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RELATIVE INFLUENCE OF NDVI IN THE ORGANIC MATTER CONTENT OF SEMIARID SOILS

David Bruno de Sousa Teixeira (1); Valéria Lourenço Ramos (2); Adão Barros de Morais (2); José Vidal de Figueiredo (2); Carlos Alexandre Gomes Costa (2)

(1) *Universidade Federal de Viçosa*, teixeiradbs@gmail.com. (2) *Universidade Federal do Ceará*,

Abstract: Soil organic matter (SOM) is an important indicator of soil quality, being directly influenced by the carbon deposition of the present vegetation. The objective of this study was to evaluate the influence of vegetation density on soil organic matter contents. For this, deformed soil samples were collected in the 0-10 cm layer for each of the three Soil and Vegetation Association (SVA) areas, SVA1, SVA2 e SVA3, in the Aiuaba Experimental Basin (12km²), Ceará, Brazil, and the organic matter content (OMC) was determined from laboratory analysis. The vegetation density was estimated from orbital images obtained by TM-LandSat 8 satellite, from which the Normalized Difference Vegetation Index (NDVI) was calculated using the reflectance values of the bands 4 (red) and 5 (near infrared). The SOM contents were correlated with the NDVI values obtained for each of the pixels in the used image where the samples were collected and the coefficients of determination were obtained. The soil analysis showed higher values and a greater amplitude of the soil organic content in the Hypochromic Luvisol area (SVA2). Results showed a good correlation between a greater presence of vegetation and the presence of organic material in the initial soil layer, presenting a positive correlation when observed SVA1 and SVA2 areas. Despite these good correlation, aspects related to the physiology of the vegetation as well as the inherent features of the present soils should be considered. In conclusion, vegetation indexes obtained by orbital images, such as NDVI, by itself, do not make possible a reliable estimation of the OMC, but can be a good indicator of the levels of organic matter in semi-arid soils when associated to analysis of the vegetation behavior.

Keywords: Vegetation density. Orbital images. LandSat 8.

INTRODUCTION

The amount of organic matter stands out as an important parameter for the characterization and evaluation of soil quality (DORAN and PARKIN, 1994; MIELNICZUK, 1999). This edaphic component is constantly changing and plays a significant influence on many of the physical, chemical and biological properties of soils, especially in their more superficial horizons. Soil organic matter (SOM) is a primary source of nutrients to plants and is responsible for much of the cation exchange capacity and water retention capacity (GREGORICH *et al.*, 1994). In addition, SOM acts on other attributes, such as nutrient cycling, the complexation of toxic elements, and the structuring of the soil.

In the Brazilian semiarid, where the predominant edaphic pattern is the crystalline basement (CUNHA *et al.*, 2010; GIONGO, 2014), the soils are mostly poorly developed, shallow and sandy (SANTOS, 2010; PEREIRA and DANTAS NETO, 2014). In these soils, the organic matter contents tend to be distributed in a heterogeneous way, being strongly influenced by the soil weathering degree as well as the vegetation under which they are located.

The adding of plant material on the surface constitutes the main element of organic increasing to the soil (BRADY and WEIL, 2009), being this dependent on the port and the physiological aspects of the vegetation. In the semiarid region, where the predominant flora is represented by caatinga vegetation, the deciduous character confers a greater dynamic in the leaves deposition on the soil, allowing the accumulation of litter and the later incorporation of this material to the lithological layer. The behavior of this kind of vegetation rapidly respond to rainfall as well as the lack of them, so they are pretty influenced by the season features.

Over the last few years, the improvement of the geoprocessing techniques, especially remote sensing technologies, has enabled an assessment of terrestrial coverage in a broader way. The vegetation indexes, such as the Normalized Difference Vegetation Index (NDVI), have been characterized as important tools for estimating and characterizing the vegetation density of a region (OLIVEIRA *et al.*, 2012) and contribute to a better understanding of the behavior of the vegetation and its influence in the soil where it is inserted.

This way, the objective of this research was to evaluate the influence of the vegetation density in relation to the soil organic matter contents, using satellite image.

