Geostatistical Analysis of NDVI in rotational and continuous grazing pastures

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Introduction

Livestock rearing is an important economical activity in Brazil, and its production is affected by pasture management methods. In this context, the use of geostatistics to analyze the spatial variability of the pastures' vegetation indices is valuable for understanding how management methods influence livestock production. Geostatistics is a tool that considers spatial dependency to interpolate data with no tendency and with minimum variance, which enables the production of precise maps using interpolated values at places that were not sampled (Vieira, 2000). The spatialization of vegetation indices such as the Normalized Difference Vegetation Index (NDVI) helps to evaluate the quality of pastures and to identify areas which may undergo a degradation process. In this study we intended to spatially evaluate two pasture management methods, rotational grazing and continuous grazing, using geostatistics and the NDVI as an indicator obtained from Landsat images of an area located in Pirassununga, São Paulo, Brazil, taken in 2011.

Material and Methods

The study area is located within the campus of Universidade de São Paulo at Pirassununga, São Paulo, Brazil, and features two pasture types with *Brachiaria brizantha*: continuous grazing (no rest and no pasture rotation) and rotational grazing (7 days of grazing and 28 days of rest). The area is located within the *Mata Atlântica* biome (Brazilian Atlantic Forest), and features average annual precipitation of 1,300 mm, average annual temperature of 23 ºC and humid subtropical climate (Cwa according to the Köppen classification). The NDVI was extracted from Landsat-5 satellite images using the method described by Conceição et al. (2015) on a 604-point grid using UTM coordinates and after calculating the Rouse et al. (1973) equation. The data were subjected to descriptive statistical analysis, normality test, and geostatistics. Semivariance was calculated according to Vieira (2000), in order to analyze the existence of spatial variability of the NDVI values in nine dates of 2011: April 28, May 14, May 30, June 15, July 17, August 2, August 18, September 3, and September 19. The semivariograms, which are graphic representations of NDVI's semivariance (with distances in meters) were adjusted according to the best correspondence model. After the adjustments were made, the data were interpolated using ordinary kriging and the semivariogram's adjustment parameters, and the results were displayed as isoline maps created using the ArcGIS 10.3 software.

Results and Conclusions

The results of the descriptive statistical analysis (Table 1) show average NDVI values ranging from 0.065 to 0.763 and with strong variation at each sampled date. As a result, the frequency distribution normality was not significant (5%) according to the Kolmogorov-Smirnov test. This variation is related to the seasonal variation in the average rainfall rate of Pirassununga according to the São Paulo State (*Secretaria de Estado de Saneamento e Recursos Hídricos*) (SÃO PAULO, 2016). The sampling refers to the dry season (sampled), from April to September, and June, July and August show low NDVI averages.

Table 1. Descriptive statistics of the NDVI values for nine dates during 2011.

Date	Average	Variance	Std.Dev.	C.V.	Minimum	Maximum	Skewness	Kurtosis
April 28	0.332	0.004	0.063	19.080	0.204	0.788	3.714	20.700
May 14	0.118	0.001	0.032	27.390	0.067	0.236	1.184	0.968
May 30	0.359	0.005	0.070	19.610	0.196	0.811	2.600	12.260
June 15	0.507	0.005	0.070	13.900	0.300	0.884	0.961	4.822
July 17	0.533	0.005	0.070	13.120	0.334	0.739	-0.596	-0.113
Aug. 02	0.636	0.008	0.087	13.700	0.371	0.807	-0.893	0.046
Aug. 18	0.065	0.000	0.003	4.161	0.057	0.072	-0.071	-0.068
Sept. 03	0.763	0.006	0.077	10.090	0.385	0.905	-1.787	3.137
Sept. 19	0.742	0.006	0.077	10.350	0.413	0.893	-1.954	4.504

Geostatistical analysis enabled the creation of semivariograms, which were adjusted individually, mostly using the exponential model, and tendencies for May 30 and June 15 were removed. All nine dates showed spatial dependency varying from 61 to 650 m. The semivariogram is shown for visualization purposes in Figure 1, scaled according to Vieira et al. (1997) and considering that the vegetation index values are at the same scale.

