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# SOIL ORGANIC MATTER LOSS
# BY WATER EROSION IN A COFFEE ORGANIC FARM

## SUMMARY

In tropical regions, water erosion is the process responsible for the redistribution and the loss of soil organic matter (SOM). Modelling can provide a diagnosis of the dynamics of SOM in agricultural production systems, and assist the proposing of conservationist measures. Therefore, this work aimed to estimate SOM losses due to water erosion in an agricultural production system, through the use of modelling techniques. The study area corresponding to the Santo André Farm, located in south-eastern Brazil.

The area of the farm is around 75 ha, and the main agricultural product is coffee (78%). The modelling was performed based on the SOM content of the area, and the estimated soil losses, according to the Revised Universal Soil Loss Equation.

To the SOM determination, soil samples were collected at 20 points, distributed over the area, in the surface layer (0-20 cm), in March 2018.

The parameter acquiring and the data analysis were performed using remote sensing techniques and a Geographic Information System, which was also used to interpolate the SOM content, through the use of the ordinary kriging. The organic matter content on the farm ranged from 1.20 to 2.46%, while the average soil loss was 25.70 Mg ha$^{-1}$ year$^{-1}$, with higher erosion rates in steepest sites. The estimated loss of total organic matter at 31.87 Mg year$^{-1}$, with an average of 0.42 Mg ha$^{-1}$ year$^{-1}$. The observed results reveal the need to implement conservationist management measures to reduce soil losses, and the consequent SOM losses.

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## INTRODUCTION

Soil organic matter (SOM) improves the structure and fertility of the soil and, consequently, increases agricultural productivity. Moreover, changes in SOM contents result in a significant variation in soil carbon stock and can affect the $CO_2$ atmospheric concentration (Lal, 2004; 2006).

Soil erosion by water is considered as a serious environmental threat (Spalevic, 2011; Spalevic et al. 2012; Nikolic et al. 2019; Chalise et al., 2019; Khaledi Darvishan et al., 2019; Ouallali et al., 2020). Water erosion can breakdown the soil structure and expose the SOM to the climatic conditions and the attack of microbial enzymes (Hancock et al., 2019; Lal, 2019). For this reason, it is an important process responsible for the carbon losses, especially in tropical and subtropical soils, due to the rainfall and temperature conditions.

In this context, the assessment of SOM dynamics in agricultural production systems is necessary to propose conservationist practices capable of mitigating the carbon losses by water erosion and, consequently, decrease the greenhouse gas emissions from agricultural soils.

Water erosion modeling can be used to simulate the erosion process and to measure the SOM losses based on factors such as climate, relief, physical characteristics of the soil, and vegetation cover with the advantages of being a simple and inexpensive method. Modeling reduces the limitations found in the direct quantification of water erosion and SOM loss, which is an expensive process that requires field experiments with continuous long-term data collections (Starr et al., 2000; Barros et al., 2018).

Based on this information, the objective of this work was to estimate the soil organic matter loss by water erosion in a coffee agricultural production system.

## MATERIAL AND METHODS

The prevailing odour from an established production unit was detected from Study area. The study area was located at Santo André Farm in the Municipality of Divisa Nova, south of Minas Gerais, at coordinates UTM 377066 at 378515 m O and 7621721 at 7622954 m S, zone 23K, Datum SIRGAS 2000 (Figure 1).