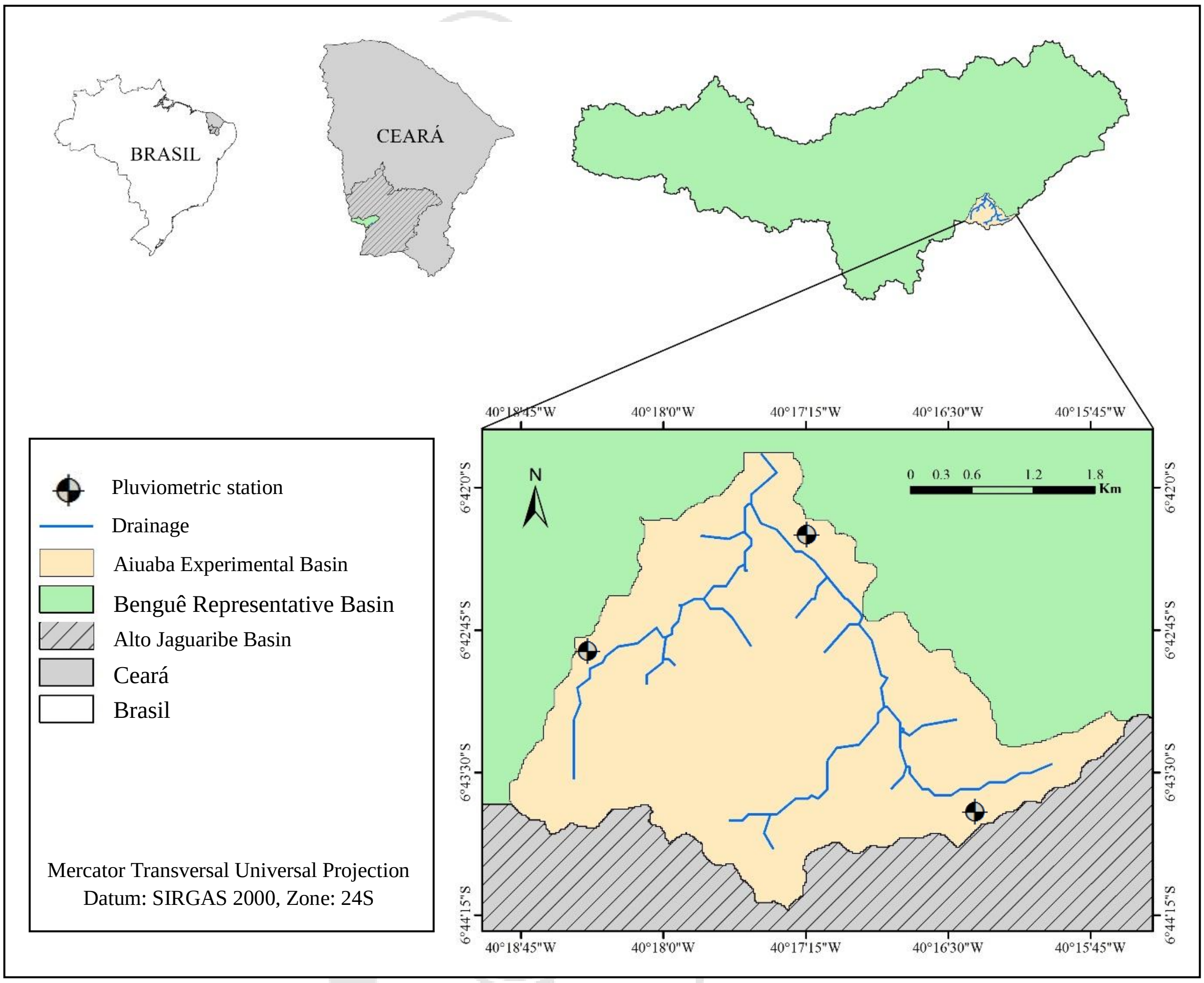
METODOLOGY

Characterization of the study area

The study area comprises the Aiuaba Experimental Basin (AEB), covering a total area of 12 km^2, located in the municipality of Aiuaba, State of Ceará, Brazil, coordinates 6º42 'S and 40º17' W (Figure 1). Inserted at the Inhamuns Sertão region, AEB is a sub-basin of the Benguê Representative Basin (BRB). The AEB area is fully preserved and is located within the Aiuaba Ecological Station, which is considered the largest federal conservation unit of the Caatinga biome, managed by IBAMA (ARAÚJO and PIEDRA, 2009).

