2 0.7 - 0.8 and RPD 1.75-2.25. Many

factors can influence the accuracy of near infrared technology such as the inaccuracy of laboratory measurement, the presence of outliers in modelling, and error in NIR measurement [27].

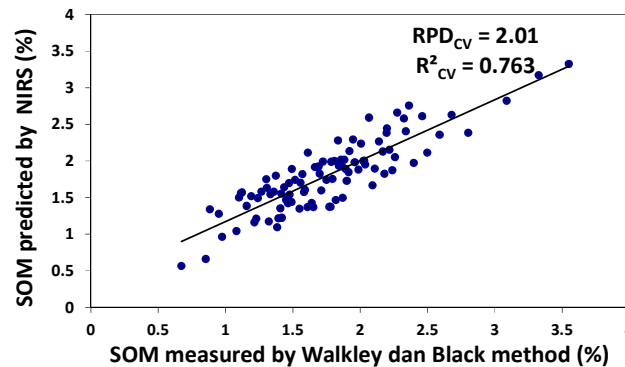


Figure 4. Accuracy of NIRS in measuring SOM.

4. Conclusion

The SOM content in the study area is mostly classified into low content, especially in areas that do not have man-made irrigation systems and with low intensity of planting. The low accumulation of organic matter from plant residue seems to be related to the low intensity of planting due to the low availability of irrigation water. Only a small portion of the area has moderate organic matter content, especially in areas that are planted more intensively (planted 3 times a year with seasonal crops), due to the availability of irrigation water. Plant residue accumulated due to higher planting intensity is considered to be the cause of higher organic matter content in the areas with higher SOM. NIRS technology is moderately accurate in measuring SOM in the study area, compared to the conventional procedure (Walkley and Black). NIR technology can be used to rapidly measure and monitor the changes in SOM in the study area, so the better organic matter management can be immediately anticipating for improved land productivity.

Acknowledgment

Thank you Dr. Raphael Viscarra Rossel (CSIRO, Australia) for letting us using the ParLeS software.

References

- [1] Wiesmeier M, Urbanski L, Hobbey E, Lang B, von Luetzow M, Marin-Spiotta E, van Wesemael B, Rabot E, Liess M, Garcia-Franco N and Wollschlaeger U 2019 Soil organic carbon storage as a key function of soils-A review of drivers and indicators at various scales *Geoderma* **333** pp 149-162
- [2] Senesi N and Loffredo E 2018 *The chemistry of soil organic matter In Soil physical chemistry* (CRC Press) p 239-370
- [3] Kay B D 2018 *Soil structure and organic carbon: a review In Soil processes and the carbon cycle* (CRC Press) p 169-197
- [4] Khan K S, Mack R, Castillo X, Kaiser M and Joergensen R G 2016 Microbial biomass, fungal and bacterial residues, and their relationships to the soil organic matter C/N/P/S ratios *Geoderma* **271** pp 115-123
- [5] Wang J J, Pisani O, Lin L H, Lun O O, Bowden R D, Lajtha K, Simpson A J and Simpson M J 2017 Long-term litter manipulation alters soil organic matter turnover in a temperate deciduous forest *Science of the Total Environment* **607** pp 865-875
- [6] Novelli L E, Caviglia O P and Piñeiro G 2017 Increased cropping intensity improves crop residue inputs to the soil and aggregate-associated soil organic carbon stocks *Soil and Tillage Research* **165** pp 128-136
- [7] Lai Z, Zhang Y, Liu J, Wu B, Qin S and Fa K 2016 Fine-root distribution, production, decomposition, and effect on soil organic carbon of three revegetation shrub species in

