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Spatial Variability of Total Nitrogen, pH, and Organic Carbon in Organic and Inorganic Farming

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Abstract
Efforts have been made to transform traditional farming practices to organic method in order to ensure sustainable production and environmental conservation. Studying the differences between these two practices through mapping provide insight into the effectiveness of the transformation, as soil characteristics varies in space. Therefore, this study examined the spatial variability of Total Nitrogen, pH, and Organic Carbon in Lombok Kulon village, Wonosari Sub-district, Bondowoso district. The method used consists of: (a) data collection; (b) data input in GIS; (c) processing data, (d) analysis and (e) presentation of results. The results showed that soil organic content in the area was generally low. Furthermore, indicators such as pH, Organic Carbon and Total Nitrogen do not present significant differences between organic and Inorganic practices. The use of Kriging in GIS environment to analyze spatial variability showed variations and inform management decisions relevant to Total Nitrogen, pH and Organic Carbon.

Keywords: Organic Farming, Inorganic Farming, Spatial Variability, Soil Properties.

1. Introduction

Significant efforts have been made to transform traditional farming into organic practices, with the belief that this transformation will ensure sustainable production while also conserving the environmental qualities (Elarajasa *et al.*, 2021). Previous studies show that the transition from conventional to organic farming can be analyzed using soil properties, with natural spatial variability. Methods for analyzing this variability, such as Kriging (John *et al*., 2021; Gözükara, 2021), have been established, however, there are still limited studies on how to assess the achievement of this transition using a spatial approach. One such method is geostatistics (Shahinzadeh *et al.*, 2022; Sahbeni, and Székely, 2022), which uses maps to represent spatial variability. Furthermore, studying the differences between these two practices through maps of predefined indicators can be useful for the future management of nutrients and fertilizers (Khan *et al.*, 2021). Additionally, by portraying these two practices in the form of geostatistical maps, it possible to conduct evaluation in an easey, practical and effective manner.

The transformation from Inorganic into organic practices have an impact on soil conditions, potentially affecting the degree of soil processes, the functioning of agro-ecosystem, and the sustainability of agricultural production systems (Aulakh *et al.*, 2022). The evaluation of its degree requires indicators such as soil properties. For example, Meena *et al.* (2020) demonstrated that organic farming led to significant improvement in water-holding capacity, bulk density, the stability of aggregate, hydraulic conductivity, and soil pH. Additionally, Xu *et al.* (2022) proved that compared to conventional cultivation, organic farming improves soil physicochemical property, soil enzyme activity, altered soil microbial diversity, and bacterial abundance was imminent in organic cultivation, thereby affecting soil structure stability. Krauss (2020) also highlights that the future benefits of organic farming can be observed from the environmental impact of conventional farming, such as loss of biodiversity and climate changes. These studies demonstrated that soil properties can be used as indicators for evaluating the changes from traditional to organic farming. Additionally, Nasiyev *et al.* (2021) and Durrer *et al.* (2021) have highlighted important soil chemical and biological properties, such as nitrogen content pH, and Organic Carbon for evaluating organic farming (Behera *et al.*, 2022). Bouasria *et al.*, 2021) claims that Organic Carbon is important for assessing soil fertility and quality. These studies show that there are available soil properties which can be used as indicators for assessing the transition from Inorganic (conventional) to organic farming practices. However, these indicators have not been implemented in this study area of Lombok Kulon village, despite existing effort to make the transformation.

The developments of Geographical Information Systems, allows for the examination of indicator changes in a spatial context. Therefore, this study aims to investigate the spatial variability of Total Nitrogen, pH, and Organic Carbon in the soils for exploring the difference between organic and Inorganic agriculture practices in Lombok Kulon village, Wonosari Sub-district, Bondowoso district. Comparing the values of these indicators will be useful in evaluating the success of this transformation. The results can then be applied to improve the future organic farming practices.