According to Koppen’s classification, the climate of the region is defined as 'Bs', tropical semiarid. The climatological normal is 560 mm/year and the monthly average of precipitation throughout the year is 46.5 mm, badly distributed (TEIXEIRA, 2017). According to Araújo and Piedra (2009), the study area presents an average annual temperature of 27ºC; annual average of air relative humidity about 62%, and total annual average sunshine of 2,600 hours. In relation to its hydro-physiographic characteristics, it should be noted that the AEB has a drainage network composed of intermittent streams, with two main rivers (COSTA, 2007). According to Farias (2008), the AEB is a drainage basin of 5th order and high drainage intensity, with a concentration time of 1.1 hours.

Figure 1 – Localization of the study area, Aiuaba Experimental Basin



Regarding the soil characteristics, three distinct classes can be found in the area: Red-Yellow Argisol, Hypochromic Luvisol, and Litolic Neosol (COSTA, 2012). The Caatinga vegetation in the basin area presents three predominant species: Catingueira (*Caesalpinia pyramidalis Tul*), Angelim (*Piptadenia obliqua*) e Jurema-Preta (*Mimosa tenuiflora* (Willd.)) Poir). According to the three soil classes present in the AEB and the vegetation specie predominant in each of them, the AEB area was subdivided in tree associations of soil and vegetation (COSTA, 2012; PINHEIRO *et al.*, 2016), called in this paper as Soil Vegetation Association (SVA): the SVA1, SVA2 and SVA3, as detailed in Table 1.

Table 1 – SVAs occupation at the Aiuaba Experimental Basin (AEB)

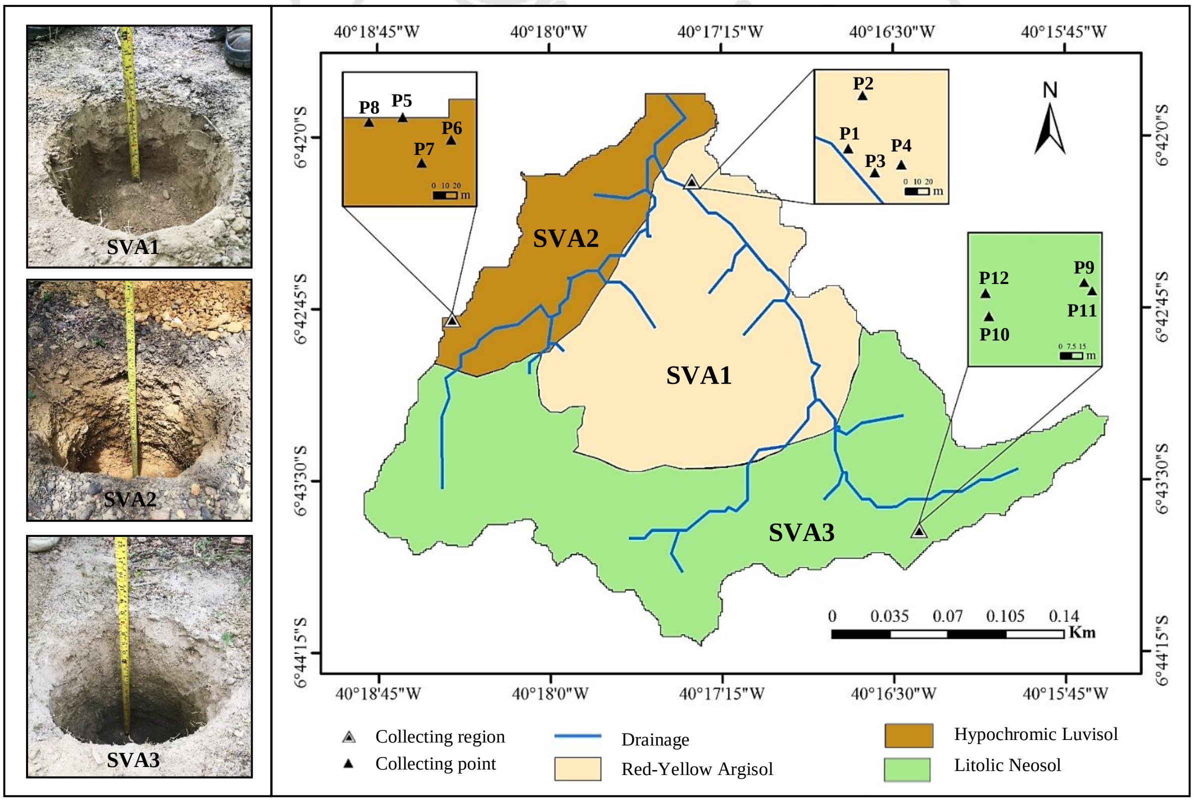
SVA	Representative vegetation specie	Soil class	Occupation (km² / %)
SVA1	Catingueira (*Caesalpinia pyramidalis Tul*)	Red-Yellow Argisol	2,40 / 20
SVA2	Angelim (*Piptadenia obliqua*)	Hypochromic Luvisol	4,08 / 34
SVA3	Jurema-preta (*Mimosa tenuiflora* (Willd.) Poir)	Litolic Neosol	5,52 / 46

