The use of circularity index of soil aggregates to differentiate degraded stratate

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SUMMARY

Among the difficulties encountered in the management of degraded areas is the characterization of the different stratum within the same area. These strata possibly need different recovery actions, compatible with the form of degradation. Based on this premise, the work proposes an initial stratification based on the visual perception of the different forms of degradation occurring in the local landscape. In this way, a better understanding of the landscape and the sampling needs are sought in order to confirm the differences. Thus, the objective of the work was to identify the different stratum in a degraded area, using soil sampling for the purposes of aggregation analysis and determination of the circularity index of the different soil aggregates. The experiment was carried out in a degraded area at the Agronomic Institute (CEA-IAC), in the city of Jundiaí - SP. The site was stratified into five degradation environments and for each of them four samples were taken for the purpose of analyzing the aggregation state. After sieving the soil sample, a sub-sample of aggregates retained in the 4 mm sieve was removed to determine the circularity index. Using 40 samples per stratum, descriptive statistical measures and the frequency histogram were obtained. The results showed that through the analysis of aggregates, the statistical processing of the circularity index and the making of frequency histograms, we can establish reliable criteria for differentiating strata in degraded areas. Thus, we can conclude that the procedures used have the potential to analyze and differentiate environments with levels of complex degradation.

KEYWORDS: RAD, variability, soil aggregation

1. INTRODUCTION

The mining industry has a strong influence on the Brazilian economy, however, the extractive model causes several environmental impacts, since to access mineral reserves it is necessary to completely remove the vegetation and the topsoil, leading to ecosystem imbalance (CARVALHO et, al. 2019). Currently more than 15% of the world's soils are degraded or in the process of degradation. In Brazil more than half of the tropical soils have some degree of degradation. Of the degraded areas, 98.8% are related to the activities of production and extraction, construction of roads, dams, industrial areas, resulting in an immediate impact on the soil (EMBRAPA, 2014; MMA, 2017).

Areas degraded by the extraction of ore show different behaviors with regard to the physical state of the soil, leading to the differentiation of degradation levels according to the history of exploration and the different micro-ecosystems (MMA, 2017; CARVALHO et al., 2019). According to Oliveira (2009) the specific richness of the plants and their heterogeneous distribution forms mosaics of micro ecosystems in the area with different composition and structure, associated with the communities of animals and microorganisms, providing strong interspecific interactions. This mosaic of ecosystems can be evidenced by the exuberance of the initial secondary vegetation, in different colors and height, combined with the rich floristic composition that currently covers the area (Peche Filho et al., 2012).

The concept of degraded area or degraded landscapes can be understood as, places where there are (or have been) processes that cause damage to the environment, by which some of their properties are lost or reduced, such as the productive quality of natural resources (FEDERAL DECREE 97.632 / 89). Ferreira et al. (2007) states that by definition a degraded ecosystem is one that, after disturbances, has eliminated, with vegetation, its means of biotic regeneration. Its return to the previous state may not occur or be quite slow. In this case, anthropic action is necessary for its regeneration as close to the original in the short term.

Most of the time, the recovery activities aim at replacing a vegetation cover in the explored area, and these activities include operations that range from landscape aesthetics, to the complete revegetation of the area, trying to maintain the typical species of the region. Naturally, this definition does not fulfill all the circumstances that involve the environmental recovery of an area, especially under the ecological aspect (LONGO, 2011, Lei et al., 2016; FENGLER et al., 2017). Thus, a management plan with recovery activities is needed to improve soil quality for the development of vegetation in the altered location (PECHE FILHO, 2017; CARVALHO et al., 2019).

Among the difficulties encountered in the management of degraded areas is the characterization of the different strata within the same area. These strata possibly need different recovery actions, compatible with the form of degradation. In this sense, the use of methodologies and tools that enable the differentiation of degraded environments is essential.

Thus, the present work aims to propose an initial stratification based on the visual perception of the different forms of degradation occurring in the local landscape. In this way, a better understanding of the landscape and the sampling needs are sought in order to confirm the differences. Thus, the objective of the work was to identify the different stratum in a degraded area, using soil sampling for the purposes of aggregation analysis and determination of the circularity index of the different soil aggregates.