The farm has an area of 75 ha, predominantly cultivated with coffee (78%), followed by pasture (12%), access roads (6%), drainage (2%), and facilities (2%). Coffee is grown under organic cultivation system, with conservationist practices, such as the management of spontaneous vegetation between the coffee tree rows and level planting. The land use map was prepared using ArcMap 10.5 software (ESRI, 2015), based on high-resolution images from the Basemap tool (ESRI, 2015) and field surveys. The soil was classified as Ferralsol (WRB, 2015) and the climate according to the Köppen classification as Tropical Mesothermal (Cwb), with annual precipitation of 1500 mm and an average temperature around 22°C (Alvares et al., 2013).
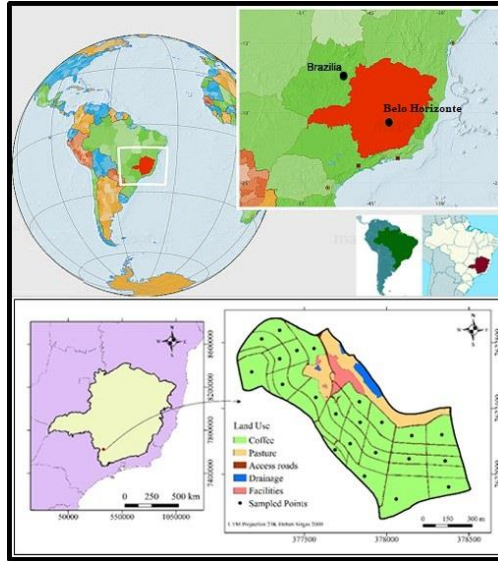
Figure 1. Location and land use of Santo André Farm, Municipality of Divisa Nova, South of Minas Gerais, Southeastern Brazil.

Soil organic matter loss. We estimate the SOM loss by water erosion using the Revised Universal Soil Loss Equation (Renard et al., 1997) according to Equation 1 and the organic matter content in the area, according to Starr, et al. (2000).

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Equation 1

where, A = average annual soil loss, in Mg ha$^{-1}$ year$^{-1}$; R = rainfall erosivity factor, in MJ mm ha$^{-1}$ h$^{-1}$ year$^{-1}$; K = soil erodibility factor, in Mg ha$^{-1}$ MJ$^{-1}$ mm$^{-1}$; LS = topographic factor, given by the relationship between length (L) and inclination of the relief (S), dimensionless; C = cover and management factor, dimensionless; and P = conservation practices factor, dimensionless.

The R factor was 6700 MJ mm ha$^{-1}$ h$^{-1}$ year$^{-1}$, determined based on the erosivity map of Minas Gerais (Aquino et al., 2012). The K factor represents the soil resistance to erosion. We adopt the erodibility value of 0.026 Mg ha$^{-1}$ MJ$^{-1}$ mm$^{-1}$ to the Latosols of the area, according to Tavares, et al. (2019).

We calculated the LS factor according to the topography of the area using the digital elevation model (DEM) (Miranda et al., 2005) based on the methodology of Moore and Burch (1986) (Equation 2). The LS values ranged from 0 to 26.3, with an average of 2.14.

$$LS = \left(\frac{FA \cdot 10}{22,13}\right)^{0.4} \cdot \left(\frac{\sin (S)}{0.0896}\right)^{1.3}$$

Equation 2

where, LS is the topographic factor, dimensionless; FA is the accumulation of flow expressed as the number of cells in the DEM grid; S is the hydrographic basin declivity in degree; and 10 is the spatial resolution of the DEM, in meters.

The average C factor was 0.17, indicating good vegetation cover. This parameter ranges from 0 to 1 according to the vegetation cover of the area, with higher values associated with sites with low vegetation density. The C factor was determined using the Durigon, et al. (2014), which is based on the normalized difference vegetation index (NDVI) (Equation 3).

$$C_r = \frac{-NDVI+1}{2}$$                                    Equation 3

where $C_r$ = soil covered factor e NDVI = normalized difference vegetation index, both dimensionless.

NDVI is a widely used indicator of vegetation vigor. This index ranges from -1 to +1, where the closer the value is to +1 the higher the plant density. The index was calculated according to Tucker (1979); using images from the Landsat-8 Operational Land Imager (OLI) satellite, bands 4 and 5, orbit/point 219/75, obtained from the Image Generation Division (INPE, 2019).

Finally, the P factor, which represents the influence of management practices on the erosion process, ranges from 0 to 1. Due to the conservationist practices, we adopted a value of 0.5.