- northwest *China Forest Ecology and Management* **359** pp 381-388
- [8] Calvelo Pereira R, Hedley M, Camps Arbestain M, Wisnubroto E, Green S, Saggarr S, Kusumo B H and Mahmud A F 2016 Net changes of soil C stocks in two grassland soils 26 months after simulated pasture renovation including biochar addition *GCB Bioenergy* **8** 3 pp 600-615
 - [9] Carvalho J L, Hudiburg T W, Franco H C and DeLucia E H 2017 Contribution of above-and belowground bioenergy crop residues to soil carbon *GCB Bioenergy* **9** 8 pp 1333-1343
 - [10] Dong L, Yu D, Zhang H, Zhang M, Jin W, Liu Y and Shi X 2015 Long-term effect of sediment laden Yellow River irrigation water on soil organic carbon stocks in Ningxia, China *Soil and Tillage Research* **145** pp 148-156
 - [11] Allory V, Cambou A, Moulin P, Schwartz C, Cannavo P, Vidal-Beaudet L and Barthès B G 2019 Quantification of soil organic carbon stock in urban soils using visible and near infrared reflectance spectroscopy (VNIRS) in situ or in laboratory conditions *Science of The Total Environment* **686** pp 764-773
 - [12] de Santana F B, de Souza A M and Poppi R J 2019 Green methodology for soil organic matter analysis using a national near infrared spectral library in tandem with learning machine *Science of the Total Environment* **658** pp 895-900
 - [13] Kusumo B H 2009 *Development of field techniques to predict soil carbon, soil nitrogen and root density from soil spectral reflectance* (Unpublished Doctoral Thesis, Massey University, Palmerston North, New Zealand)
 - [14] Nawar S and Mouazen A M 2019 On-line vis-NIR spectroscopy prediction of soil organic carbon using machine learning *Soil and Tillage Research* **190** pp 120-127
 - [15] Mayrink G O, Valente D S M, Queiroz D M, Pinto F A C and Teofilo R F 2019 Determination of chemical soil properties using diffuse reflectance and ion-exchange resins *Precision Agriculture* **20** 3 pp 541-561
 - [16] Ng W, Minasny B, Montazerolghaem M, Padarian J, Ferguson R, Bailey S and McBratney A B 2019 Convolutional neural network for simultaneous prediction of several soil properties using visible/near-infrared, mid-infrared, and their combined spectra *Geoderma* **352** pp 251-267
 - [17] Stafford A D, Kusumo B H, Jeyakumar P, Hedley M J and Anderson C W 2018 Cadmium in soils under pasture predicted by soil spectral reflectance on two dairy farms in New Zealand *Geoderma regional* **13** pp 26-34
 - [18] Kusumo B H 2018 In Situ Measurement of Soil Carbon with Depth using Near Infrared (NIR) Spectroscopy *IOP Conference Series: Materials Science and Engineering* **434** 1 pp 012235
 - [19] Chang C W, Laird D A, Mausbach M J and Hurburg C R J 2001 Near-infrared reflectance spectroscopy – principal component regression analysis of soil properties *Soil Science Society of America Journal* **65** pp 480-490
 - [20] Viscarra Rossel R A 2008 ParLeS: Software for chemometric analysis of spectroscopic data *Chemometrics and Intelligent Laboratory Systems* **90** pp 72-83
 - [21] Kusumo B H, Sukartono S and Bustan B 2018 Rapid Measurement of Soil Carbon in Rice Paddy Field of Lombok Island Indonesia Using Near Infrared Technology *IOP Conference Series: Materials Science and Engineering* **306** 1 pp 012014
 - [22] Kusumo B H 2018 The rapid measurement of soil carbon stock using near-infrared technology *IOP Conference Series: Earth and Environmental Science* **129** 1 pp 012023
 - [23] Kusumo B H, Arbestain M C, Mahmud A F, Hedley M J, Hedley C B, Pereira R C, Wang T and Singh B P 2014 Assessing biochar stability indices using near infrared spectroscopy *Journal of Near Infrared Spectroscopy* **22** 5 pp 313-328
 - [24] Halvorson A D, Wienhold B J and Black A L 2002 Tillage, nitrogen, and cropping system effects on soil carbon sequestration *Soil science society of America journal* **66** 3 pp 906-912
 - [25] Ortega R A, Peterson G A and Westfall D G 2002 Residue accumulation and changes in soil organic matter as affected by cropping intensity in no-till dryland agroecosystems *Agronomy Journal* **94** 4 pp 944-954
 - [26] Saha S K, Nair P R, Nair V D and Kumar B M 2009 Soil carbon stock in relation to plant diversity

- of homegardens in Kerala, India *Agroforestry systems* **76** 1 pp 53-65
- [27] Malley D F, Martin P D and Ben-Dor E 2004 Application in analysis of soils. Near-Infrared Spectroscopy in Agriculture, Agronomy Monograph no. 44. 'ed Barbarick K A, Roberts C A, Dick W A et al (Madison, Wisconsin, USA: American Society of Agronomy, Inc., Crop Science Society of America, Inc., *Soil Science Society of America, Inc.* pp 729-784