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2. Research Methods

The study location is in Lombok Kulon Village, Wonosari Sub-District and the district of Bondowoso, as shown in Figure 1, covering an area of 409 Ha. Figure 1 indicates that: (a) IOR and QR are the abbreviations for Inorganic and Organic rice. As shown in the same Figure, about one third of the study area has been practicing organic farming since 2008, while the remaining fraction still employs conventional agricultural practices. The organic farming are has been certified since 2017, with an extension period of certification until 2021, and the certificate number is 370-LSO-005-IDN-02-20. Finally, this study was conducted from December 2020 to March 2021.

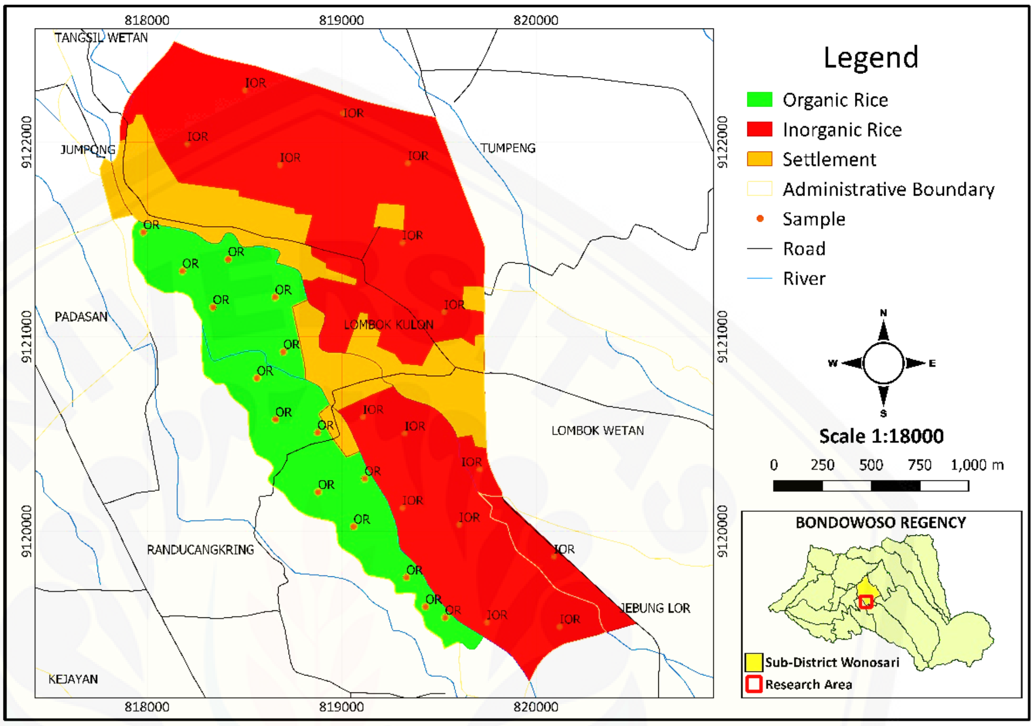

Figure 1. The maps of study area in Lombok Kulon Village, Wonosari Sub-district, The District of Bondowoso. It shows the organic (OR) and Inorganic (IOR) rice fields in green and red, respectively.

The tools used in this study were Quantum GIS (QGIS) software version 3.16, laboratory equipments for analysing pH, Total Nitrogen Content and Organic Carbon, Global Positioning Systems (GPS), and 1: 25.000 base map (topographic maps from Spatial Information Agency).

The methodology used in this study can be explained as follow:

(a) Initial survey was conducted to collect the general information of the study area. At this stage, the farmers were interviewed based on the fertilizer used;

(b) The study area was, then drawn in the topographic maps, and a sampling strategy was established;

(c) Samples of the soil were collected after the harvesting period using the purposive random sampling technique, with the locations being shown in Figure 1. Furthermore, 30 samples were collected at a depth of 20 cm from the top soil and equally divided into two practices of organic and Inorganic farming;

(d) The 30 samples were identified by their coordinates using GPS, and then projected to Universal Transverse Mercator (UTM), zone 49S;

