Remotely Piloted Aircraft and NDVI as Tools for Monitoring the Quality of the No-Tillage System

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Abstract
Dry-mass variability in no-tillage systems (NTS) can affect the soil's functional dynamics. Tools such as remotely piloted aircraft (RPA) equipped with vegetation sensors stand out for monitoring and quantifying this variation. In this context, the present study evaluated the effect of dry-mass variability of a black oat cover crop on NDVI measured with an RPA over soybean. The study was conducted in a 75-ha area in Boa Vista das Missões, RS. The field was divided using a square sampling grid of 70.71 × 70.71 m, resulting in 147 sampling points where black oat dry mass was collected. A fixed-wing RPA was used to obtain NDVI in soybean at R5. Results showed high variability in black oat dry mass across the area. NDVI acquired with the RPA proved to be a useful tool to assess variability caused by dry-mass production under no-tillage.

Keywords: dry mass; *Avena strigosa*; *Glycine max*.

Introduction
Remotely Piloted Aircraft (RPA), popularly known as "drones," have emerged as an important technology in precision agriculture. In agriculture, RPAs began in Japan in the 1980s, when Yamaha was tasked with developing an unmanned helicopter for harvest management and pesticide application (YAMAHA, 2011). Since then, several research hypotheses have been explored with this technology, mainly because agricultural information windows are typically very short (ZARCO-TEJADA et al., 2008). This ability to quickly supply information is a key advantage of RPAs compared with other data sources, such as satellite imagery.

Given the complexity of systems like monitoring no-tillage system (NTS) quality, technologies capable of real-time monitoring of management effects on NTS and crop productivity deserve attention. The main way to monitor NTS quality is by the quantity and quality of dry mass entering the production system, since dry mass from specific cover crops and/or cash-crop residues is the principal component driving the soil's chemical, physical, and biological processes (DIEKOW et al., 2005; SANTI et al., 2015). Accordingly, this study sought to evaluate how black oat dry-mass variability affects NDVI obtained with an RPA over soybean.

Materials and Methods
The study was conducted in a 74-ha area under NTS for over 10 years, located in Boa Vista das Missões, RS, Brazil (27°71'66"S to 27°72'55"S and 53°33'13"W to 53°34'08"W). The regional climate is humid subtropical (Cfa) with hot summers, with maximum temperatures ≥ 22 °C, minimums between −3 and 18

°C, and mean annual precipitation of 1,900–2,200 mm (ALVARES et al., 2013). The soil at the experimental site was classified as a Typic Dystrophic Red Latosol (SANTOS et al., 2013), very clayey in texture.

The area was first divided into a square sampling grid of 70.71 × 70.71 m, yielding 147 sampling points. At each point, black oat (*Avena strigosa* Schreb.) dry mass was sampled at physiological maturity using a 0.25 m^2 frame, with three replicates per sampling point. Samples were oven-dried at 65 °C to constant mass, weighed to 0.01 g precision, and values were extrapolated to Mg ha^{-1}.

Under the black oat cover, soybean was sown on 11/16/2015. When soybean reached R5, an RPA flight was performed to compute NDVI (Normalized Difference Vegetation Index). The aircraft was a fixed-wing platform equipped with a modified Canon S110 camera; flight altitude was 200 m, resulting in a 7.66 cm pixel size. Image processing and orthomosaic generation were carried out in Pix4Dmapper. The spatial distribution map of black oat dry mass was generated in Surfer 10. Because no prior geostatistical analysis was performed, the inverse distance squared interpolator was used to create the dry-mass distribution map.

Results and Discussion

From Table 1, the hypothesis of normal distribution for black oat dry mass was rejected, which agrees with skewness and kurtosis values deviating from zero and indicates a trend toward log-normal distributions—confirmed by the Shapiro–Wilk (W) test at 5% significance. The coefficient of variation (CV) was 26.37%, classified as "high" (20 < CV < 30%) according to PIMENTEL-GOMES & GARCIA (2002). Dry-mass values ranged from 2.22 to 7.72 Mg ha^{-1}. As an initial analysis, this indicates variability in dry-mass productivity under NTS—an aspect to consider in Precision Agriculture management, particularly within Smart Management Plans (SMPs) that tailor cover-crop strategies to zones requiring differentiated treatment according to soil chemical, physical, and biological factors.

Table 1. Descriptive statistics for black oat dry mass.

