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Aggregates and organic matter stability in soils submitted to different temperatures in West Bahia, Brazil

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***Abstract*— *Estimates indicate that about 30% of the planet's surface suffers from seasonal fires. In Brazil, in the first half of 2020 these numbers already reached 62.402 km2equivalent to 0.7% of the national territory. Due to the high temperatures that fire can reach on agricultural land, this practice can have negative consequences for the physical, chemical and biological properties of the soil. In this study four soil classes were obtained (Red Yellow Argisol, Haplic Vertisol, Red Yellow Latosol and Haplic Cambissol) predominant in the Western region of Bahia.Four samples were removed by point and then were taken to carry out analyzes at the Soil Physics Laboratory of the University of the State of Bahia. After preparing the sample, the aggregates were placed in a petri dish and then were subjected to firing in a muffle oven at temperatures of100, 200, 300, 400, and 500ºC, After cooling for 24 hours inside the muffle, they were placed in the appliance Yoder to carry out analyzes related to soil aggregation. The results showed that soils with a higher percentage of organic matter obtained the best aggregation results, as already presented by several authors. Regarding the temperature variation, when subjected to combustion at 200ºC, the soil presented a decrease in aggregation compared to the ambient temperature. However, lower averages were observed in those submitted to 300ºC with the exception of the MiAg variable. The increase in soil temperature changed the distribution of aggregates mainly in classes with a diameter smaller than the class of 1 <Ag <2 mm).*

I. INTRODUCTION

Forest fires are natural phenomena common to tropical, temperate and boreal regions. These phenomena have undergone modifications in their behavior due to global changes, which directly affect fertility and structure of soils as well as their management and sustainability (Bento-Gonçalves et al., 2012; Lopes and Machado, 2017). It is also known that the conservation of soil vegetation cover promotes the diversification of microorganisms (suppressiveness), inhibiting the development of soil diseases and prolonging their sustainability (BETTIOL E GHINI, 2005; LOBMANN et al., 2016).

Chuvieco and Giglio (2008) state that more than 30% of the earth's surface suffers from the presence of seasonal fires. In Brazil, in 2020, fires had already reached an area of 312.140 km2 (3.67% of the Brazilian territory). Among the Brazilian biomes, the cerrado was the most affected by forest firesthis year. In this period, 139.644 km2 were burned, which corresponded to 44.74% of the burned area in the country (INPE, 2020).

Chen et al. (2016), state that clay soils, when subjected to temperatures above 100 ºC are influenced by their morphological characteristics, highlighting those of a physical nature. Campo et al. (2014) when studying macro- and micro-aggregates of soils subjected to different temperatures, identified that these physical attributes are interfered with the temperature rise at the maximum threshold of 750 ºC where macro-aggregates are able to regenerate but with erosive tendencies due to their low stability.

Chen et al. (2012), when conducting studies on fire behavior in boreal forests, concluded that fires generate direct consequences on the stability of aggregates and on soil organic carbon. Nunes et al. (2019) found a decrease in the aggregation of Red Yellow Latosol subjected to high temperatures in a similar work on Brazilian cerrado soils. For Badía Villas et al. (2014) soils submitted to open air combustion reduced water repellency and aggregate stability up to 2 cm in depth with different intensities depending on the properties of each soil.

Soil aggregation can be hierarchical by organic binding agents, such as: (a) transient, mainly polysaccharides, (b), temporary, fungal roots and hyphae (c) persistent, resistant components associated with polyvalent metallic cations and polymers strongly adsorbed to soil particles (TISDALL AND OADES, 1982). Therefore, the stability of aggregates in soils subjected to fire is more susceptible to changes in soil organic carbon than in organic molecules contained in macro aggregates (CHEN AND SHRESTHA, 2012).

After a high-intensity fire, the organic matter content is in general,negatively affected to the surface horizons. However, in low intensity fires the soil organic matter content can increase due to the contribution of plant material (MINAYA, 2013).

Based on exposed above, this work aimed to evaluate the effects of different temperatures in four classes of soils in Western Bahia on the stability and diameters of aggregates and organic matter.

