Spatial variation of soil moisture content and soil water repellency in the sugarcane land

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Abstract: Measuring soil water content, soil water repellency and analysis spatial variation of the sugarcane land by combining classical statistics and geo-statistics, in this article. The results showed that: the means of soil moisture content and soil water repellency were smaller, in the case of long time without rainfall and these two soil properties were positively correlated. The distribution of soil moisture content and soil water repellency in the spatial distribution was similar, as well as the high threshold values were distributed in the northeast corner. The analysis results of the spatial variability degree for soil water content and soil water repellency were the same, meanwhile, variable coefficient and spatial correlation of soil moisture content were shown as medium, but soil water repellency shown as less relevant, under variable coefficient and geo-statistical spatial structure analysis.

keywords: Soil moisture, WDPT, Geo-statistical analyst, Spatial distribution.

1. Introduction

Transmission and retention of liquid soil moisture were effected by soil vegetation, physics and chemistry properties, soil conditions and climate etc [1]. The phenomenon was called soil water repellency that soil particulate of surface layer could not or difficult be wet by surface moisture due to certain factors. Soil water repellency would present different degrees of repellency with different soil moisture content and organic matter content. The study of Ghadim et al. [2] showed that soil repellency prevented the surface runoff and infiltration and made it more vulnerable to erosion, soil erosion and other problems. Sun et al. [3] simulated the spatial structure characteristics and variability of soil water repellency with the GIS technology and geo-statistical analysis methods. Therefore, studying variation and the spatial distribution of soil moisture content and soil water repellency, based on sugarcane field under no rain for a long time, provided certain scientific basis for irrigation program and soil erosion prevention and control.

2. Materials and methods

2.1 General situation of test area

The test plot is located in the Guilin Academy of Agricultural Sciences (25°4' N、109°44' E) in Guilin, China, and with the subtropical monsoon climate. The mean annual rainfall is about 1894 mm, with 60% to 80% of the precipitation occurring between April and September each year in the

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area. The mean evaporation is between 1490 mm and 1905 mm, and the mean annual temperature is 18 ℃. The area of 14175 m^2 (135 m×105 m) was selected by using hand held GPS in soybean planting plot and sugarcane planting plot respectively, and every 15 m set one measuring point, totaling 80 points. Meanwhile 20 subordinate measuring points were randomly set in each experimental areas, a total of 100 measurement points was set in entire experimental area.

2.2 Sampling and analysis

Before the test beginning, samples were collected from two test plots (0-6 cm) and taken to the laboratory for determination of soil texture, bulk density, total porosity, and organic matter. The soil moisture content (0-6 cm) at each measurement point was measured by a HH2 Moisture Meter (Theta-probe Type ML2x) and the device was calibrated, before the measurement. WDPT (water drop penetration time) was widely used to determining soil water repellency and specific operation process was as follows: a standard dropper to 10 drops of distilled water (0.05 ml) dropped to each measurement point of soil surface and a stopwatch recorded the time that drops of water from the soil surface completely seeped into the soil so that the size of soil repellency was determined; Taking arithmetic average of the time as the final result in the end. The classification criteria proposed of soil water repellency by Letey et al. [4] was adopted and it provided: soil had no water repellency when WDPT was less than 5 s, but it was opposite more than 5 s. Soil had slight water repellency, strong water repellency, serious water repellency when WDPT was between 5 s and 60 s, between 60 s and 600 s, between 600 s and 3600 s corresponding and soil had soil was extremely water repellency when greater than 3600 s.

Variogram function (CV) is major spatial variation analysis method of classical statistics.

Variation function is defined as: $CV=S/x$ （1）

In the formula, S is standard deviation, x is variable mean.

The half variant function and exponential model analyzed the data of space change, and obtained four important parameters: Nugget (C_0), Partial Sill (C), Sill ($C + C_0$), and maximum correlation range, in geo-statistical analysis. The nugget indicated the size of random mutation; The sill value included structural variance and random variance, which was the limit of the semi-variogram function. The spatial correlation can be represented by the spatial structure ratio, that is, the ratio of the partial sill (C) to the sill ($C + C_0$), and the larger the value is, the stronger the spatial correlation is. According to the study of Cambardella et al. [5], the spatial correlation between variables is very strong when the spatial structure ratio is greater than 75%; and the spatial correlation between the variables is moderate when the spatial structure ratio is 25% to 75%; the spatial correlation of the variables is very weak when the spatial structure ratio is less than 25%. All the data were calculated and analyzed by SPSS 20.0 (SPSS Inc., Chicago, USA). Geo-statistical analysis and spatial distribution mapping of soil heat capacity were performed with ArcGIS 10.0 (ESRI, USA) software.

3. Result and analysis

3.1 The soil properties

Sampling undisturbed and disturbed soil in the sugarcane land and testing in the laboratory produced results and results showed: clay content was the maximum in the soil particle composition, accounting for 38.05% and sand content was 35.67%, as well as silt 26.28%. Soil bulk density was 1.43g·cm^{-3}, soil organic matter content was 13.35g·Kg^{-1} and total soil porosity was 43.78%.

3.2 Statistical description of Soil moisture content and soil water repellency

Table 1 illustrated the soil moisture content was generally low and the mean value was 0.105 cm^3·cm^{-3}. The WDPT mean was 6.204 s, the infiltration time was quicker and belonged to the weak water-borne soil. The variation coefficient of soil moisture was 0.209, belonging to moderate variation and the WDPT variation coefficient was 0.025, belonging to weak variation, therefore the variation of soil moisture content was greater than WDPT. The change of soil moisture content ranged of 0.030 ~ 0.105 $cm^3 \cdot cm^{-3}$; WDPT changed in the range of 6.000 ~ 6.571 s. The soil moisture content and WDPT value were small result from the viscosity grain content, soil bulk density and the total porosity, under long time without rainfall.