(f) The samples were then analyzed in the laboratory of Soil Chemistry and Fertility at the Department of Soil, Faculty of Agriculture, University of Jember. The analysis included Total Nitrogen, pH and Organic Carbon using standardized laboratory procedures. These parameters were investigated using Kjeldahl method, pH meter, and UV VIS Spectrophotometry at a wavelength of 561 nm, respectively;

(g) The results of laboratory analysis were then inputed into QGIS for further analysis and mapping;

(h) The analysis of pH, Total Nitrogen and Organic Carbon in GIS was conducted by using Moran Indices, classification (Soil Study Agency, 2009) and Geotatistical method, namely Kriging;

(h) Interpretation of the results.

The Root Mean Square Error (RMSE) was employed for assessing the accuracy of interpolated maps. According to Li, *et al*, (2020), the accuracy of an interpolation will be higher when the RMSE value is close to 0. The following formula is used for the calculation:

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(X_2 - X_1)^2}{n}} \quad (1)$$

Information:

n = Number of Samples

X_2 = Values of Chemical Analysis

X_1 = Interpolated Values

3. Results and Discussion

3.1. Results

The code of samples, the locations (UTM coordinate systems), and the values of soil properties for each sample was tabulated and summarized. Table 1 shows the results of laboratory analysis of 30 samples for the soil properties of Total Nitrogen, pH and Organic Carbon. Meanwhile, Table 2 shows the summary of statistical data on soil properties.

Table 1. The results of the analysis of Total Nitrogen, C-Organic and pH.

Sample code	Easting	Northing	Total Nitrogen (%)	Organic Carbon (%)	pH	Farming practices
1	818206.552	9121990.350	0.18	0.92	6.05	Inorganic
2	818503.624	9122266.107	0.15	0.77	5.87	Inorganic
3	818683.343	9121881.364	0.19	0.80	5.93	Inorganic
4	819008.024	9122148.608	0.18	0.79	6.46	Inorganic
5	819340.136	9121891.825	0.17	0.85	6.83	Inorganic
6	819312.721	9121481.975	0.21	0.82	6.32	Inorganic
7	819527.406	9121126.111	0.20	0.84	6.49	Inorganic
8	819109.222	9120586.824	0.28	0.90	6.25	Inorganic
9	819323.533	9120502.367	0.26	0.98	6.18	Inorganic
10	819312.817	9120119.699	0.26	0.78	6.03	Inorganic
11	819604.296	9120032.884	0.18	0.81	5.83	Inorganic
12	819709.933	9120317.925	0.17	0.89	5.79	Inorganic
13	819747.261	9119531.140	0.20	0.77	5.91	Inorganic
14	820121.138	9119509.188	0.21	0.92	6.15	Inorganic
15	820091.909	9119869.361	0.19	0.98	6.03	Inorganic
16	817980.294	9121536.751	0.23	0.93	6.62	Organic
17	818416.629	9121397.741	0.27	0.99	6.82	Organic
18	818181.339	9121337.626	0.30	0.9	6.92	Organic
19	818338.378	9121150.958	0.34	1.01	6.74	Organic
20	818657.950	9121202.746	0.19	1.04	6.84	Organic

Table 1 (Continued)

Sample code	Easting	Northing	Total Nitrogen (%)	Organic Carbon (%)	pH	Farming practices
21	818700.789	9120921.600	0.23	1.15	7.03	Organic
22	818564.544	9120786.559	0.30	1.19	6.57	Organic
23	819118.450	9120270.541	0.23	1.23	6.38	Organic
24	818659.813	9120574.337	0.25	0.82	6.42	Organic
25	818876.393	9120507.085	0.29	0.92	7.19	Organic
26	818879.252	9120201.222	0.35	1.06	6.15	Organic
27	819061.989	9120023.228	0.32	0.95	6.18	Organic
28	819333.356	9119762.636	0.30	0.88	6.28	Organic
29	819532.351	9119556.175	0.34	0.83	6.30	Organic
30	819431.901	9119611.709	0.32	0.95	6.74	Organic

According to Table 2, the range values of soil properties for the overall area were 5.79-7.19 (pH), 0.77-1,23 (C-Organic), and 0,15-0,35 (Total Nitrogen) respectively. Meanwhile, the range values for organic fields were 6,15-7,19 (pH), 0,82-1,23 (C-Organic) and 0,19-0,35 (Total Nitrogen), and that of Inorganic fields were 5,79-6,83 (pH), 0,77-0,98 (C-Organic) and 0,15-1,28 (Total Nitrogen).

