Journal of Agricultural Science; Vol. 10, No. 8; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Spatial Variability in Stability of Aggregates and Organic Matter of an Oxisol

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Received: April 8, 2018 Accepted: May 19, 2018 Online Published: July 15, 2018

doi:10.5539/jas.v10n8p328 URL: https://doi.org/10.5539/jas.v10n8p328

Abstract

Soil preparation may break its structure, destabilize the aggregates, and cause the loss of organic matter (OM). The study of spatial variability of soil attributes is an important indicator of soil physical quality. The aim of this study was to describe the spatial variability of the stability of aggregates and organic matter in Oxisol (Yellow Latosol) under different management systems.We collected simple samplings of soil in the eastern mesoregion of Maranhão, Brazil. Experimental areas with two distinct management systems were studied: conventional tillage and no-tillage. In each experimental area, we fitted a rectangular mesh of 50 points with 40m of spacing and 0.00 to 0.20 mof depth. The response variables were: weighted mean diameter (WMD); geometric mean diameter (GMD); percentage of aggregates (on classes of size between 1-2 mm and above 2 mm); and organic matter (OM). The no-tillage management showed high values of WMD, GMD, class of aggregates and OM. Maps of WMD and GMD were spatially correlated to OM map at no-tillage management. Soil properties had a spatial-dependent structure. The management system influenced the stability of aggregates and the amount of organic matter.

Keywords: Brazilian savanna, cohesive soils, conventional tillage management, management with no-tillage, ordinary kriging

1. Introduction

Soil preparation breaks its structure, which destabilizes the aggregates and leads to losses of organic matter. The stability of aggregates is an important indicator to assess the physical quality of the soil. The aggregation influences gas exchange, infiltration, retention, and water availability. It also affects soil resistance to compaction (Braida, Bayer, Arbuquerque, & Reichert, 2011), which associated with good land use and management practices, contributes to raising soil organic matter (OM), an essential condition for high productivity (Dexter & Youngs, 1992).

The study of spatial variability using geostatistical techniques has been widely used to evaluate changes in the behavior of physical and chemical attributes of soil (Coutinho Alho, Costa Campos, Pinheiro da Silva, Campos Mantovanelli, & Menezes de Souza, 2014; Corado Neto et al., 2015; Ribeiro et al., 2016). Analyses of semivariance and ordinary kriging interpolation allow the estimation of studied attributes in non-sampled areas, besides being a valuable tool for plans of further samplings, management of specific sectors, and optimization of agriculture inputs.

At the grain production region of Brasilian savanna, farmers have difficult to maintaining plant cover during the off-season of soybean and maize. The mechanized soil technologies and torrential rains at the beginning of the plantations causes large losses of sediment and consequent water erosions. Using geostatistical technics might help to improve the management practices and optimize the crop. At this context, we aim to characterize the spatial variability of the stability of aggregates and organic matter, using geostatistical techicnics, in Oxisoil (Yellow Latosol) under different management systems.

2. Materials and Methods

The study was carried out at Anapurus, located in the microregion of Chapadinha, eastern Maranhão, Brazil, at the geographical coordinates of 3°45′S, 43°10′W (Figure 1). The climate is tropical with a dry-winter season (Aw) according to Köppen. The rainy season lasts from January to June, and the dry season occurs from July to December. Mean annual precipitation reaches 1704 mm, theaverage temperature exceeds 26.9 °C, and relative humidity ranges from 70 and 73%. Altitudes range from 100 to 400 m, with topographical reliefs from wavy to smooth-wavy (GEPLAN, 2002). The elevated temperatures of the region promote an increase in the decomposition rate of residues, contributing to a low permanence of straw on the ground.

