Estimação da matéria orgânica do solo, em função dos atributos químico-físicos do solo, em áreas tropicais de cana de açúcar

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Resumo: Este estudo tem como objetivo quantificar a matéria orgânica do solo em canaviais comerciais no Brasil, usando a técnica de regressão linear múltipla com variáveis de atributos do solo. O experimento foi realizado em uma lavoura canavieira nos municípios de Motuca, Guariba, Pradópolis e Aparecida do Taboado. A técnica utilizada foi a regressão linear múltipla e a variável dependente foi a matéria orgânica do solo (MOS) e as variáveis independentes foram fósforo disponível (P), capacidade de troca catiônica (CTC), temperatura do ar (Tair), temperatura do ar. solo (Ts), densidade de partícula (Dp) e umidade do solo (Us). A técnica de aprendizado de regressão linear múltipla estimou o MOS em função das variáveis P, CTC, Tair, Ts, Dp e Us, em áreas de cana-de-açúcar crua, mostrando a existência de alta relação entre variáveis independentes e dependentes. Estudos como este, relacionados à determinação de parâmetros de solo são importantes para os agricultores, pois as informações geradas podem ser utilizadas no gerenciamento e na tomada de decisões do processo produtivo e financeiro, sendo uma alternativa para a caracterização não só de MOS, mas também de outros atributos do solo.

Palavras-chave: matéria orgânica do solo; Regressão linear múltipla; atributos físicos e químicos do solo; Análise multivariada.

Estimation of soil organic matter, as a function of soil chemical-physical attributes, in tropical sugarcane areas

Abstract: This study aims to quantify soil organic matter in commercial sugarcane fields in Brazil using the multiple linear regression technique with soil attribute variables. The experiment was carried out in a sugarcane field in the municipality of Motuca, Guariba, Pradópolis and Aparecida do Taboado. The technique used was multiple linear regression and the dependent variable was soil organic matter (MOS) and the independent variables were available phosphorus (P), cation exchange capacity (CTC), air temperature (Tair), air temperature. soil (Ts), particle density (Dp) and soil moisture (Us). The multiple linear regression learning technique estimated the MOS as a function of the variables P, CTC, Tair, Ts, Dp and Us, in areas of raw sugarcane, showing the existence of a high relationship between independent and dependent variables. Studies like this one, related to the determination of soil parameters are important for farmers, as the information generated can be used in the management and decision-making of the productive and financial process, being an alternative for the characterization not only of MOS, but also of other soil attributes.

Keywords: soil organic matter; multiple linear regression; soil physical and chemical attributes; Multivariate analysis.

Introduction

The covering formed by the sugarcane straw provides a condition that favors the accumulation of carbon in the soil, contributing to the mitigation of GHGs in the agricultural production of ethanol and sugar. According to data from the National Supply Company – [1], in the 2018/2019 harvest the planted area was around 8.59 million hectares and production was 620.44 million tons. The maintenance of straw in the crop allows the increase of soil organic matter, which can generate an amount of residues of 10-20 t ha^{-1} [2]. Organic residues that are formed by animal and vegetable residues, in different stages of decomposition [3], which is left on the soil after harvesting, resulting from the interactions that occur between the straw and the atmospheric, physical and chemical attributes of the soil.

Objectives

The spatial variability of edaphoclimatic conditions in Brazilian regions directly interferes with organic matter, affecting the soil organic carbon dynamics. In this context, the objective of this work was to develop a mechanistic-empirical model, using the exploratory multivariate analysis of multiple linear regression data to predict the influence of each element of the soil-plant-atmosphere system in the soil organic matter quantification process, using the variables of the physical and chemical attributes of the soil and climatic data, in commercial areas cultivated with the sugarcane culture in Brazil.

Methodology

The study was carried out in a commercial area with sugarcane cultivation, under the raw cane management system, in Guariba - SP, Pradópolis - SP, Motuca - SP and Aparecida do Taboado - MS. In SP, the soils were classified as Latossolo Vermelho Eutroférrico and in MS as Latossolo Vermelho Distroférrico. Both had a clayey texture and the climate was Aw, with an average annual temperature of 23.7 ºC. Soil temperature was recorded by the LI-COR system (LI-8100). Soil moisture (Us) was measured by TDR equipment (Time Domain Reflectometry - Hydrosense TM, Campbell Scientific, Australia). After completion of the measurements, soil samples were collected at a depth of 0 to 0.10 m and later sieved in a 2 mm mesh. For chemical analysis, the following attributes were extracted: cation exchange capacity (CTC) and available phosphorus (P) content of the soil [4]. From these same samples, the Dp was also determined [5]. the air temperature (Tair) was obtained by the NASA Power platform. All assessments were carried out at the beginning of the sugarcane crop development phase. Data were initially analyzed using descriptive statistics and the Shapiro-Wilk test at a 5% probability level. Then, the correlation matrix was performed using the Pearson method. The statistical technique used for the elaboration of the empirical-mechanistic model was the exploratory analysis of the multiple linear regression data. To evaluate the performance of the model, the following statistical indices were used: Coefficient of determination (R^2), Adjusted coefficient of determination (R^2 adj), Mean squared error (MSE), Mean squared error (RMSE), Akaike information criterion (AIC) and Schwarz Bayesian Criterion (BIC).