Table 2. Summary statistics of pH, C-Organic and total Nitrogen.

Soil Properties	Min	Max	Mean	Median	Coefficient of variant (%)	Coverage of data
pH	5.79	7.19	6.38	6.31	0.93	Overall study area (Combined Inorganic and organic)
C-Organic	0.77	1.23	0.92	0.91	14.05	Overall study area (Combined organic and inorganic)
Total Nitrogen	0.15	0.35	0.24	0.23	98.61	Overall study area (Combined Inorganic and organic)
pH	6.15	7.19	6.61	6.62	0.71	Organic fields
C-Organic	0.82	1.23	0.99	0.95	12.28	Organic fields
Total Nitrogen	0.19	0.35	0.28	0.30	57.74	Organic fields
pH	5.79	6.83	6.14	6.05	0.74	Inorganic fields
C-Organic	0.77	0.98	0.85	0.84	9.60	Inorganic fields
Total Nitrogen	0.15	0.28	0.20	0.19	87.08	Inorganic fields

Figure 2 shows the changes of the coefficient of variance for the overall study area, organic, and Inorganic fields, respectively. As shown, the highest values for the three soil properties was discovered in overall study area, suggesting a significant differences between the data from organic and Inorganic farming practices. Figure 2 also shows that there was a similar pattern observed, with the highest being Total Nitrogen, followed by C-Organic and pH. There was quite big difference in the values of variance of three soil properties for organic and Inorganic agricultural practices, with inorganic being the lowest. This shows that more homogenous values of soil properties were observed in the Inorganic farming practices than in organic. Farming practices could be the main reason for this, as the characteristics of data affect the result of spatial analysis.

Figure 3, 4 and 5 shows the results of kriging and classes for the three soil properties. As observed, there are differences in the observed spatial patterns of each soil property based on the interpolation results obtained through the krigged method. Figure 3 indicates that low pH values are distributed in the north and south, while the moderate to high values are mostly located in organic soils. According to Figure 4, the high and low Organic Carbon values are identified in organic and Inorganic lands, respectively. Figure 5 shows that high nitrogen values have the smallest area, while most areas have at low to moderate nitrogen values. The results of Moran analysis showed that the values of Indices area are 0,633 (pH), 0,466 (C-Organic) and 0,595 (Total Nitrogen). This indicates that clustering of the data was most observable in pH, followed by Total Nitrogen and C-Organic. The visual interpretation of the interpolated values seems to agree with these indices. For example, the clustering of pH was more observable than in other two soil properties, while weak clustering was prominent in C-Organic and Total Nitrogen.

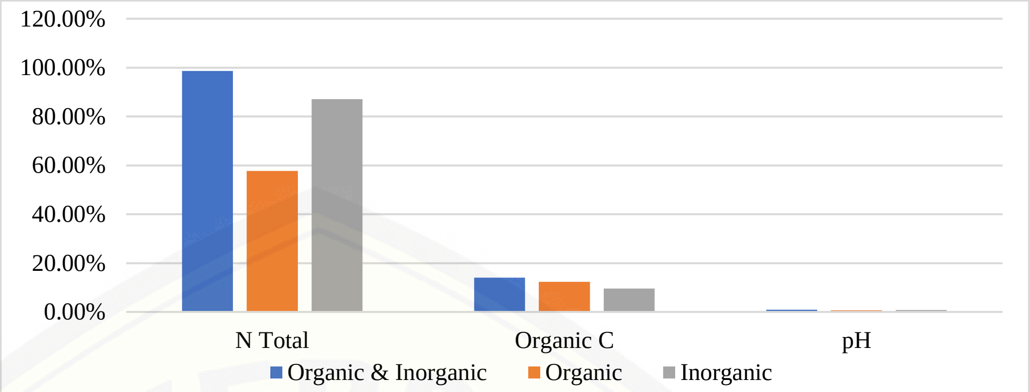

Figure 2. The values of coefficient of varians of pH, C-Organic dan Total Nitrogen for overall area, organic farming and inorganic farming.