Source: Pinheiro *et al*. (2016)

Soil collecting and analysis

Deformed soil samples from the 0-10 cm layer were collected at four distinct points in each of the three SVAs present in the AEB (Figure 2), totaling twelve collecting points. The collecting was performed on April 28, 2017, and the distance between the points was sufficient for them to represent different pixels contained in the orbital image.

Figure 2 – Trenches and soil collection points



The organic matter contents were achieved from the determination of the values of Total Organic Carbon (TOC) that are obtained from the oxidation of soil organic carbon by dichromate (Cr^{6+}) in the presence of concentrated sulfuric acid (H_2SO_4), methodology explained in details in the Manual of Soil Analysis of Embrapa (1997). The analyzes were carried out at the Soil Laboratory of Embrapa Agroindústria Tropical, Fortaleza-CE.

Image acquisition and processing

It was used an image obtained by the TM-LandSat 8 satellite available by the United States Geological Survey (USGS), with spatial resolution of 30 meters. The selected image was the result of the passage of this satellite in the April 7, 2017 (Path 217 and Row 65). The criteria for selecting the image were the proximity to the date of the field collecting and the lower percentage of clouds covering the interest areas, so this interference could be minimized.

The software ENVI® version 5.1 was used to obtain the values of reflectance of the image, from which made possible the spectral characterization of the evaluated pixels. The NDVI values were obtained through the reflectance of the red and the near-infrared bands, respectively represented by the bands 4 and 5.

Statistical analysis

The correlation between organic matter contents and NDVI values obtained by satellite images was based on descriptive statistical analysis, where the trend line and R^2 values were observed.

RESULTS AND DISCUSSION

Organic matter contents

The results of the organic matter obtained through the laboratory analysis evidenced the different edaphic pattern of the three SVAs, presenting a greater variation for the SVA1, as shown in Table 2.