Results and discussion

The multiple linear regression equation that was estimated to explain the MOS as a function of the variables P, CTC, Tair, Ts, Dp and Us was represented by Equation 1:

$$MOS = -62.8932 - 0.5957P + 0.4946CTC - 3.2200e^{-15}Tair - 5.3290e^{-15}Ts + 22.4228Dp - 2.2200e^{-15}Us$$

Where: MOS: soil organic matter (g dm^{-3}); P: available phosphorus (mg dm^{-3});

CTC: cation exchange capacity (mmolc dm^{-3}); Tair: air temperature up to 2 meters above the ground (°C); Ts: soil temperature (°C); Us = soil moisture (% of volume); Dp: particle density (kg dm^{-3}); Us: Soil moisture (mm).

The value of the coefficient of determination of this model was R^2 = 0.999, and its respective adjusted value was, that is, 98.5% of the variations in the MOS estimate can be explained by variations in the values of the independent variables. The remaining 1.5% are sources of variations that are explained by other factors. Regarding the likelihood study of the model, the Akaike test (AIC) was performed, whose value was -1430 and the Schwarz Bayesian Criterion test (BIC), whose measured value was -1422. In both cases, he observed that the independent variables showed strong relationships with the dependent variable, showing that there is a strong relationship between the studied variables.

As a function of the predicted model for the MOS, the value of the linear coefficient was -62.8932 and presented statistical significance within the model (p-value = 0.000), showing that this coefficient strongly impacts the determination of the model. When the slopes were analyzed, the following results were obtained for the dependent variables: P = -0.5957, CTC = 0.4946, Tair = $-3.2200e^{-15}$, Ts = $-5.3290e^{-15}$, Dp = 22.4228 and Us = $-2.2200e^{-15}$. Regarding the level of significance, p-values of 0.000, 0.000, 0.477, 0.433, 0.000 and 0.516, respectively, were observed. The variables that showed strong explanatory power in the model, through the level of significance, were P, CTC and Dp. The Us, Tair and Ts variables did not show a significant level that could impact the model, but if this model is replicated for another data set, a greater relationship can be observed.

Observed MOS versus Estimated MOS

The linear regression formula that was estimated to validate the estimated MOS values as a function of the observed values was represented by Equation 2:

Where: MOS_estimated: soil organic matter (g dm^{-3}) estimated; MOS_observed: soil organic matter (g dm^{-3}) observed.

Similar to the study of the prediction of MOS, the value of the coefficient of determination of this model was R^2 = 0.999, and the value of the adjusted coefficient of determination was that is, 98.5% of the variations in the estimate of the MOS can be explained by variations in values of the independent variables. The remaining 1.5% are sources of variations that are explained by factors. In addition, the Akaike test (AIC) was also performed, whose value was -1468. The value found by the Schwarz Bayesian Criterion (BIC) to describe the interactions between the variables that maximize the probability of choosing the true model, whose measured value was -1466. For the two evaluative parameters, strong interactions of the independent variable with the dependent variable were observed, evidencing the strong interaction of the observed MOS with the estimated MOS.

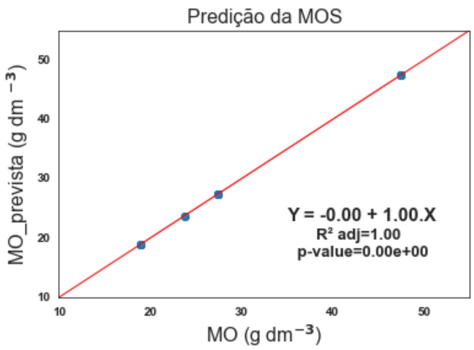

Figure 1. Plotting observed MOS data versus estimated MOS by the regression equation.

Figure 1 shows the graph of observed MOS versus estimated MOS. It is observed that the straight line angle, in relation to the linear fit was 45 degrees, characterizing the strong relationship between the observed MOS and the estimating MOS. In addition, also obtained the values of the RMSE (root mean squared error) which means the "root mean squared error" and also the MSE (mean squared error) which means the "mean squared error", values of 0 were found. stops the two parameters, showing that the observed and estimated values had high correlations.

Conclusions

It was observed that the multiple linear regression learning technique was able to estimate the MOS as a function of the variables P, CTC, Tair, Ts, Dp and Us, in areas of raw sugarcane, showing the existence of a high relationship between independent and dependent variables.

Studies like this one, related to the determination of soil parameters are important for farmers, as the information generated can be used in the management and decision-making of the productive and financial process, being an alternative for the characterization not only of MOS, but also of other soil attributes.

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