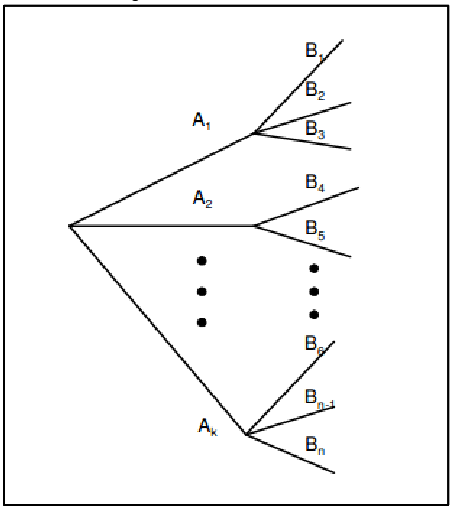
2. METHODOLOGY

The experiment was carried out in a degraded area of the Engineering and Automation Center of the Agronomic Institute (CEA-IAC), in a study area of 2.0 hectares. The region is located in the domains of the Jundiaí River basin, in the city of Jundiaí- SP, bounded on the north by the Don Gabriel Paulino Couto Bueno Highway, on the east by the Bandeirantes Highway and on the south by Antônio Picinato Avenue.

The climate, according to the Koppen classification, corresponds to the humid mesothermal without drought (Cfa), in which the average temperature of the hottest month is above 22 ° C, with an average altitude of 762 m.

For visual identification of the landscape, a system based on the decision tree was used, similar to the proposal De Melo Figueiredo & Tavares de Carvalho (2005), as shown in Figure 1.

Figure 1. Decision tree.

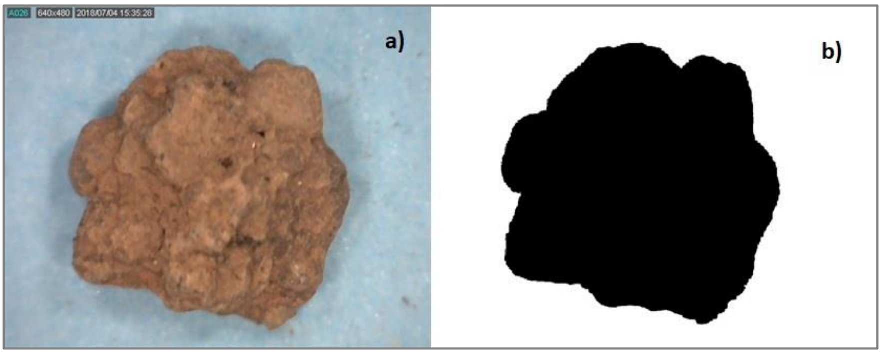


FONT: De Melo Figueiredo & Tavares de Carvalho (2005)

The visualization of the different stratum started with the understanding of the macro landscape from the physical point of view, in the integration of the eluvial, colluvial and alluvial conditions, thus determining the drainage conditions of the area due to the need for intervention in the release or retention of runoff and sediment in the environment. The complementary branches were defined and determined according to the observer's knowledge in light of the biological complexity where the soil, vegetation and ecological interactions were identified and scored. Thus, an array of attributes was generated where the variable can be determined.

After stratifying the area, four soil samples were collected in each stratum to verify the aggregation status and determine the circularity index. The soil samples were taken at a depth of 0-20 cm and passed through the drying process in the open air in the laboratory, then they were sieved in a Soloteste vibrating device at maximum intensity for 3 minutes. From the material retained in the 4 mm sieve, 10 aggregates were randomly selected to be photographed through a digital microscope of the Dino Lite model AM-211, with processing in the ImageJ program. The images were converted to black and white and filtered through the command to eliminate noise (EMBRAPA, 2017; PECHE FILHO, 2018) (Figure 2).

Figure 2 - Gross aggregate image (a) and processed image (b).



FONT: Peche Fillho, 2018.