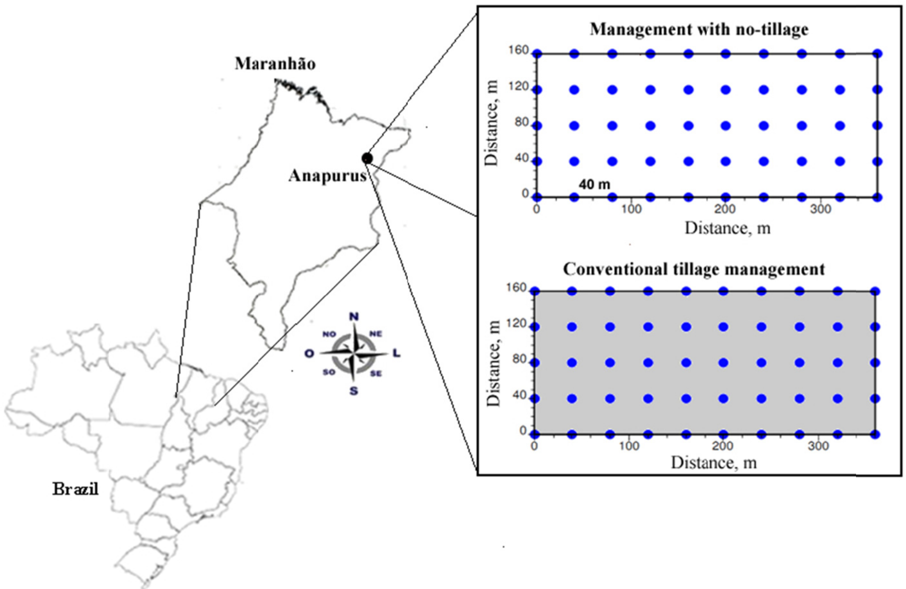

Figure 1. Study area and distribution of sampling site

Farmers are cultivating soybean in the experimental areas along the last 20 years. Soybeans are planted from January to February and harvested from April to May. GEPLAN (2002) classifies the local soil as Oxisoil (Yellow Latosol).

We studied two areas with distinct managements.One with conventional tillage management, in which the soil remains uncovered, and an annual subsoiling is done.The otherone comprised a no-tillage management, without soil disturbance, in which, after the soybean harvesting,farmers plant the millet as a vegetation cover during the off-season period.

We collected the soil through simple sampling. In each experimental area was installed a rectangular mesh composed of 50 sampling points with regular spacing of 40 m, at a depth of 0.00-0.20 m (Figure 1). For each sample, the stability of aggregates was determined by wet sieving using the sieves of 2.0, 1.0, 0.5, and 0.25mm (Yoder, 1936; Kemper & Chepil, 1965).

The results were expressed as the percentage of the aggregates retained in the sieves above 2 m and between 2 and 1 mm. The values were used to calculate the geometric mean diameter (GMD) and weighted mean diameter (WMD). WMD is directly related to the percentage of large aggregates retained in the sieves with larger meshes, while GMD represents the estimation of the size class of aggregates of higher occurrence (Castro Filho, Muzilli, & Podanoschi, 1998). The organic matter content (OM) was measured by wet oxidation through titration of the excess of potassium dichromate with ammoniacal ferrous sulfate (Donagema, de Campos, Calderano, Teixeira, & Viana, 2011).

The descriptive statistics (mean, median, minimum, maximum, coefficient of variation, asymmetry, and kurtosis) of the dependent variables was carried out to identify the trends of dispersion and data distribution (Bourgault, Journel, Rhoades, Corwin, & Lesch, 1996). The Kolmogorov-Smirnov test was used to verify the data normality at a level of 5%. The coefficient of variation (CV) was classified according to Warrick and Nielsen (1980), in which a CV lower than 12% suggests a low variance, a CV between 12% and 60% is moderate, and a CV above of 60% suggests a high variance.

To identify the spatial variability of soil attribute, we used the semivariogram method following the principles of the intrinsic hypothesis (Isaaks & Srivastava 1989). We calculated the variance by the separation distance between samples to determine the experimental semivariograma according to the following Equation:

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \quad (1)$$

where, $\hat{\gamma}(h)$ represents the experimental semivariance for a distance of h; $z(x_i)$ is the value of the attribute for the sample point I; and $N(h)$ is the number of pairs of points separated by distance h. The parameters for the theoretical model of the semivariogramwere defined as: nugget; structural variance; sill; and range. Nugget is the value of semivariance for the distance zero and is the random component of variance. Sill is the value ofsemivariance at which the curve stabilizes at a constant value. The range is the distance from the origin to where the plateau reaches stable values, showing the distances beyond which samples are not correlated.

We choose the best model comparing the correlation coefficient obtained by the cross-validation technique and the highest coefficient of determination (R^2). Models with a coefficient of determination close to 1 were chosen to characterize the studied phenomenon. The classification of the degree of spatial dependence (DSD) was based on the ratio between the nugget effect and sill .The spatial dependence was considered weak for DSD > 75%, moderate for DSD between 25% and 75%, and strong for DSD < 25% (Cambardella et al., 1994).