II. MATERIAL AND METHODS

Location and characterization of the area

The samples were collected in four municipalities in the west of Bahia in places chosen according to the soil class. Table 1 shows the location of the areas, municipality, current land use and geographic coordinates.

Table.1: Municipality, current land use and geographic location of the studied areas.

Municípality	Current Use	Latitude	Longitude
Barreiras (PVA)	Fallow	12º08'34,69" S	44º57'41,87" O
Riachão das Neves (VX)	Pasture	11º58'54,57" S	44º57'38,99" O
Luís Eduardo Magalhães(LVA)	Permanent preservation area (APP)	12º06'16,00" S	45º20'20,20" O
Barreiras (CX)	Jatropha	12º08'37,29" S	44º57'48,94" O

The climate of the region, according to Koppen's classification, is of the Aw type (rainy tropical) with rain from October to April and dry period from May to September with an average annual temperature of xxx °C and rainfall ranging from 800 to 1800 mm in the far west of the state (AIBA, 2012).

The evaluated soils were classified as Red Yellow Ultisol (Ultisols), Haplic Vertisol (Vertisols), Red Yellow Latosol (Oxisols) and Haplic Cambisol (Inceptisols), whose particle size and organic matter (OM) are shown in Table 2.

Table.2: Composition of the particle size of the study areas

Soil	Sand	Silt	Clay	OM
	........................g kg^{-1}	....		$g.kg^{-1}$
RedYellowArgisol(PVA)	590,02	187,44	222,50	26,84
HaplicVertisol (VX)	418,14	394,64	187,22	17,01
RedYellowLatosol (LVA)	831,58	45,41	122,01	19,12
HaplicCambisol (CX)	765,55	170,03	64,31	17,85

Sampling and experimentation

For the physical characterization and determination of organic matter (OM) of the soil, samples were collected randomly in the previously chosen areas (Table 1) at a depth of 0.00 to 0.20 m with the aid of a cylinder with a capacity of 0.001 m-3. Analyzes were performed at the Soil Physics and Chemistry Laboratory of the State University of Bahia (UNEB).

The determination of granulometry was performed using the pipette method (Embrapa, 2017). Aggregate stability (Ag) was obtained by wet way. In the separation of aggregates by wet way, the procedure of

Kemper and Rosenau (1986) was adopted. In water sieving in the Yoder apparatus were used a set of mesh sieves of 2.00; 1.00; 0.50; 0.25 and 0.106 mm Samples of 50g of aggregates were pre-wetted by capillary action and transferred to a set with the five sieves mentioned above. They were subjected to vertical agitation for 15 min and immersed in a container with water. The soils retained in each sieve were taken to an oven at 105 °C for 24 hours. Then, the mass of water-stable aggregates in each diameter class was weighed and calculated. Weighted mean diameter (MWD) and geometric mean diameter (GMD) values were obtained according to expressions 1 and 2, respectively.

$MWD = \sum_{i=1}^{n}(xi.wi)$ ....eq. 1

Where: xi = average diameter of the aggregate classes;

wi = proportion of each class in relation to the total.

$GMD = (exp \sum_{i=1}^{n}(wp.logxi))/(\sum_{i=1}^{n} wi)$......eq. 2

Where: wp = weight of the aggregates of each class in grams;

xi = mean diameter of aggregate classes in grams;

wi = proportion of each class of aggregates in relation to the total.

An aliquot of each sample was transferred to petri dishes that withstand high temperatures and prevent overlapping between aggregates. These samples were subjected to the following treatments: control (room temperature at 25°C), 100, 200, 300, 400 and 500 ºC, heated in a muffle oven for 10 min. After this procedure, the samples were left to rest for 24 hours to assess the stability of the aggregates in water.

Aliquots of macros (MaAg) and micro aggregates (MiAg), removed after being subjected to treatments, were placed in a crucible and macerated in order to obtain smaller particles that were passed through an 80 mm mesh sieve. The organic matter (OM) content was estimated based on the total organic carbon (TOC) according to the method described by Embrapa (2017).

Qualitative data were subjected to analysis of variance and means were tested by Tukey's test ($p<0.05$) and quantitative data by regression. The computer program AgroEstat (2019) was used to perform the analysis of variance and to the regression, the software SigmaPlot 12 (2011) was applied.