Variable	*Minimum*	*Mean*	*Maximum*	*CV (%)*	*Standard Deviation*	*Skewness*	*Kurtosis*	*W test (1)*
Dry Mass	*2.22*	*4.50*	*7.72*	*26.37*	*1.18*	*0.54*	*−0.27*	*0.96**

(1) W test: Shapiro–Wilk normality test; (*) significant at $p < 0.05$, indicating rejection of the normal-distribution hypothesis.

From Figure 1, comparing the spatial distribution map of black oat dry mass with the NDVI map obtained by RPA over soybean at R5, zones with higher dry-mass productivity coincided with higher NDVI values. This visual relationship suggests that variability in the predecessor crop's dry mass can influence the main crop in NTS—here, black oat dry-mass variability influencing soybean. Potential explanations include: (a) dry mass influencing soil chemical, physical, and biological attributes (and/or these attributes influencing dry-mass production); (b) dry-mass productivity associated with the area's management history through management zones; and (c) effects from nutrient cycling provided by dry mass. The latter is likely the most appropriate, since black oat is efficient at nutrient recycling—extracting nutrients from deeper soil layers via its root system and depositing them near the surface through its above-ground biomass (BORTOLINI et al., 2000).

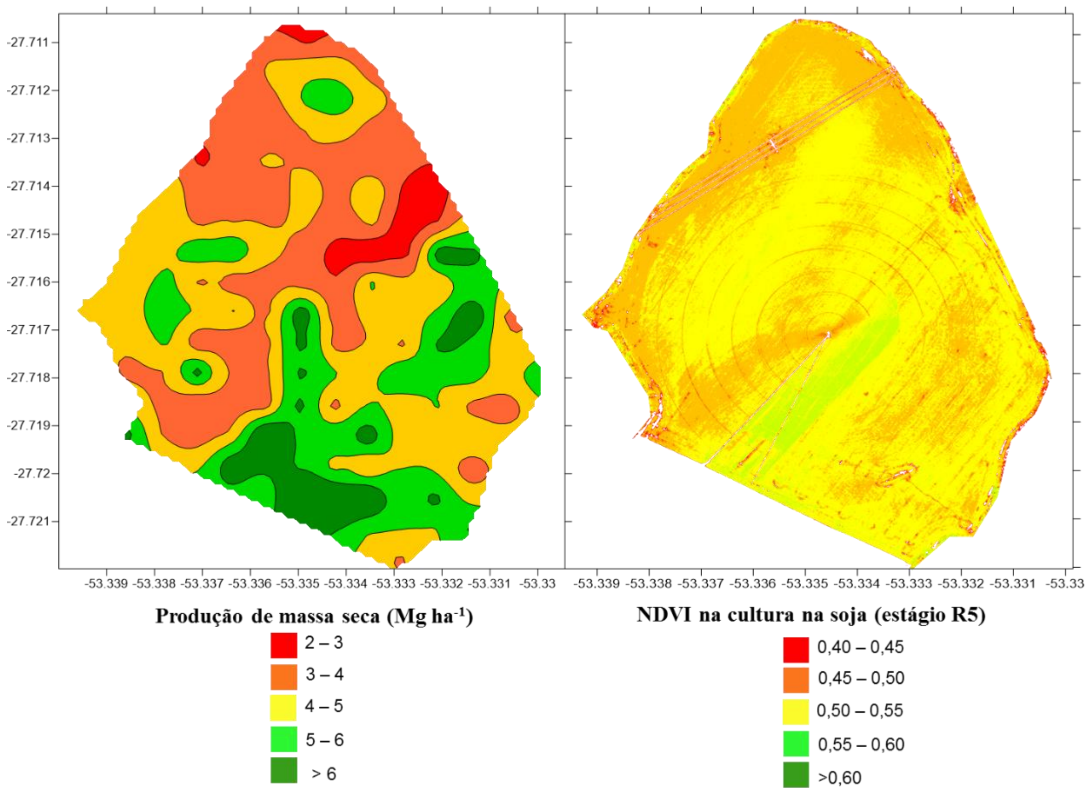

Figure 1. Map of the spatial distribution of black oat dry mass and the NDVI obtained with the RPA over soybean.

Conclusion

Black oat dry mass showed high variability across the study area. NDVI obtained with an RPA is a useful tool for evaluating variability caused by dry-mass production in no-tillage systems.

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