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Temporal stability of soil moisture in irrigated carrot crops in Northeast Brazil

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ABSTRACT

Soil water content plays an important role on crop productivity, mainly in the semiarid zones of the world. Given the importance of water resources to agricultural systems, investigations of soil moisture spatio-temporal variability can contribute to soil management, especially at highly heterogeneous irrigated soils occurring in alluvial valleys of the Brazilian northeast. In this sense, techniques which allow identifying and reducing the number of samples for soil moisture analysis are required. Additionally, the impact of management alternatives to control soil water losses by evaporation, such as mulching, on moisture temporal dynamics must be addressed. In this study, the temporal behavior of soil moisture was evaluated for an irrigated plot in the semiarid region of northeast Brazil. A pilot area of 1800 m^2 was cropped with carrots, and irrigated daily adopting two management treatments: one with mulch (using beans residues), and another without mulch. A total of 101 access tubes for neutron probe readings were installed in a 5 m × 5 m grid, with measurements at 20 and 40 cm depths. Readings were taken twice a week during the 96-day crop cycle, comprising 20 measurement campaigns. These data were evaluated by descriptive statistics and temporal stability methods (relative difference and Spearman's rank correlation). Mulching proved to be efficient in retaining soil moisture and reducing variation coefficient, thus decreasing soil water spatial variability. In addition, the values of the Spearman's correlation coefficients were high among the measurement campaigns results, indicating temporal dependence along the entire crop cycle. Based on the relative difference technique, locations at the sampling space could be identified which reproduced the average soil moisture pattern of the pilot area, representative of alluvial valleys of the Brazilian semiarid region. Temporal stability is an important issue in crop fields, in terms of reducing costs and time for adequate water management in irrigated areas.

1. Introduction

Soil moisture is a key variable in understanding a series of hydrological and climate processes on different spatial and temporal scales (Brocca et al., 2009; Heathman et al., 2009). From a hydrological point of view, soil moisture controls surface runoff, infiltration, water storage, and drainage. In addition, soil moisture is important for irrigation management and productivity prediction, mainly in areas under high evaporative demand.

Studies on soil moisture have been conducted on different spatial (1 m^2 to several km^2) and temporal (days to years) scales and have used various measurement techniques (gravimetric sampling, time domain reflectometer, capacitance, and neutron probes) (Hupet and Vanclooster, 2002). Furthermore, these studies have been conducted in a large variety of hydrological and climate conditions (Hupet and Vanclooster, 2002; Martínez-Fernández and Ceballos, 2005; Guber et al., 2008; Brocca et al., 2009).

There is a considerable body of knowledge that considers the spatial variability of soil properties, particularly moisture content, but little is still known about the temporal variability of soil properties (Martínez-Fernández and Ceballos, 2005). Studies on soil water in field conditions that emphasize water dynamics in the crop root area are even less frequent, particularly addressing the impacts of mulching on the soil moisture stability. Detailed analysis of the water behavior during crop development provides elements that are essential for establishing and improving agricultural management practices aimed at optimizing productivity (Rocha et al., 2005; Starr, 2005).

The technique developed by Vachaud et al. (1985) can be considered as a reference for temporal stability studies. In their research, a method was proposed for reducing the number of observations required for characterization of a given soil physical property. The authors reported two techniques. The first is a relative