III. RESULTS AND DISCUSSION

Distribution of aggregates at each temperature

Initially, for all temperatures considered, there was a greater distribution in the class of aggregates greater than 2 mm (Ag > 2 mm) in all soils, regardless of temperature. It is noteworthy in this class of aggregates that VX presented the lowest values at temperatures of 200 and 300 °C, while CX decreased at temperatures of 400 and 500 °C. In the other classes of aggregates, these soils showed a tendency to increase at these same temperatures (Figure 1).

In general, the increasing variation in temperature did not change the stability of aggregates larger than 2 mmexcept for Vertisol and Cambisol. Inthe other classes of aggregates, there are significant differences ($p < 0.05$) in the temperatures such as: 100 °C between the PVA and the soil VX, LVA and CX, 200 and 300 °C between VX and PVA, LVA and CX, 400 °C and 500 °C between CX and the other soils in classes of 1 < Ag < 2 mm, 0.5 < Ag < 1 mm, 0.125 < Ag < 0.5 mm. In the class of 0.106 < Ag < 0.125 mm, there is a difference in LVA at 100 °C, in PVA and LVA at 300 °C, PVA, VX and LVA at 400 and 500 °C, all presenting the lowest values. For Ag < 0.106 mm, at temperatures of 25, 100, 200 and 300 °C, VX was different from other soils, showing the highest values.

In classes of 1< Ag < 2, 0.5 < Ag < 1, 0.125 < Ag < 0.5, 0.106 < Ag < 0.125 and Ag < 0.106 mm, there is a tendency to increase the percentage of aggregation when compared with the results of ambient temperature, mainly in PVA (100 and 200 °C), VX (100, 200 and 300 °C) and CX (400 and 500 °C) soils. This could have happened due to the Ca^{2+} content of these soils, which makes them more resistant to hydration (Nunes et al., 2019). The LVA, on the other hand, presented a drop in these percentages with the increase in temperature, results that are similar to those of previous authors who also worked with the Red Yellow Latosol and found that for the native cerrado soil the temperature caused a reduction in the percentage of aggregates greater than 2 mm.

Weighted average diameter, geometric average diameter, macro aggregates and micro aggregates as a function of temperature

In all studied soils, there is a tendency for the MWD, GMD and macro aggregates (MaAg) variables to decrease as the temperature increases to a certain value, except for the LVA soil in which these attributes behave inversely proportional the rise in temperature (Figure 1). For micro aggregated variable (MiAg), the curves behave inversely to the previous variables. Another fact that stands out is that, as equations that describe these relationships, they were important as a function of temperature for MWD in PVA ($p <0.11$) and LVA ($p <0.01$) soils, in the GMD and MaAg variables only in the soil LVA ($p < 0.01$) and no MiAg in PVA (0.10) and LVA ($p < 0.05$) soils.