3.2. Discussion

The results on Figure 3 show that organics farming yields higher values for the three soil properties than its Inorganic counterpart. Despite that Inorganic agricultural land applies organic fertilizers such as composting, the values of these soil properties are still significantly different. The pH values in organic farming indicate higher minimum and maximum values were observed. This is likely due to addition of organic fertilizers which increase and stabilize pH values (Yuniarti, 2020). Organic carbon appear to play a role in nitrogen availability and pH elevation in organic fields. This is also supported by previous study which stated that the use of organic matter can provide nitrogen almost equivalent to the application of chemical fertilizers (Kumar *et al*., 2017). Other studies stated that the ongoing basis of organic fertilizer input can provide a higher availability of nitrogen (Tripathi *et al*., 2014; Banik *et al*., 2006 ; Urmi, *et al*., 2022 and Rahman *et al*., 2016). The decomposition process of organic fertilizer will release nutrients through mineralization and form humus. The mineralization process will release acidic and basic cations. Furthermore, acidic cations such as ammonium ($NH4^+$) are adsorbed by humus and soil colloids, while basic cations will help increase the concentration of OH^- ions. OH^- ions which will react with H^+ ions and form water (H_2O), thereby increasing the acidity of agricultural land. However, the values of variances shows that thein pH of organic farming is higher due to varying fertilizer dose and application times. Compared to Organic Carbon and pH, different pattern was observed for Total Nitrogen. As shown in Figure 2, the values of Total Nitrogen in organic farming are lower, which could be due to factors such as leaching and evaporation, and the use of Inorganic fertilizers in Inorganic farming.

The Figures 3, 4 and 5 draw a particular attention to Organic Carbon due to the presence of low and very low classes, despite the addition of soil organic matter in organic farming practices. The low values of Organic Carbon in the south-west part of the study area indicated the potentials of land degradation when no effort is made. However, this region had higher values than the north-east part of the study area, which is practiced in conventional ways, and therefore poses are more serious condition. Therefore, it is necessary to underscore the significant importance of maintaining and raising soil organic matter content through good agricultural practices, use of conservation soil management, elaborating crop rotation, and optimal fertilization recommendations (mineral and organic). Despite being premature to attribute this solely to the transformation into organic farming, it is likely the primary responsible factor. Dewi *et al*. (2022) stated that the long-term use of organic fertilizers can increase the absorption of soil Organic Carbon. Furthermore, the longer the application of organic farming, the higher the soil Organic Carbon sequestration which will be to a certain limit (Qaswar *et al*., 2020).