Table 1 Descriptive statistics characteristics of soil water content and water repellency

Soil property	Minimum	Maximum	Mean	Standard deviation	Standard error	Coefficient of Variation（CV）
water content （$cm^3 \cdot cm^{-3}$)	0.030	0.105	0.064	0.013	0.001	0.209
WDPT(s)	6.000	6.571	6.204	0.154	0.017	0.025

3.3 Geo-statistics description of Soil moisture content and soil water repellency

Table 2 showed the geo-statistics results of soil water content and water repellency in sugarcane test area. The maximum correlation distance of soil moisture was 129.22 m, but the soil water repellency was 40.07 m, both were higher than the distance between the observational points in the experimental area, proving spatial correlation between these observations. The nugget value of soil water content were less than partial sill, but it was opposite for soil water repellency, which showed that the spatial variability of soil moisture in sugarcane land was mainly influenced by atmospheric rainfall, while soil water repellency by man-made tillage factors. From the spatial structure, the spatial structure of soil moisture content was 62.89%, which belonged to moderate spatial correlation, however, the spatial structure ratio of soil water repellency was less than 25% and the spatial correlation was weak.

Table 2 Geo-statistics results of soil water content and water repellency

Soil property	Range (m)	Nugget	Partial sill	Sill	Spatial structure ratio (%)
Soil water content	129.22	7.82E-05	1.33E-04	2.11E-04	62.89
Soil water repellency	40.07	1.81E-02	4.15E-03	2.23E-02	18.63

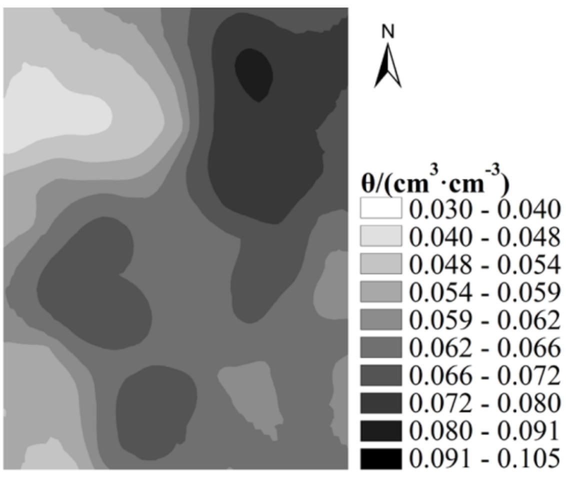

Fig.1 The spatial distrbution of soil water content

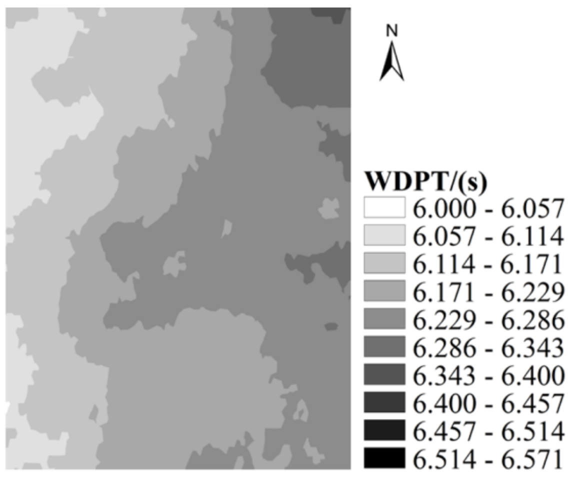

Fig.2 The spatial distrbution of soil water repellency

The spatial distribution of soil moisture content and water repellency were obtained in two soil properties by using the Kriging interpolation method in ArcGIS for geo-statistical analysis of moisture content and water repellency. The shades of each figure represented the height of the numeric value, the darker the color, the higher the soil heat capacity, the shade of each picture changes have their own changed threshold. In figure 1, the high threshold of soil moisture was located in the northeast corner, as well as the middle and south, while, low threshold was located in the northwest corner. From figure 2, the high and low threshold distribution azimuth of soil water repellency was similar to the distribution of soil moisture content, and the threshold value rises from west to east. The main causes of these changes were human factors by planting sugarcane in the furrow irrigation method used in the trench storage of water, combined with the impacts of sunlight and rainfall, affecting the soil moisture distribution uneven and changing the soil water-repellent size and the distribution of the respective space.

3.4 Correlation analysis of soil water content and soil water repellency

The Pearson correlation analysis was carried out by spss20.0 in order to more deeply understand the relationship between soil moisture content and soil water repellency in sugarcane surface layer. The correlation coefficient of soil moisture content and soil water repellency was 0.501, which was significant positive correlation ($P<0.01$).

4. Conclusion

The spatial variation of soil moisture and soil water repellency was analyzed in sugarcane soils land, with classical statistical analysis, geo-statistics and correlation analysis. The results showed that the mean values of soil moisture and water repellency were small and these two soils properties were positively correlated, on the condition of no rainfall for long time, which proved that soil moisture was the main factor influencing soil water repellency. The spatial variation degree of soil moisture content and soil water repellency was the same, in the spatial structure analysis of variation coefficient and statistic. The variation coefficient and spatial correlation of soil moisture content were moderate, while soil water repellency were small. The main causes of these changes were the common effects of soil properties, climate and human factors.

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