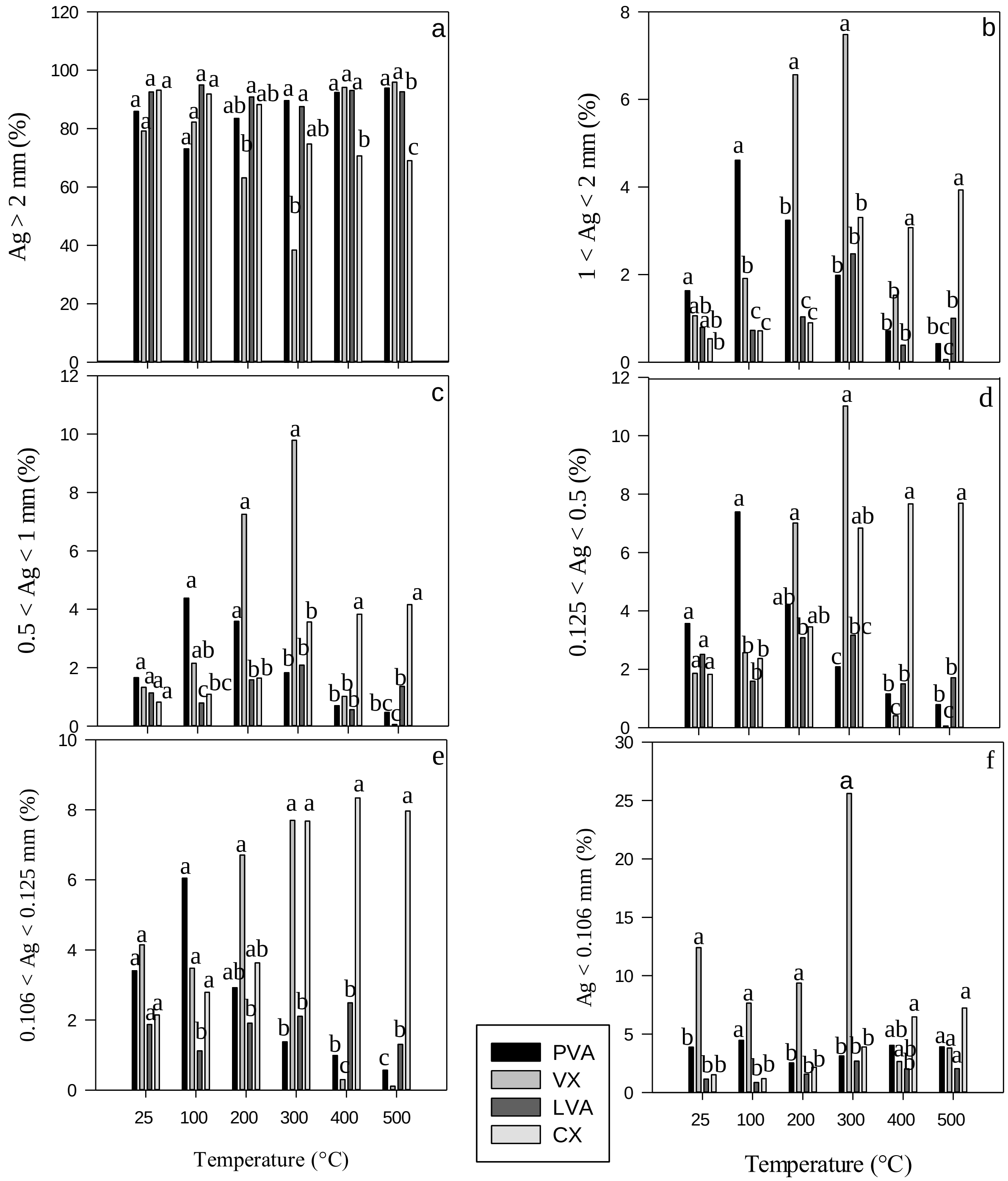

Fig.1: Distribution of stable aggregates in water at different temperatures.