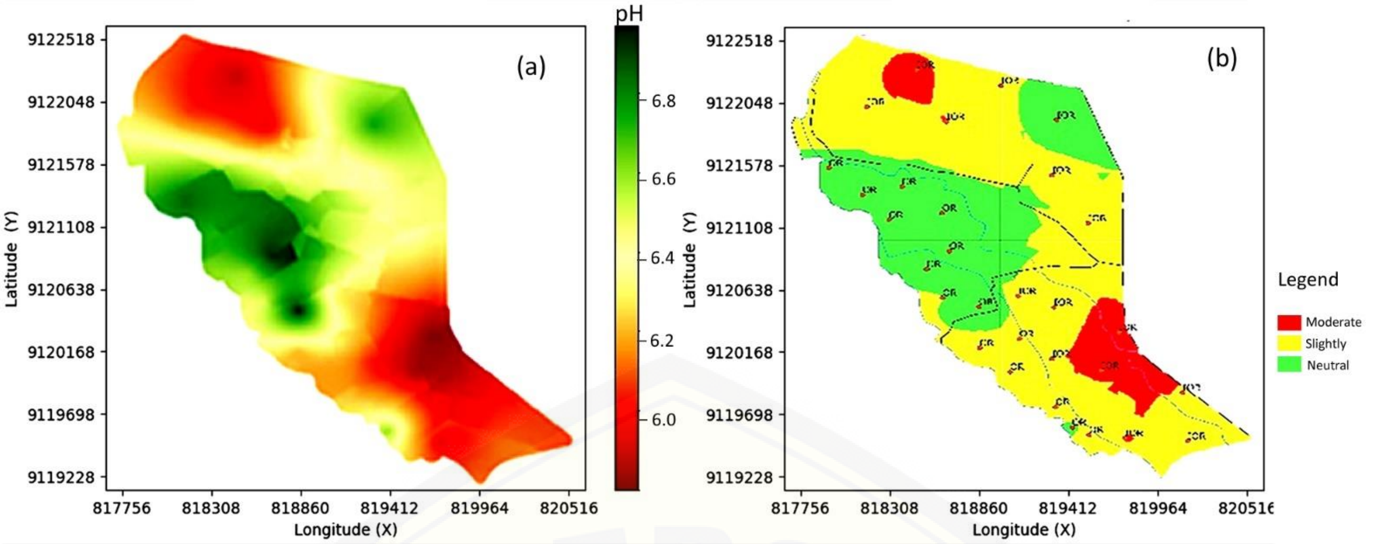

Figure 3. Distribution of pH. (a) Interpolated (kriging), (b) the associated classes (b). Note: moderate: 5.6 – 6, slightly: 6.1 – 6.5, neutral: 6.6 – 7.0.

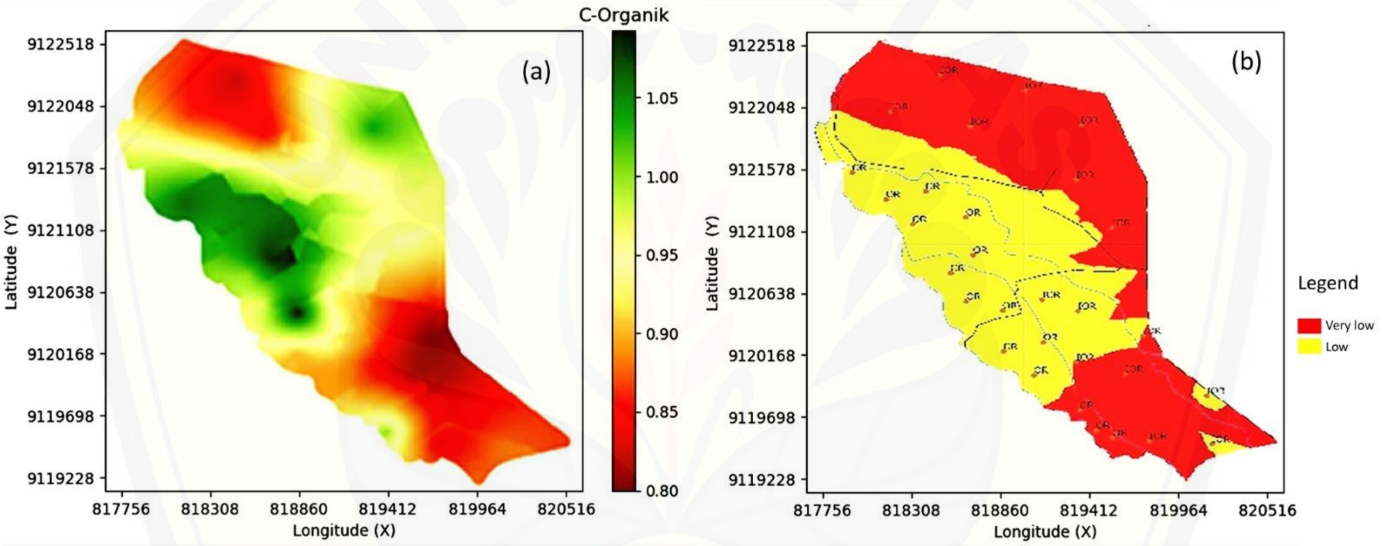

Figure 4. Distribution of C-Organic. (a) Interpolated (kriging), (b) the associated classes. Note: very low: <1, low: 1 – 2.