Then the circularity index was obtained in 40 samples and determined using Equation 1 (FERREIRA & RASBAND, 2011).

$$IC = 4\pi \; x \; \frac{A}{P^2}$$ - Equation 1.

Where:

- *IC* corresponds to the circularity index;
- *A* corresponds to the aggregate area;
- *P* corresponds to the aggregate perimeter.

The circularity index values vary between "0" and "1". As the value approaches "0" the corresponding shape of the aggregate is that of an elongated rectangle. When the value approaches "1" the corresponding shape of the aggregate is that of a perfect circle.

The values obtained were subjected to descriptive statistical analysis using the program Microssoft Excel, with the determination of histograms for visual graphic analysis according to the guidelines of Negri Neto et al. (1993).

3. RESULTS

The results obtained through the decision tree attributes matrix and the objective variable are shown in Table 1.

Table 1. Visual attributes of the decision tree.

	RELIEF POSITION			SOIL CONDITION			VEGETATION CONDITION			FAUNA CONDITION		
variable	*eluviate*	*colluviate*	*alluviate*	*present horizons*	*horizons removed*	*Cond. Sprólito*	*Thin Shrub Vegetation*	*Thin Tree Vegetation*	*Dense forest vegetation*	*Absence of Meso and soil macrofauna*	*Presence of Meso and macrofauna soil*	*Total*
Stratum 1	4	0	0	3	1	0	3	1	0	0	1	13
Stratum 2	1	2	1	1	2	0	2	1	0	0	2	12
Stratum 3	1	1	2	0	1	1	2	0	0	0	2	10
Stratum 4	3	1	2	3	2	0	2	0	0	0	2	15
Stratum 5	0	1	4	0	1	1	0	0	0	0	0	7

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The variable object of the matrix was considered with the level of degradation of the area, Table 1 shows a total of 5 different stratum (Figure 3) identified by visual analysis.

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Figure 3. Stratum defined by visual perception.

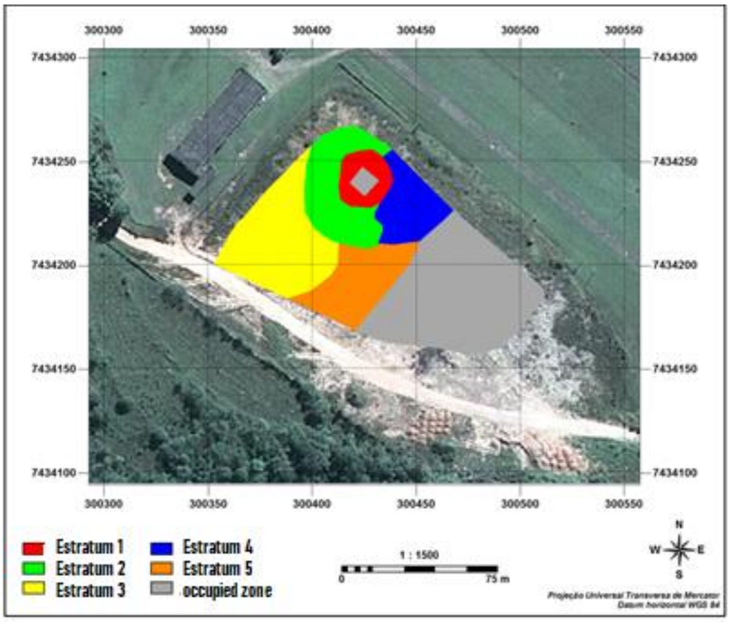

Table 2 shows that the mean values of the circularity index (CI) for the five stratum are close, with an amplitude of 0.025. However, when analyzing the amplitude related to the median and the mode, the amplitude differences were considerable. For the median, the CI values showed an amplitude of 0.040. For mode, the CI values presented an amplitude of 0.110.