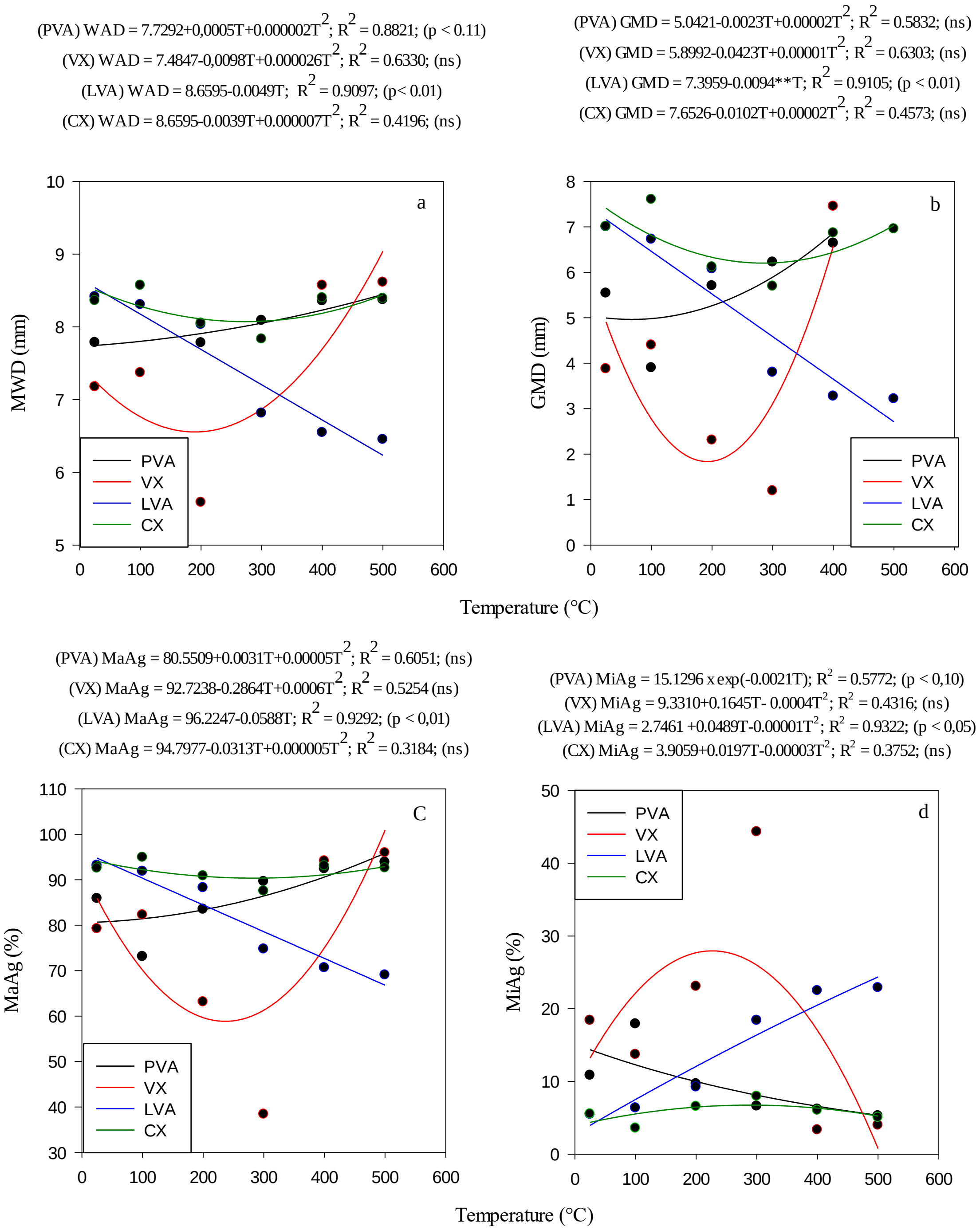

Fig.2: Weighted mean diameter (a), geometric mean diameter (b), macro-aggregates (c) and micro-aggregates (d) as a function of temperature.

The results of MWD, GMD and MaAg for PVA, VX and GX soils were similar to those found by Thomaz (2011), especially from the temperature of 200 °C for Canada Chernosol with wet sieving. When soils are subjected to a temperature of 200ºC, the destruction of cementing agents occurs, affecting the larger aggregates. This effect influences the values of MWD, GMD and MaAg.(Mataix-Solera et al., 2011; Thomaz et al., 2017).

The increase in the stability of aggregates from certain temperatures was already observed by Thomaz and Fachin (2014), when they raised the temperature from 550 to 650 °C despite the decrease in organic matter. For LVA in this temperature range, MWD, GMD and MaAg described a decreasing curve as a function of soil temperature. As this soil is located in a permanent preservation area, where there is a predominance of bioenic aggregates, it may have favored an inverse relationship between temperature and these attributes. This occurred with the work by Nunes et al. (2019) in which they found a similar relationship for forest soils. In addition to altering soil aggregates, Thomaz (2017) warns that fire in agricultural areas can harm soil chemistry, biology and fertility.

Organic matter (OM) in macro aggregates (MaAg) and micro aggregates (MiAg) as a function of soil temperature

The relationship between organic matter and temperature variation in all studied soils describes a decreasing and significant exponential function for both macro aggregation and micro aggregation with probability ranging from 0.01 to 0.10 (Figure 3). It is also observed in Figure 3a, for MaAg that the PVA, LVA and CX soils formed a group with curves in which they presented higher organic matter content compared to VX. However, in all soils there is loss of organic matter with increasing temperature, converging to values similar to 500 °C. In a similar work, Thomaz (2017) found that a temperature of 250 °C with 15 min duration was sufficient to reduce OM. In the ether hand, Thomaz et al. (2014) did not observe the effect of fire on soil organic depletion in the surface layer.