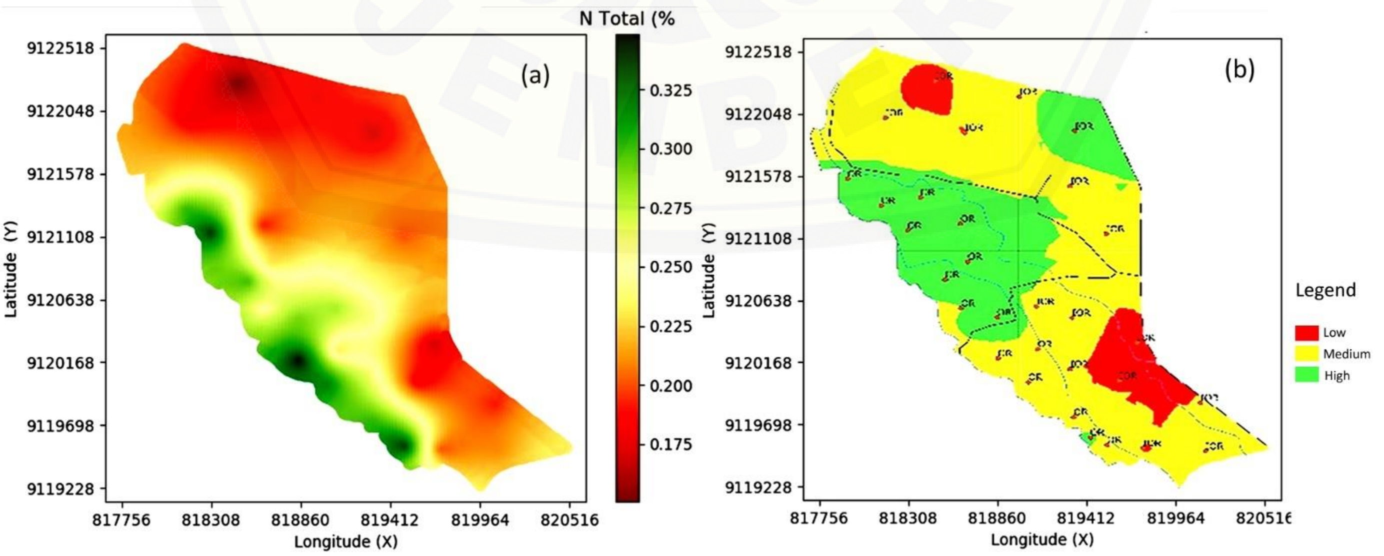

Figure 5. Distribution of Total Nitrogen. (a) Interpolated (kriging), (b) the associated classes (b). Note: low: 0.1 – 0.2%, medium: 0.2 – 0.3%, high: >0.3%.

The semivariogram, as shown in Figure 6, indicate that the exponential model is the best fit. As presented in Table 3, the analysis of the semivariogram reveals that various soil properties yield different values for components such as sill, range, and nugget effects. The performance of the three exponential semivariograms is shown in Table 3.