The ordinary kriging technique was used to interpolate values at non-sampled locations. This technique is based on a weighted moving average of the neighboring points, obtained by the equation:

$$\hat{z}(x_0) = \sum_{i=1}^{N} \lambda_i z(x_i), \text{ with } \sum_{i=1}^{N} \lambda_i = 1 \quad (2)$$

where, $\hat{z}(x_0)$ represents the value estimated at point 0; N is the number of values used in the estimation; λ is the weight associated with each observed value; and $z(x_i)$ is the value observed at point i. The weights (λ_i) of each neighbor point are set using the adjusted semivariogram model, resulting in a minimum estimate of variance (Soares, 2006).

3. Results and Discussion

Although the values of asymmetry and kurtosis indicate some asymmetric distributions, the averages and medians of all assessed attributes are close, pointing out that the data do not show marked asymmetry (Table 1). Furthermore, the adjustment of the theoretical distribution of data found in nature is only approximate (Warrick & Nielsen, 1980). All variables at no-tillage system had a normal distribution (Table 1). Although the normality is not a requirement for geostatistical analysis, it is desirable that the distribution present little asymmetry. Distribution of data with very long tailsimpairs the analysis, especially when estimates are based on average, as the ordinary kriging technique (Isaaks & Srivastava, 1989).

The highest coefficient of variation (CV) was found for the aggregate class larger than 2 mm (56.55%), at the no-tillage management, and the lowest was obtained by OM (6.55%; classified as low variability) in the conventional management (Table 1).The coefficient of variation of GMD, WMD, and aggregate class showed moderate in variability. Although the CV is a dimensionless measure that allows comparing the variability among different attributes, it does not allow analyzing the spatial variability of soil attributes and its spatial pattern.

Table 1. Descriptive statistics of weighted mean diameter (WMD), geometric mean diameter (GMD), percentage of aggregates on class size > 2 mm and 2-1 mm, and organic matter (OM) for conventional and no-tillage managements of soybean at Oxisoil

Attribute	Mean	Median	CV (%)	Minimum	Maximum	Skewness	Kurtosis
Conventional management							
GMD (mm)	0.86	0.80	30.00	0.45	1.48	0.83	-0.15
WMD (mm)	1.65	1.52	30.86	0.76	2.73	0.52	-0.58
> 2 (%)	23.41	21.67	46.52	6.33	47.69	0.64	-0.48
2-1 (%)	38.04	36.49	33.53	14.00	62.38	0.31	-0.88
OM (g dm^{-3})	23.39	23.08	6.55	21.17	28.08	1.65	3.24
No-tillage management							
GMD* (mm)	0.89	0.84	35.89	0.49	1.92	1.23	1.71
WMD* (mm)	1.63	1.54	36.70	8.82	3.24	0.88	-0.46
> 2* (%)	22.33	20.99	56.55	6.09	57.39	1.07	0.88
2-1* (%)	37.60	36.53	42.05	13.72	76.34	0.56	-0.34
OM* (g dm^{-3})	22.41	22.12	8.89	19.46	30.31	1.44	4.02

Note. *: Normal distributionby Kolmogorov-Smirnov test at 5% of significance level.

In both management systems, all attributes showed spatial dependence and adjusted to the spherical model (Table 2). The spherical model has been the most used to describe the behavior of soil attributes. Regardless of the management system, the evaluated variables showed a moderate degree of spatial dependence (DSD), according to the classification of Cambardella et al. (1994). The stronger the degree of spatial dependence, the more influenced by formation factors (texture, mineralogy) the soil attributes will be, while attributes with weak spatial dependence are more influenced by extrinsic properties, such as management.

The range represents the distance at which the sampling points are spatially correlated with each other, that is, points located in an area of radius equal to the range are more homogeneous with each other. Therefore, high ranges mean low data variability. Range estimates also might indicate sampling density. Studied attributes showed large range at no-tillage management, meaning lower variability (Table 2). The low range (high variability) of soil attributes at the conventional management might be due to the soil disturbing by the tillage.