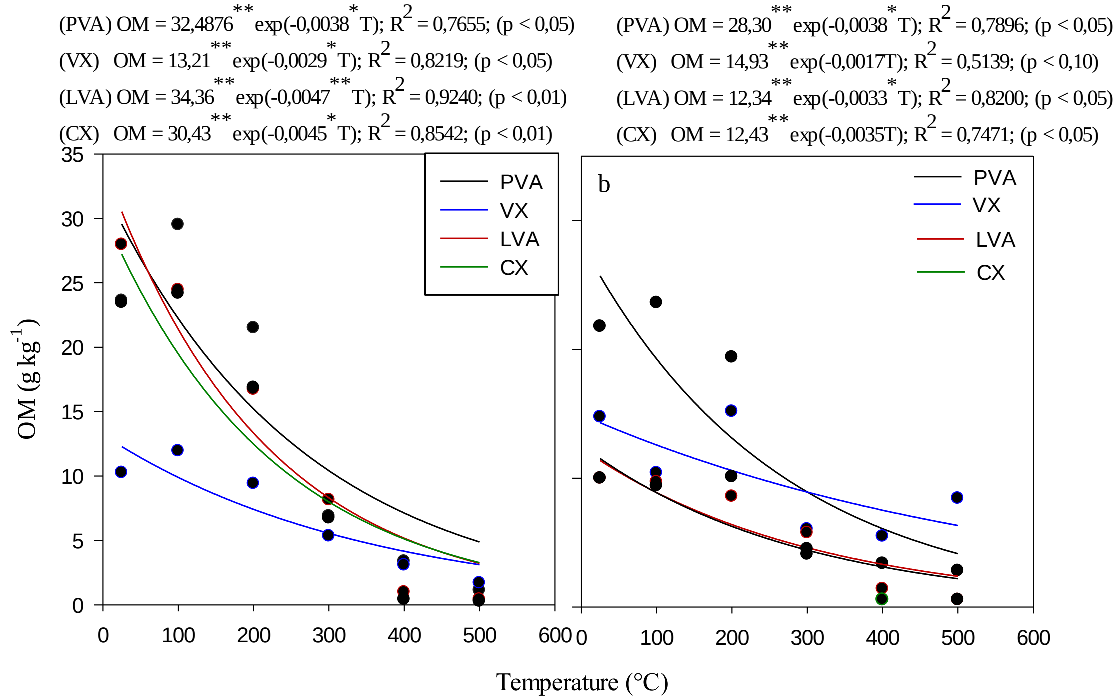

Fig.3: Effect of increasing temperature variation on soil organic matter in macro (a) and micro-aggregates (b).

Figure 3b shows the soil OM as a function of temperature for the MiAg in the four evaluated soils. It is verified that the highest organic matter contents in micro aggregates are in PVA and VX soils, while LVA and CX presented similar contents. These results are different for typical orthic chromic luvissols and typical orthic hypochromic luvissols in which temperatures above 400ºC, even with longer exposure to heat, there were higher values of total organic carbon, especially in aggregate class of smaller diameter. This occurs because organic matter is retained within the aggregates, especially in soil micro aggregates (Silva et al. 2010).On the other hand, Chen et al. (2016) state that temperatures above 100°C, depending on the duration, can already cause a reduction in organic matter and changes in clays.

In general, the effects of fire on soil organic carbon depend on the type of fire, fire duration and intensity, soil moisture, soil type and vegetation (GONZÁLEZ-PERES et al., 2004; COAN et al., 2014).

IV. CONCLUSIONS

The increase in soil temperature changed the distribution of aggregates, especially in classes with diameter smaller than the class of 1< Ag < 2 mm);

The PVA, VX and CX soils for the attributes MWD< GMD and MaAg presented a minimum aggregation point for a certain temperature;

The soils, PVA, VX and CX, both in macro-aggregates and in micro-aggregates showed losses of organic matter with increasing temperature.

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