DAILY RAINFALL AND SIMULATED MAIZE YIELD AT PIRACICABA LOCAL SCALE SPATIAL VARIABILITY (1,000 HA): DATA REVISITED

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1. INTRODUCTION

This study revisits the rainfall data set from a local scale experiment (1,000 ha) reported by Reichardt et al. (1995), presenting original evidence on statistical properties of the local spatial variability of rainfall and crop yield in Piracicaba, SP (Brazil).

Reichardt et al. (1995) analyzed the local scale variability of rainfall, presenting many interesting insights into the subject. Among their conclusions they indicate that the "correlation between data from pairs of observations data were not correlated with the separation distance, indicating that at this scale of the process the variability is a randomic process." The conclusion was correctly drawn given the information considered, which included only 9 correlation estimates and 9 separation distances from each of 9 collection points and a 10th point corresponding to the official weather station.

We show, however, by considering more information available in the original experiment, a statistically significant decrease in the correlation with increases in the separation distance with respect to the rainfall measured at two points. This effect was strong enough to allow statistical rejection of the notion that at this scale the "variability is a randomic process" with respect to rainfall and separation distance. To provide additional insights into the same subject, with an alternative procedure, we examine the relation between the separation distance and correlation of maize yields from two data points, simulated here by an implementation of the "FAO – De Wit Model", fed with the weather information available from each collection point and the official weather station, considering different sowing dates. The results followed the same pattern observed with the rainfall data measured at 2 points: a statistically significant decrease in the correlation with increases in the separation distance for the simulated yields, at this scale.

2. MATERIALS AND METHODS

The rainfall data set used here is the same reported in Reichardt et. al. (1995) and includes data collected from Nov. 2, 1993, to Oct. 30, 1994, at the official local weather station and 9 additional collection points randomly chosen within an area of about 1,000 ha inside the Campus of the University of São Paulo, Piracicaba, SP, Brasil (22°44' south, 43°33' west), 580m above the sea level and 250 km inside the continent, according to the authors, who provide additional information on the data collection.

2.1 Missing values and general computations

We managed the missing data in the original study considering 4 alternative procedures: (a) substitution by the measured rainfall at the local weather station; (b) substitution by an weighted average of the available observations using the inverse of the distance between points (normalized) as the weight; (c) substitution by the value estimated by a maximum likelihood procedure; (d) elimination of the daily observations (for all collection points) when some value were missing at some point. The results reported in next section considered the treatment of missing values by procedure (a). Procedures (b) and (c), in spite of being more sophisticated, produced results similar to those computed with the use of procedure (a) in the context of this study. The simulation of yields required estimations of missing values which eliminates the application of procedure (d) in this case. Even when the analysis of rainfall data considered procedure (4) for missing values the essence of the results remained the same as those reported in next section.

The computation of correlation coefficients and distances between the possible pairs of rainfall collection points (including the local station) used all available data (with the considerations in last paragraph) and point location information provided by Reichardt et al. (1995). This procedure increased from 9 (in the original study) to 45 the observation pairs (correlation coefficients and distances) available.

2.2 Maize yield simulation (FAO Model)

The rainfall data measured at each collection point was used to compute simulated maize crop yields for 2 different cultivars: Contimax 322 and Cargill 805 (1409°C.day and 1140°C.day from sowing to maturity) with an updated version of the FAO – De Wit Model implemented in software by Rolim et al. (1998), following guidelines presented by Doorenbos & Kassam (1979). The yields simulated for each point considered sowing dates separated 5 days apart, from Nov 1993, to Jun 1994. Daily temperatures and solar radiation values used in each simulation were the ones measured at the official weather station. The variability of the crop grain yield among the data points, for each sowing date, was due, therefore, only to differences in the rainfall at each data point.

2.3 Regression analysis procedures

The statistical analysis considered 3 alternative regression procedures: (a) conventional OLS regression assuming homogeneous variances; (b) weighted OLS regression assuming variances dependent on a function of the separation distance between two points; (c) robust regression using the LMS estimator, which is insensitive to outliers (Davies, 1993). For procedures (a) and (b) Johnston (1984) is classic reference. The implementation of procedure (b) used Bayesian methods described in Gelman et al. (1995, p. 257-259) to examine the relation between error variance and distance.