Table 2. Models and parameters estimated from semivariogram experiments of weighted mean diameter (WMD), geometric mean diameter (GMD), percentage of aggregates on class size > 2 mm and 2-1 mm, and organic matter (OM) for conventional and no-tillage managements of soybean at Oxisoil

Attribute	Model	Nugget effect	Sill	Range	DSD (%)	R^2
Conventional management						
GMD (mm)	Spherical	0.027	0.06	72.81	42.02	0.83
WMD (mm)	Spherical	0.090	0.26	77.83	34.78	0.72
> 2 (%)	Spherical	48.37	122.20	79.36	39.58	0.90
2-1 (%)	Spherical	68.35	168.80	73.30	40.49	0.64
OM (g dm^{-3})	Spherical	1.06	2.47	88.06	43.08	0.97
No-tillage management						
GMD (mm)	Spherical	0.06	0.12	75.29	45.82	0.76
WMD (mm)	Spherical	0.12	0.24	87.33	50.05	0.87
> 2 (%)	Spherical	39.89	99.80	89.20	39.96	0.88
2-1 (%)	Spherical	89.20	199.40	85.84	44.73	0.98
OM (g dm^{-3})	Spherical	0.05	0.11	118.59	52.48	0.86

Note. DSD = degree of spatial dependence; R^2 = coefficient of determination.

The WMD, GMD, class of aggregates > 2 mm and 2-1 mm, and OM showed higher values in the soil with no-tillage than conventional management (Figure 2). The conservation tillage systems provide low disturbance to the ground and retain crop residues on the surface, which preserve its structure, retain more water in the surface layer, and increase the organic matter (Santos, Souza, Nóbrega, Bazzi, & Gonçalves, 2012). These feature explain the difference in aggregates between the two management systems. The GMD and WMD maps showed correlation with OM map in the no-tillage management, which indicates the importance of organic matter for the stabilization of aggregates.

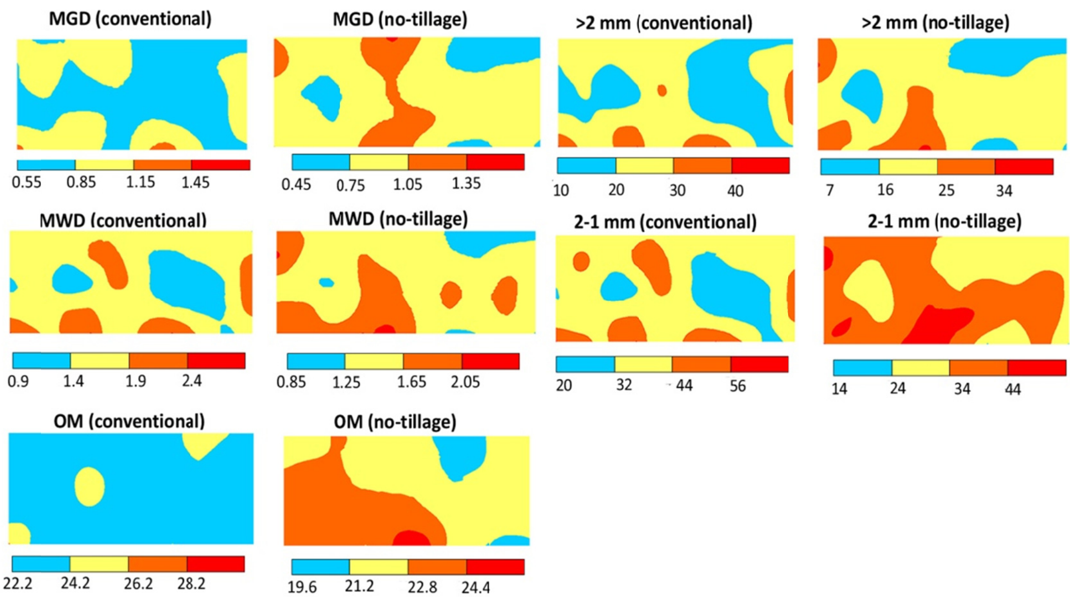

Figure 2. Spatial distribution maps of the weighted mean diameter (WMD), geometric mean diameter (GMD), percentage of aggregates on class size > 2 mm and 2-1 mm, and organic matter (OM) for conventional and no-tillage managements of soybean at Oxisoil

4. Conclusions

The studied attributes showed a spatial dependence on structure. The management system affected the stability of aggregates with higher amount of organic matter at no-tillage management.

Acknowledgements

Foundation for Research and Scientific and Technological Development of Maranhão (FAPEMA), Federal University of Maranhão and Federal University of Campina Grande for funded the study.

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