To determine soil organic matter (SOM) contents, we collected soil from the superficial layer (0-20 cm) in 20 points distributed in the subbasin (Figure 1A), and both SOM and soil density (Ds) were estimated according to Embrapa (2017). The collection of the samples was carried out in March 2018. The SOM contents were interpolated by the ordinary kriging method using the Geostatistical Analyst tool from the ArcMap 10.5 software (ESRI, 2015).

## RESULTS AND DISCUSSION

The soil organic matter showed spatial dependence in the area, with the exponential model fitted, generating an $R^2$ of 0.92. The SOM contents ranged from 1.20 to 2.46%, with higher levels founded mainly in coffee (Figure 1B). The management of spontaneous vegetation and organic fertilization may have been the reason for the high SOM content in areas with coffee cultivation.

The average soil loss was quantified at 25.70 Mg ha$^{-1}$ year$^{-1}$, with higher water erosion intensity in slope areas, and sites with low plant density (Figure 2A). The average soil loss is considered high for the study conditions (> 15.00 Mg ha$^{-1}$ year$^{-1}$), according to Avanzi, et al. (2013), indicating the necessity for a comprehensive management plan seeking to reduce erosion rates at Santo André Farm. It is worth mentioning that, in the short term, areas with higher levels of erosion (Figure 1A) should be prioritized to the adoption of mitigation measures.

The total SOM loss was 31.87 Mg year$^{-1}$, with an average of 0.42 Mg ha$^{-1}$ year$^{-1}$. As expected, the highest rates of SOM loss occurred in areas with severe erosion (Figure 2C). Considering that coffee is cultivated in an organic system, any SOM loss results in several damages to the soil and causes additional costs to the producer by replacing the nutrients and organic matter lost contents, seeking to guarantee a satisfactory soil fertility level.
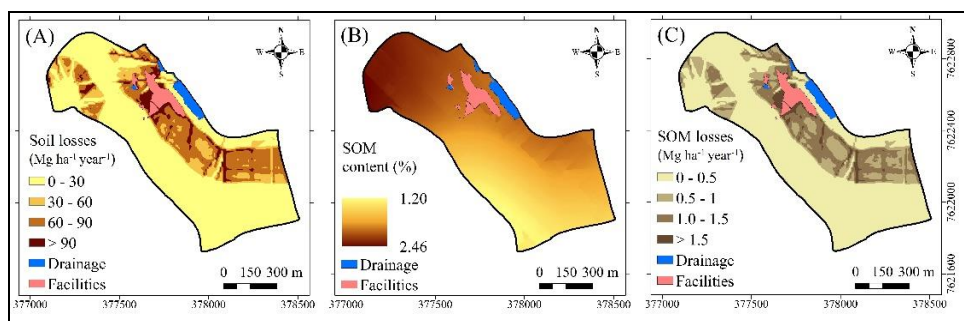
Figure 2. Soil losses (A), SOM content (B) and SOM losses (C) from Santo André Farm, Municipality of Divisa Nova, south of Minas Gerais, Brazil. Notes: SOM: Soil Organic Matter.

Controlling water erosion is a key mechanism for SOM loss mitigation and enhance soil carbon sequestration. According to Rimal and Lal (2009), SOM loss can be mitigated by the adoption of sustainable land management practices, such as no-till, level planting, and satisfactory soil vegetation cover. These practices can improve soil aggregation, improve water infiltration, and decrease runoff. Thus, the farm must adopt conservationist practices to reduce the SOM loss to minimum rates and guarantee the sustainability of the production system.

## CONCLUSIONS

The soil organic matter content on the farm ranged from 1.20 to 2.46%. The average soil loss was 25.70 Mg ha$^{-1}$ year$^{-1}$, with higher erosion rates in high declivity areas. The methodology used to estimate the total organic matter loss at 31.87 Mg year$^{-1}$ with an average of 0.42 Mg ha$^{-1}$ year$^{-1}$. The approach provided satisfactory results, which are useful in farm management planning.

## ACKNOWLEDGEMENTS

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