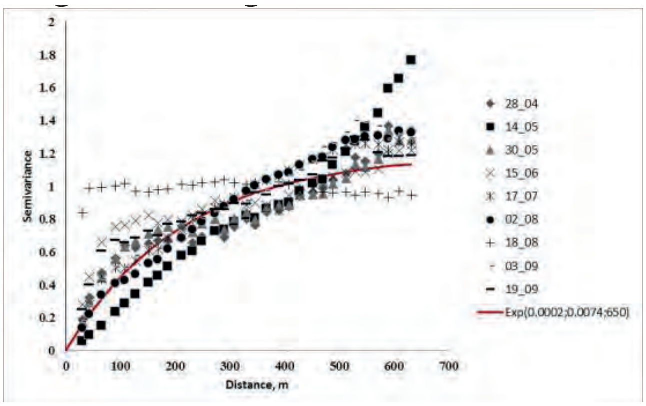

Figure 1. Scaled NDVI semivariogram adjusted using the exponential model for nine dates in 2011.

The maps obtained using ordinary kriging (Figure 2) show the monthly NDVI variation spatially. Places that were not sampled had their values interpolated.

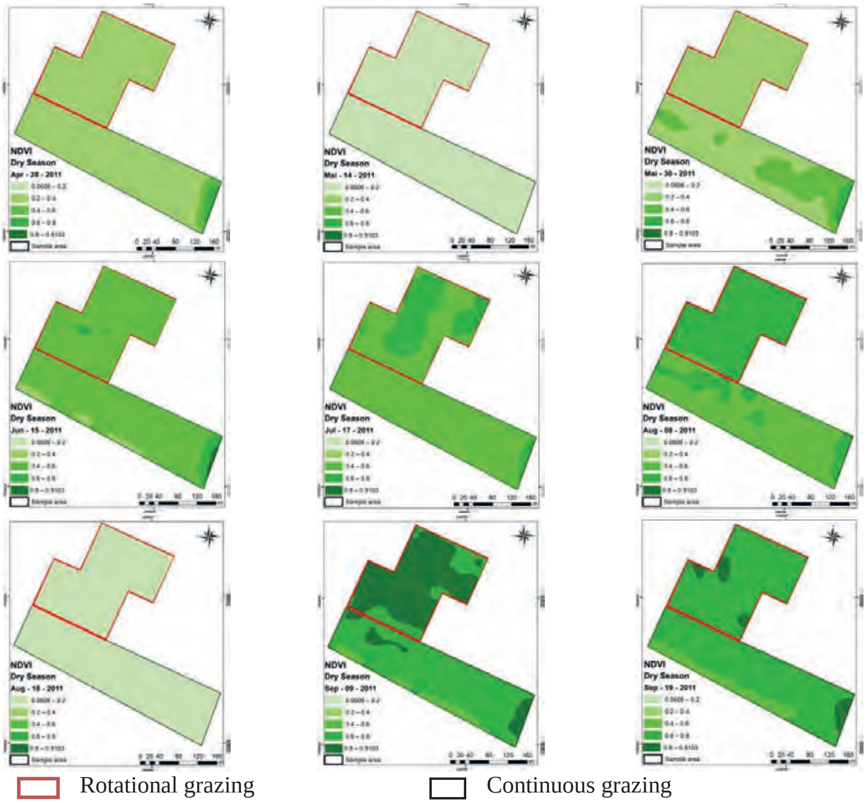

Figure 2. Maps of NDVI values interpolated using ordinary kriging in nine dates along 2011. The rotational grazing system leads to a better recovery of the pasture's vegetation index, even under water stress conditions, especially in July, August and September, except for August 18, when the whole area showed NDVI values lower than 0.2. We therefore conclude that resting the pastures enables restoring their leaf area index, thus leading to a greater soil coverage and hence reaching greater management efficiency.

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