3. RESULTS AND DISCUSSION

Figures 1 and 2 summarize the main results in this study. They show statistically significant evidence (close to 0.1% Type I error) suggesting that the coefficients related to the distance in the conventional and the weighted OLS procedures are different from zero and negative.

These results do not support the notion that at the 1,000 ha scale the "variability is a randomic process" with respect to rainfall (or yields) and separation distance. In both cases, regression procedures (b) and (c), which take into account heteroscedasticity (and outliers), resulted in steeper linear equations and greater R^2 values (with procedure (b).

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Figure 1. Rainfall Correlation x Distance - Piracicaba

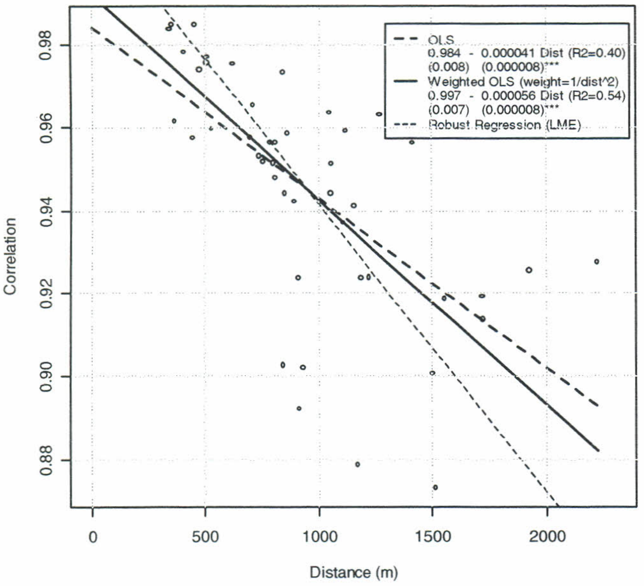

Figure 2. Maize Yield (Short) Correlation x Distance - Piracicaba

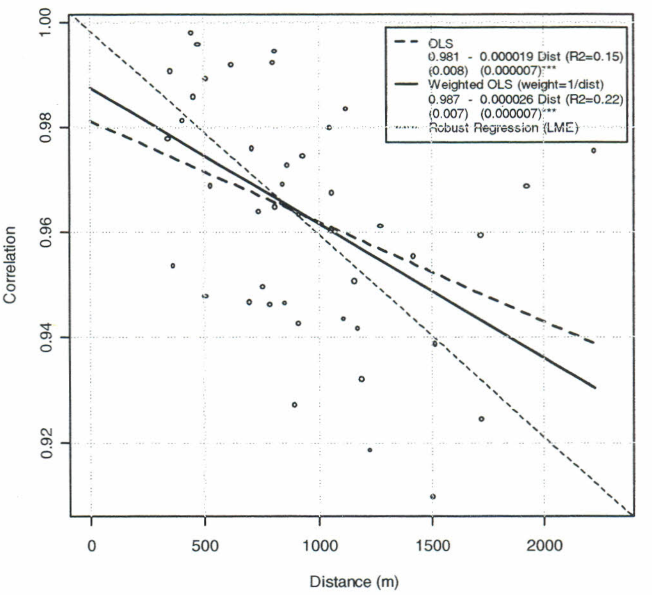

Figure 1 presents the relation between the rainfall correlation and distance estimated by all regression procedures. Figure 2 presents the relation between the simulated maize yield (short season cultivar) and separation distance. The yield correlation (Figure 2) decreases at a slower rate as the separation distance increases if compared with the rainfall correlation case (Figure 1). The notion of correlations and separation distance being a randomic process is not supported in this case as the Type I error is close to 0.1%. As for the long season cultivar, the results computed showed the same general pattern observed in Figures 1 and 2, with the yield correlation decreasing at a slower rate as compared with the short season cultivar.

4. CONCLUSIONS

Research on spatial variability of weather variables [Camargo & Hubbard (1998)] and crop yields [Hoogenboom (2000)] developed at different regional scales has shown results that have clear implications to agricultural production and risk management, agrometeorology, crop modeling, experimentation, and other areas of application. This study presents evidence on the spatial variability of rainfall and crop yields for the 1.000 ha scale suggesting that even at this scale correlation of variables related to rainfall at 2 points are not statistically independent from the separation distance within the considered conditions.

5. REFERENCES

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