The standard deviation and coefficients of variation (CV) show uniformity in the CI for all stratum. Regarding the dispersion of values, Stratum 1, 2 and 4 present medium dispersion, Stratum 3 and 5 present data with low dispersion. The results for kurtosis show significant differences in the behavior of the data in relation to the average, confirming the potential differences between the five stratum. The negative asymmetry shows that the CI values tend to be higher than the average, so in all stratum we have possibilities to find 4 mm aggregates well differentiated with tendencies to rectangular shapes. Table 2 allows a detailed analysis of the statistical results.

Table 2. Descriptive statistics of the circularity index.

Parameters	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Average	0.729	0.729	0.751	0.732	0.726
Standard error	0.012	0.013	0.008	0.013	0.007
Median	0.750	0.725	0.750	0.760	0.720
Mode	0.750	0.820	0.770	0.800	0.710
Standard deviation	0.075	0.079	0.050	0.085	0.043
Coefficient of variation (%)	10.338	10.880	6.660	11.639	5.889
Sample variance	0.006	0.006	0.003	0.007	0.002
Kurtosis	0.002	-1.013	0.401	1.107	1.624
Asymmetry	-0.826	-0.276	-0.391	-1.244	-0.524
Minimum	0.530	0.570	0.610	0.480	0.590
Maximum	0.840	0.850	0.840	0.840	0.810
Total data	40.000	40.000	40.000	40.000	40.000

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Through the analysis of the histograms obtained, it is possible to verify visual differences regarding the frequency of the data. The behavior of the CI values allows to characterize the graphic differences according to the shapes influenced by the degradation process in the different stratum.

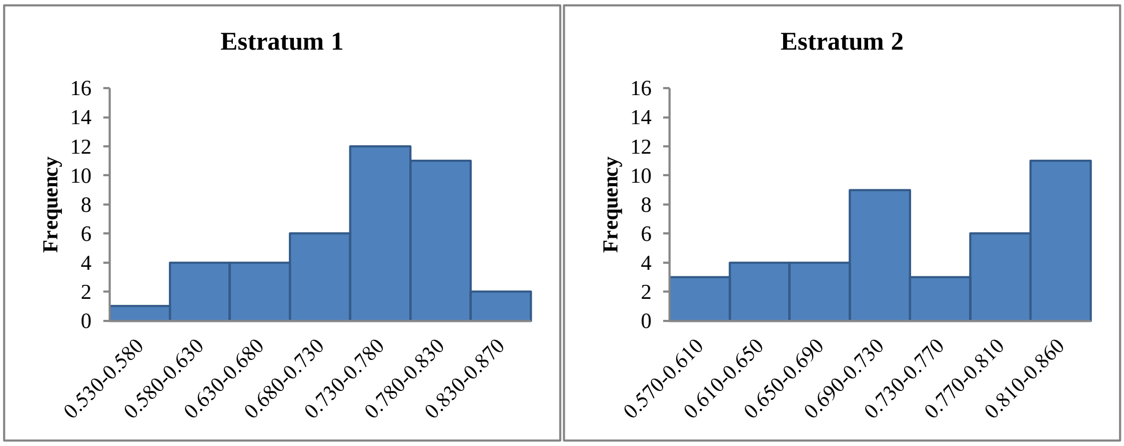
The data obtained show that Stratum 1 presents 53% of the CI values concentrated between 0.730 and 0.830 and 60% of the data are above average (0.729). Stratum 2 presents a binomial distribution with 50% of the CI values concentrated in two distinct peaks. In the first peak, values between 0.690 and 0.730, and in the second peak, values between 0.810 and 0.860. The average appears at the first peak and 50% of the values are above it.

In the third stratum, 30% of the values are concentrated between 0.750 and 0.785, with 55% being above the average. Stratum 4 presents 67% of the data concentrated between 0.720 and 0.840, with 35% of the data surely being above average. In Stratum 5, a concentration of 65% of the data is observed between 0.695 and 0.765, with 45% of the values being above the average.

The similarities between the histograms of Stratum 1 and Stratum 2 can be related to their position in the relief, as they are located in a higher region. The study area can be characterized as a hill; thus, the degradation originates in the removal of material from the highest to the lowest, and the mining process did not completely eliminate the upper part of the land, allowing the formation of different degraded stratum depending on the amount of material removed.

