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Monitoring variability in cash-crop yield caused by previous cultivation of a cover crop under a no-tillage system

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ABSTRACT

Cover crops may be a factor in the variability of soil fertility in areas under a no-tillage system (NTS); one which is not taken into account when fertilising the cash crop. The aim of this work was to evaluate the effect of the variability caused by the dry matter and nutrient cycling of the cover crop on the yield of the succeeding cash crop, by means of the NDVI, calculated by a portable ground sensor and using an unmanned aerial vehicle (UAV). The study was carried out in two areas of a Oxisol cultivated under NTS, where soil samples were taken, for chemical analysis and to evaluate the dry matter and nutrient accumulation in a winter cover crop of black oats. NDVI readings were taken at the R5 and R5.5 stages in soybean. A portable sensor was used seeking a comparison with the readings made by the UAV. It could be seen from the results, that the cover crop has an influence on the main crop under NTS. In the present case, the dry weight of the black oats as well as the accumulated nutrients of nitrogen, phosphorus and magnesium, showed the highest correlations with grain yield in the soybean, whereas for the chemical properties of the soil under evaluation, organic matter had the most influence on the grain yield. The NDVI assessed using the portable ground sensor and with the UAV, was efficient in evaluating the effects of variability in the crop of black oats and in the cycled nutrients.

1. Introduction

Measuring the variability of various parameters of the soil, crops and production environment has always been the aim of studies into the different areas of knowledge in the agricultural sciences, with the use of new technologies providing the tools to manage and understand this variability (Jones et al., 2015; Damian et al., 2016).

In Brazil, the no-tillage system (NTS) represented, and still represents, the main innovation in agriculture, in which the entire production system of the country was modified to meet the conservationist practices of this system. According to Cerri et al. (2009), NTS is a cropping system whereby the soil is turned only in the sowing furrow, and where some of the main interests are related to ground cover with suitable crops, or to crop residue from the previous harvest that are left on the surface. To this effect, the adoption of NTS has culminated in numerous studies that have sought to measure the effects of cover crops on rotation schemes under NTS, in which the results pointed to benefits that cover the physical (Costa et al., 2011; Kondo et al.2012), chemical (Torres et al., 2008; Bressan et al., 2013) and biological quality of the soil (Santos et al., 2008; Cunha et al., 2012), as well as environmental benefits from the lesser use of mineral fertilisers (Boer et al., 2007; Crusciol and Soratto, 2009) and from reducing the effects of carbon in the environment (Amado et al., 2001; Carvalho et al., 2014). However, despite the innumerable benefits that cover crops provide at the level of an agricultural production system, these have become yet another factor in variability that need to be taken into account under NTS management (Teixeira et al., 2016).

Fertilisation management is usually performed based on soil samples, after which the cover crop is planted and fertilisation carried out for the main crop only at the end of the cover-crop cycle. However, as already discussed, crop residue, especially from cover crops, can be a source of variability in the soil that is not taken into account in the fertilisation process. With this approach, the use of technology can be of great value in assessing the variability caused by cover crops on the main crop. Based on this, the NDVI (Normalized Difference Vegetation Index) may be one alternative, since it displays a correlation with crop yield (Boken and Shaykewich, 2002; Sultana et al., 2014; Lopresti et al., 2015; Peralta et al., 2016), besides serving as an indicator of numerous

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other anomalies that may indicate the variability caused by cover crops. The NDVI can be employed by means of portable sensors placed on machines, from satellite images (Tarnavsky et al., 2008), and more recently by sensors carried on so-called unmanned aerial vehicles (UAV). UAVs are noteworthy as the most-recent technology to be employed in agriculture; but despite this, the technology has emerged as one of the main innovations in agriculture, whose use is rapidly on the increase, and the subject of worldwide research, where some studies already show the potential of this technology for use in agriculture, as is the case with studies into the control of invasive plants (Granados et al., 2016), disease (Calderón et al., 2014) and irrigation management (Dugo et al., 2013; Bellvert et al., 2014).

The use of methodologies that seek to measure, understand and manage the variability that residue from cover crops causes in the main crop can represent a great advance in the management of a complex system such as NTS, mainly through the use of vegetation indices, as is the case of the NDVI. Based on this, the aim of the present study was to evaluate the effect of variability caused by the dry matter and nutrient cycling of a cover crop on the yield of the succeeding main crop, using the NDVI calculated by a portable ground sensor and a UAV.

2. Material and methods

2.1. Characterisation of the study area

The study was carried out using crops of black oats (*Avena strigosa* Schreb.) and soybean [*Glycine* max (L.) Merrill] o in two areas located in the town of Boa Vista das Missões in the State of Rio Grande do Sul (RS), Brazil, during 2015/2016 (Area 1) and 2016/2017 (Area 2), with Area 1 corresponding to 73.96 ha and Area 2 to 38.46 ha (Fig. 1). The climate in the region is subtropical humid with hot summers, type Cfa (Alvares et al., 2013), with a maximum temperature equal to or greater than 22 °C, a minimum temperature between −3 and 18 °C, and an average annual precipitation of between 1900 and 2200 mm. The distribution of precipitation, and the maximum and minimum daily temperatures during the black oat and soybean crop cycles in areas 1 and 2, are detailed in Fig. 2.