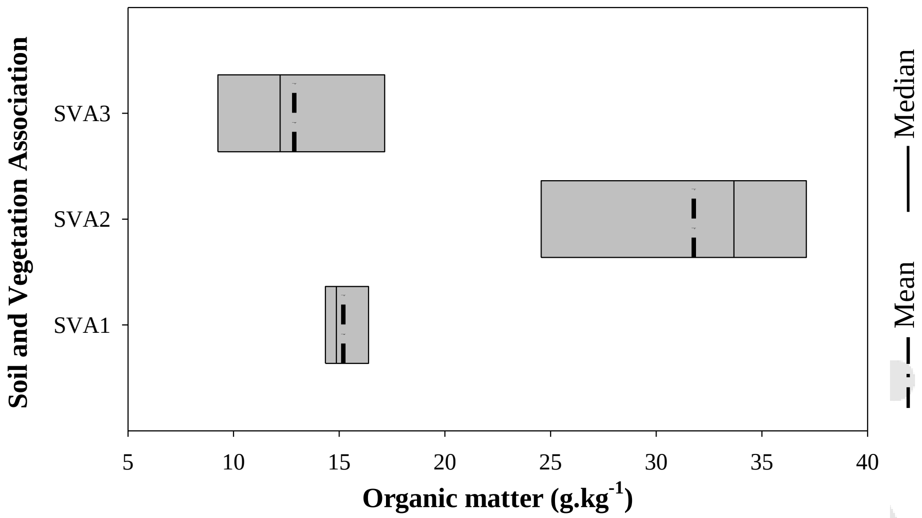
Table 2 – Soil organic matter for the 0-10 cm layer in the tree SVAs present in the AEB

SVA	Organic matter ($g.kg^{-1}$)	SD	CV(%)
SVA1	15.1	1.12	13.5
SVA2	31.7	7.04	4.5
SVA3	12.8	4.24	3.0

SVA: Soil and Vegetation Association. SD: Standard deviation. CV: Coefficient of variation.

Figure 3 shows the difference between the mean, median, as well as the amplitude of the organic matter contents for the three SVAs. Compared to the values found by Oliveira *et al*. (2009), also for a preserved semi-arid Caatinga area, the levels of MOS in the present work are considered low, indicating that not only the contribution of the vegetation (plant residue adding) but also the intrinsic characteristics of the soil influence its organic matter contents. It can also be highlighted the SOM values obtained for SVA2 in relation to the other SVAs, as well as their amplitude when observed the four collecting points.