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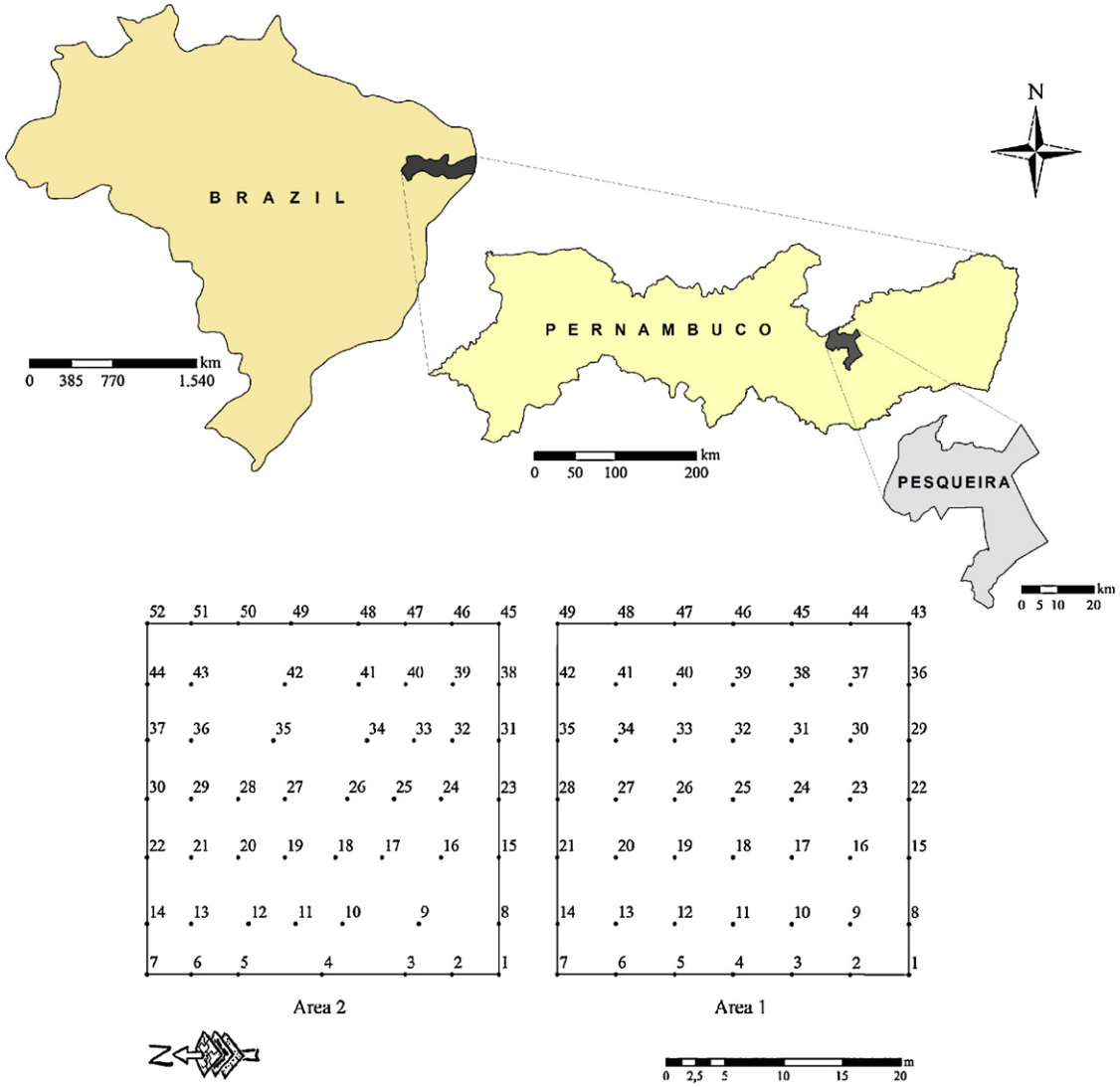

Fig. 1. Map of Brazil, Pernambuco State, Pesqueira municipality and framework of the investigated site with location of the measurement points in the area 1 (no-mulching) and 2 (with mulching).

difference technique, where analyses are performed on the deviations between the individually observed values and the average value for all observations. As a result, small variations in the relative differences among the spatial positions (as a function of time) indicate temporal stability. The other technique makes use of the nonparametric Spearman test. Temporal stability may be used to answer a number of questions related to soil properties sampling designs in highly variable fields, addressing both economic and technical aspects. Moreover, the verification of temporal stability may generate clearer and more precise scientific information that may be used with reduced uncertainty (Melo Filho and Libardi, 2005). In recent years, a series of studies have been developed that focus on these problems and try to understand the temporal behavior of soil moisture (Melo Filho and Libardi, 2005; Martínez-Fernández and Ceballos, 2005; Starks et al., 2006; Brocca et al., 2007; Cosh et al., 2008; Guber et al., 2008; Schneider et al., 2008; Brocca et al., 2009; Heathman et al., 2009).

Soil moisture temporal stability should be evaluated for different climate conditions, crops, soil classes, topographic elevation, and soil cover characteristics. Mulching adopting inorganic materials (sand, alluvial sediments, gravel fragments, polyethylene), as well as crops and animals residues (Yamanaka et al., 2004; Yuan et al., 2009; Xie et al., 2010; Balwinder-Singh et al., 2011; Fuchs and Hadas, 2011) might reduce soil water losses, runoff, development of weeds, and it may increase organic content in soil and improve soil structure. In semiarid regions under salinization risk, evaporation reduction could play an important role on controlling salt accumulation at soil surface and subsurface.

Given the importance of soil moisture dynamics to agricultural production, mainly in semiarid regions, and with the goal of identifying and reducing the number of measurements necessary to characterize soil properties, the objective of this study is to evaluate the temporal stability and dependence of soil moisture in an irrigated carrot plot in the Brazilian semiarid by means of the relative difference and Spearman's correlation methods. In addition, crop residues from beans has been evaluated as a mulching technique, for controlling soil moisture and its effect on temporal stability in semiarid regions, considering local climate conditions and soil characteristics.

2. Materials and methods

2.1. Experimental area and soil characterization

The experimental area ("Nossa Senhora do Rosario farm") is located in Pesqueira, Pernambuco State, in northeastern Brazil