The terrain in the region is gently undulating, with the soil in the two areas classified as a Oxisol (Typic Hapludox). The management used in the areas has included the adoption of a no-tillage system (NTS) for more than 20 years, and the use of PA tools, such as geo-referenced soil sampling and geo-referenced harvest monitoring.

2.2. Sampling plan for soil and plants

The areas were geo-referenced using a Garmin® Legend GPS (Garmin International, Inc., Olathe, KS, USA). A sample grid with a cell size of 70.71 × 70.71 m (0.5 ha) was established for the two areas with the aid of the CR-Campeiro 7 Software (Giotto and Robaina, 2007), which interpolates a central coordinate for each pixel based on the grid size, and which resulted in 147 and 76 sampling points for Areas 1 and 2 respectively (Fig. 1).

2.3. Soil and plant properties

Soil samples for chemical analysis were taken from the 147 (Area 1) and 76 (Area 2) geo-referenced points after a harvest of maize and before sowing the winter cover crop, on 15 April 2015 (Area 1) and 24 April 2015 (Area 2).

The soil samples were collected from the 0.00–0.10 m layer with a quadricycle equipped with a threaded bit, powered by hydraulic drive. This depth was chosen for sampling as it is the recommended depth for areas under NTS, and has been historically used in the study areas. Fourteen sub-samples were taken in a 10 m radius of the central point of each sample cell, to make up a composite sample. After collection, the samples were identified and sent to the Soil Laboratory of the Federal

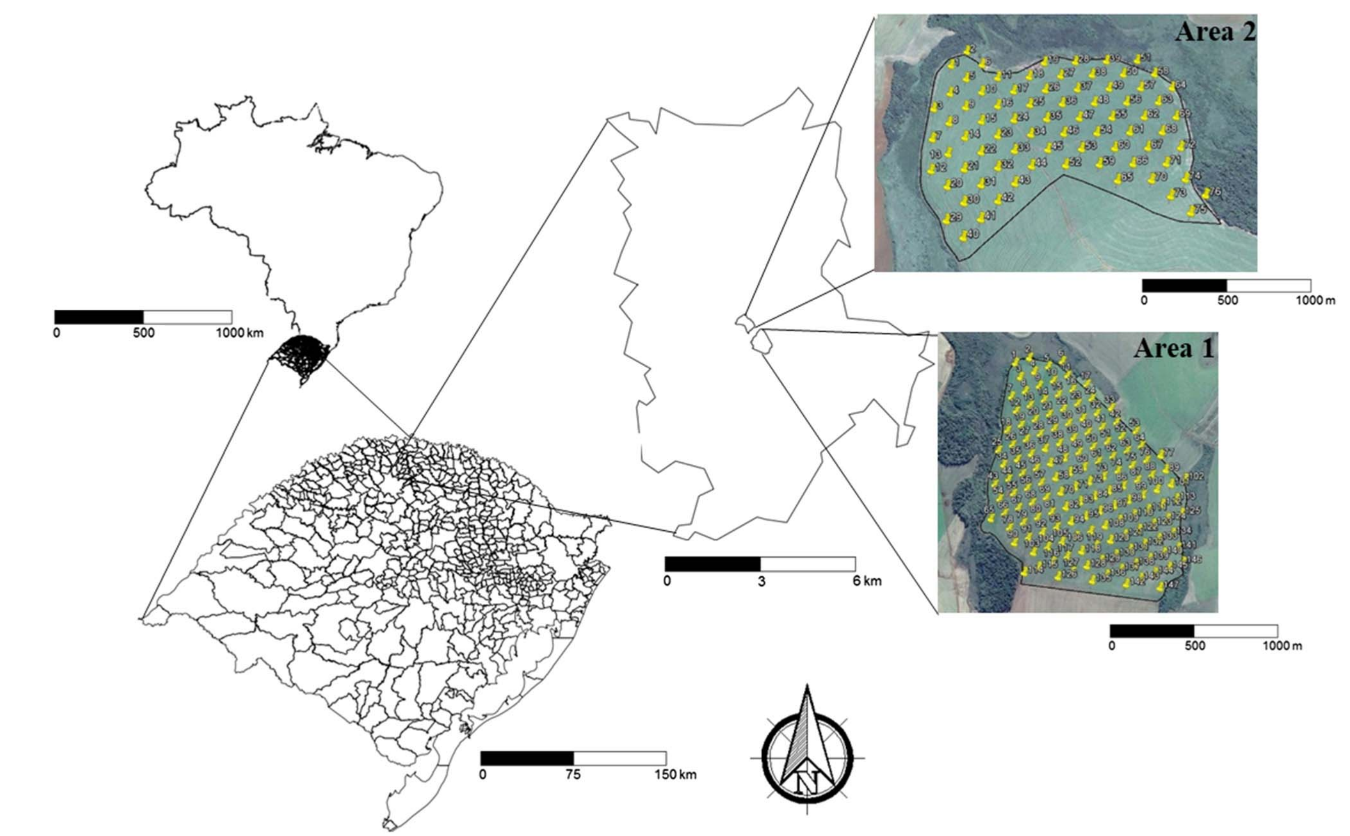

Fig. 1. Geographical location of the experimental areas used in the study.