Figure 3 – Mean and median organic matter contents for the three SVAs

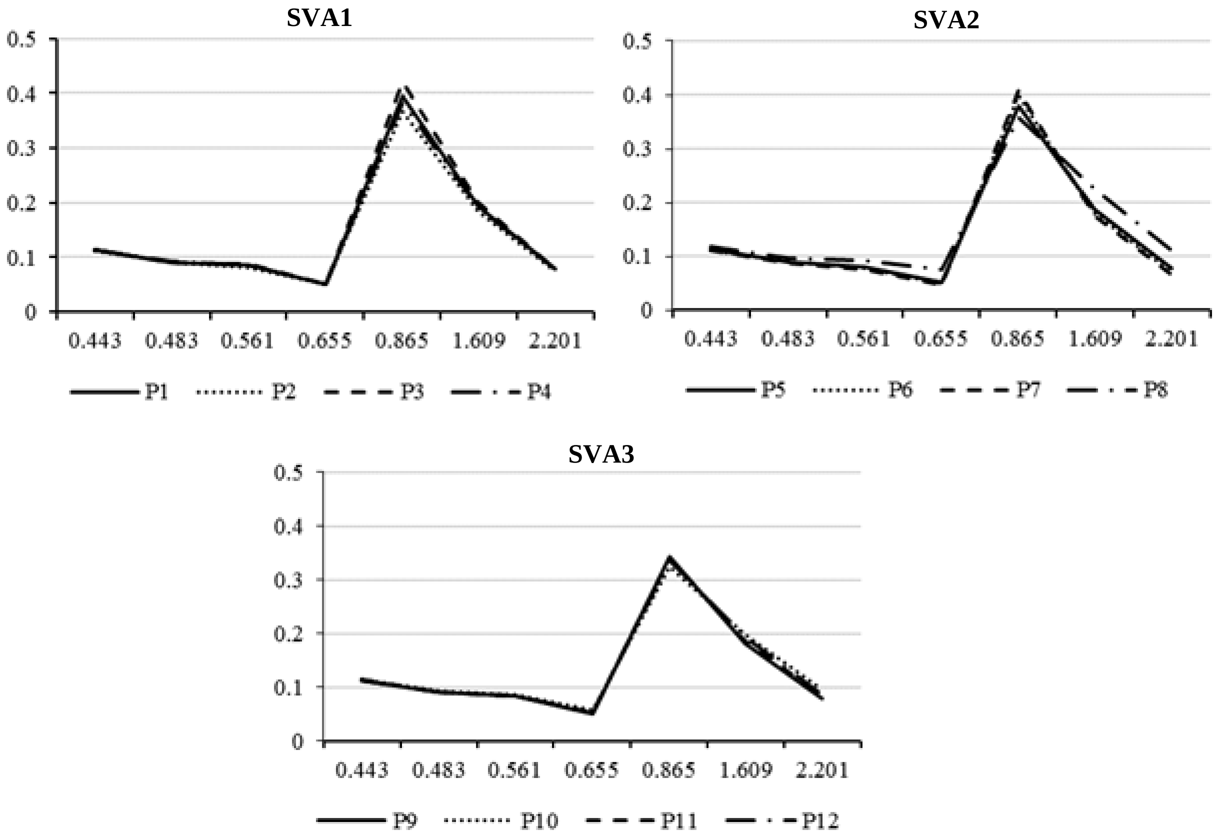


Vegetative density

The vegetation spectral behavior showed similar pattern when observed the reflectance obtained for the three SVAs (Figure 4), with a peak between 0.3 and 0.4 at the wavelength of 0.865 μm. The lowest values were observed for the length of 0.655 μm.

The mean for the NDVI values considering the four collection points, for each of the three SVAs were 0.77; 0.74; and 0.72 for SVA1, SVA2 and SVA3, respectively. The NDVI varies from -1 to 1, with the value 1 being considered as the maximum value of vegetation density in the pixel under analysis (OLIVEIRA and GALVÍNCIO, 2009). In this way, an intense vegetation presence is characterized for the three areas of the evaluated image, as well as a low variation of those although they are constituted of distinct predominant species. This high vegetation density observed is due, mostly, because the image used is dated from the rainy season, when the foliar area and density is greater. It is also emphasized the absence of clouds interference for the evaluated pixels.