As shown in Table 3, the values of RMSE are small, indicating that there was no significant error of interpolated figures. The values of the nugget and sill ratios were also small, except for C-Organic. This shows a strong spatial dependence for Total Nitrogen and pH, but not for C-Organic (52.94%). These results suggested that sampling was adequate to represent the spatial variability of soil properties such as Total Nitrogen and pH. High value of this ratio on C-Organic indicate that more samples are needed on the study area. Furthermore, field survey and interview proved there were variations for applying organic fertilizers amongst farmers depending on the availability. For example, farmers apply organic fertilizer without having to calculate its needs. The values of nugget effect (C0) were generally small, but its higher values were observed on pH. This indicate that there is a short-range spatial variability probably related to the influence of agriculture activities conducted by farmers

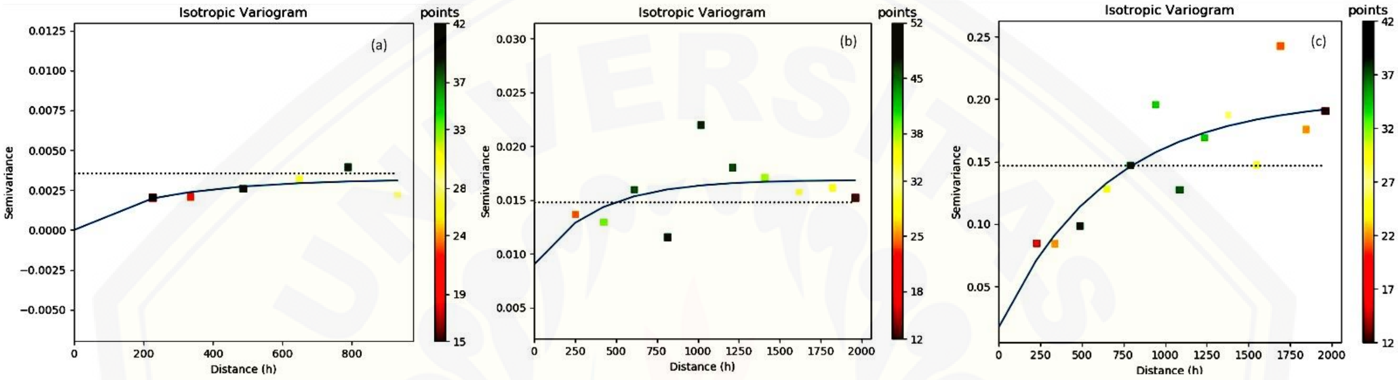

Figure 6. Exponential Semivariogram of (a) Total Nitrogen (b) Organic Carbon and (c) soil pH.

Table 3. The calculation of RMSE in three different soil properties.

Variable	(C0)	(A)	(C0+C)	Lag (h)	(C0)/(C0+C) x 100%	RMSE	R^2	Max. Distance
Total Nitrogen (%)	0	820.631	0.003	150	0	0.042	0.496	1000
C-Organic (%)	0.009	1130.030	0.017	200	52,94	0.109	0.189	2000
pH	0.017	1959.452	0.201	150	8,45	0.296	0.389	2000

In this case: (C0): Nugget Effect; (A): Range; (C0+C): Sill

From this discussion, it is suggested that the management of Total Nitrogen and pH is more practically conducted in the study area, while more efforts are needed for C-Organic management. It is important to note that the study is based on limited data and case study, hence, further study as well as long-term studies in a wider area and over time, using this method, are needed to fully understand the spatial variability.

4. Conclusion

This study concludes that soil organic content in the study area was generally low, indicating a need for additional organic fertilizer. Despite a slightly increase in pH and Organic Carbon, some processes responsible for Nitrogen loss need particular attention. The use of Kriging in a GIS environment to analyze spatial variability can reveal such variations and provide insights for soil management in the study area.

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Author Contributions

Conceptualization: Yagus Wijayanto, Anggara Dwi Pamungkas; **methodology**: Yagus Wijayanto, Anggara Dwi Pamungkas; **investigation**: Yagus Wijayanto, Anggara Dwi Pamungkas; **writing—original draft preparation**: Yagus Wijayanto, Anggara Dwi Pamungkas; **writing—review and editing**: Yagus Wijayanto, Anggara Dwi Pamungkas; **visualization**: Yagus Wijayanto, Anggara Dwi Pamungkas. All authors have read and agreed to the published version of the manuscript.

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