Stratum 2 presents itself in a colluvial (central) position where material originating from the highest part occurs and material leaving or loss to the lowest parts. This fact may explain the occurrence of binomial distribution of CI data.

Figure 4. Histogram of the circularity index of Stratum 1 and 2.



Stratum 3 and 5 are located in an alluvial region (low) area that receives the material deposited in different layers according to the intensity of the degradation. The region defined as Stratum 3 presents areas occupied by vegetation and with diversified biological activity, which may explain the occurrence of aggregates with more circular tendencies; the same does not occur in the region defined as Stratum 5, which does not present any type of vegetation and low diversified biological activity.

Figure 5. Histogram of the circularity index of Stratum 3 and 4.

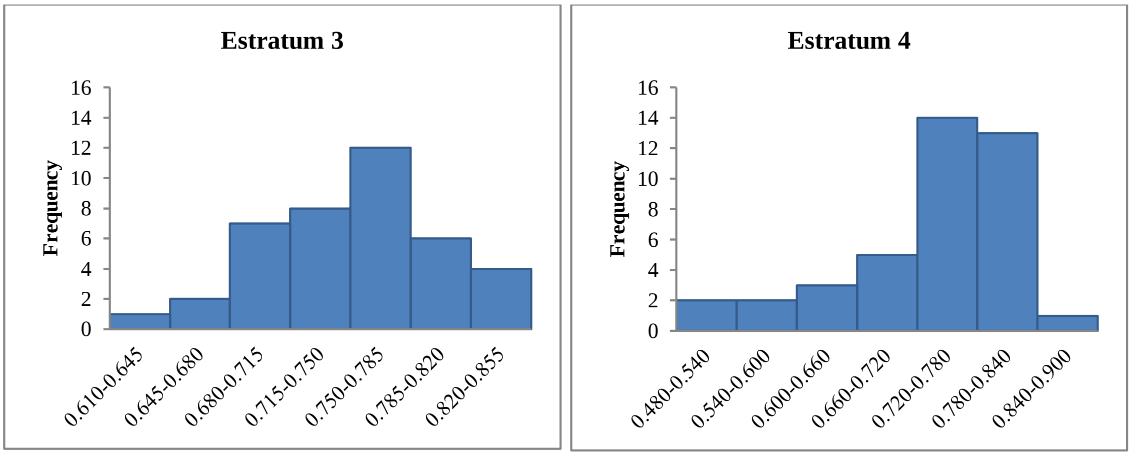
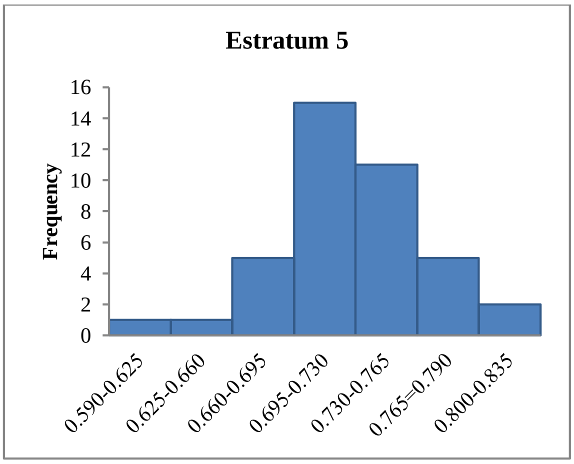


Figure 6. Histogram of stratum 5 circularity index.



4. CONCLUSION

In general, the circularity index allowed to confirm different effects of degradation in the study area. The statistical analysis of the circularity index confirmed the visual differences between the five stratum proposed.

The indexes obtained in the upper stratum (1 and 4) were the highest, confirming that the biological activity present influenced the rounded shape of the aggregates retained in the 4 mm sieve. Thus, through the graphic behavior that allowed to confirm visual differences obtained in the field, we can say that the methodology proved to be practical, effective and low cost. Therefore, the procedures used have the potential to analyze and differentiate environments with complex degradation levels.

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