Figure 4 – Spectral curve for the vegetative reflectance in the three SVAs



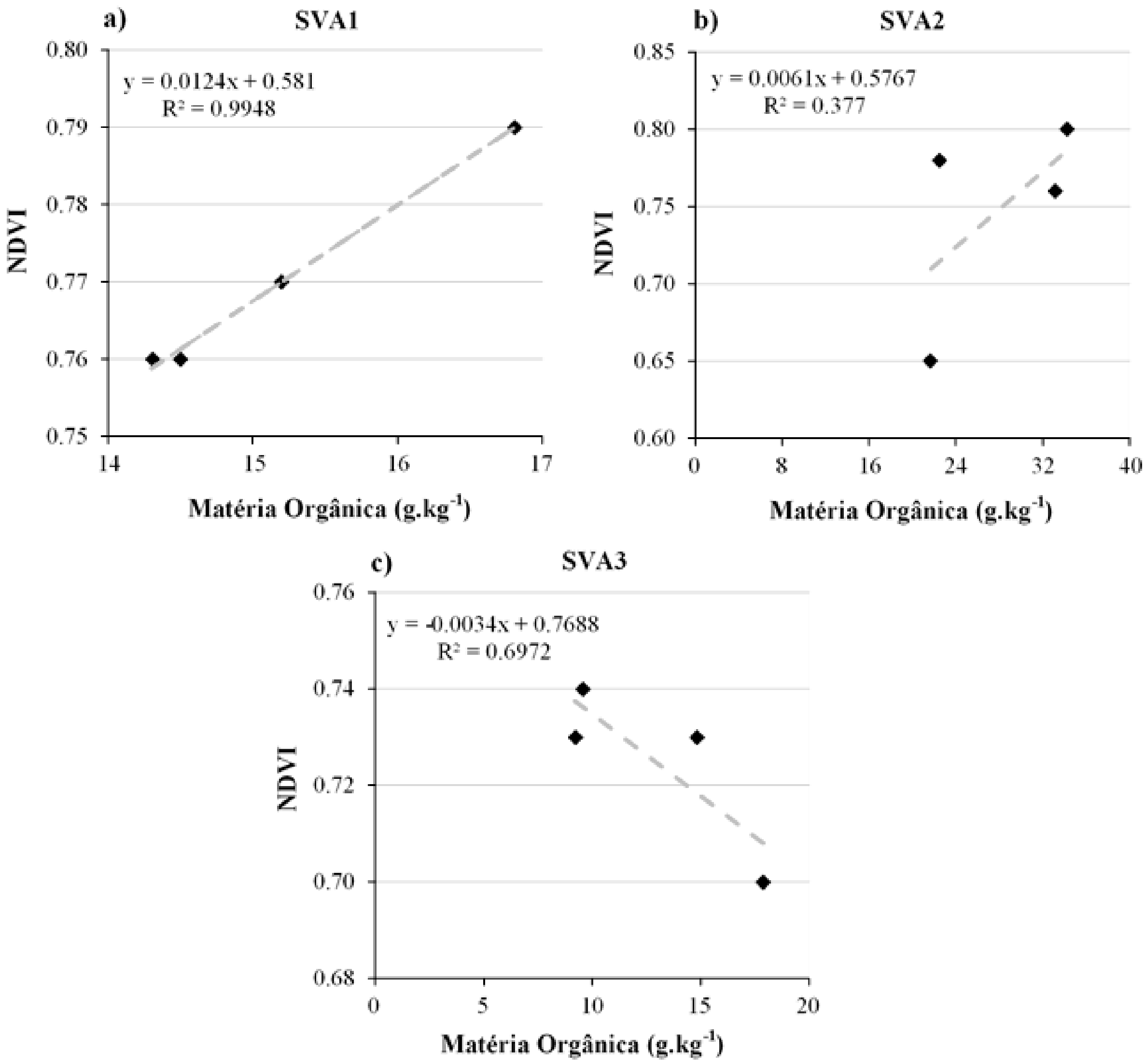
Soil organic matter and NDVI correlation

The organic matter content (OMC) and the NDVI values obtained for each of the collecting points are listed in the Table 3 and its correlation is represented in Figure 5.

Table 3 – Organic matter content and NDVI values for the tree SVAs.

SVA	Collecting Point	OMC ($g.Kg^{-1}$)	NDVI
SVA1	P1	15.2	0.77
	P2	14.3	0.76
	P3	14.5	0.76
	P4	16.8	0.79
SVA2	P5	21.7	0.65
	P6	22.5	0.78
	P7	34.3	0.8
	P8	33.1	0.76
SVA3	P9	9.5	0.74
	P10	17.9	0.7
	P11	9.2	0.73
	P12	14.9	0.73

Figure 5 – Soil organic matter and NDVI correlation obtained for a) SVA1, b) SVA2, e c) SVA3



It was observed a positive correlation between the organic matter content and the NDVI values obtained for the SVA1 and SVA2 (Figure 5a e 5b), presenting coefficients of determination, respectively, in the order of 0.99 e 0.37. For the SVA3, despite the good coefficient of determination obtained (R^2=0,69), the correlation was negative, characterizing an inverse relation between the vegetative density increasing represented by the NDVI and the OMC values.

In general, the results of the present study were similar with those obtained by Yang *et al.* (2015), that using satellite imagery, estimated the levels of MOS and created a distribution map to them, also correlating to NDVI, reaching a R^2 = 0.67. These authors also corroborate the influence of other factors such as topography, climate and the intrinsic edaphic features in the organic matter contents in the superficial layer of the soil.

CONCLUSIONS

A higher vegetation density corroborates to obtain more expressive organic matter contents in the superficial layer of the soil. Despite the good correlation between a higher vegetation presence and higher organic matter content, aspects related to the physiology of the vegetation as well as the characteristics inherent to the present soils should be considered. This way, using vegetation indexes obtained by orbital images, such as NDVI, by itself, do not make possible a reliable estimation of the OMC. However, when associated to the analysis of the vegetation behavior it can be a good indicator of the levels of organic matter in semi-arid soils.

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