USE OF FARMER'S EXPERIENCE FOR MANAGEMENT ZONES DELINEATION

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Abstract.*In the management of spatial variability of the fields, the management zone approach (MZs) divides the area into sub-regions of minimal soil and plant variability, which have maximum homogeneity of topography and soil conditions, so that these MZs must lead to the same potential yield. Farmers have experience of which areas of a field have high and low yields, and the use of this knowledge base can allow the identification of MZs in a field based on production history. The objective of this study was to evaluate the use of the farmer's experience in the delineation of MZs. Using data of elevation, soil penetration resistance, sand, silt, clay and soybean yield, the spatial correlation matrix was created to select the layers that influenced the yield. Then, the selected data were interpolated and the MZs were delineated using Fuzzy C-Means clustering method with SDUM (Software for Delineation of Management Zones). The farmer's experience layer was obtained using a mobile application developed for this. The MZs were delineated considering three cases: a) without the use of variable farmer's experience; b) with the variable farmer's experience and stable soil properties selected in the variable selection stage; and c) only with the variable farmer's experience, considering two, three and four sub-regions. The study showed that the use of the farmer's experience to set MZs can be an efficient and simple tool and reduce costs in the MZs setting process when compared to the traditional method of using stable soil variables and the relief. It should be noted that the good results obtained using the farmer's experience variable may have been positively influenced by the farmer's knowledge of this area for a long time.*

Keywords. *mobile devices; AgDataBox Mobile; agricultural management; management unit; software*

Introduction

The agricultural production sector is heading toward the smart management of production. According to Sorensen et al. (2011), it is necessary to increase profit margins with the highest quality of cultivated products and ensure the compliance of production areas with environmental standards. The use of information systems and decision-making support in agricultural management has great potential to achieve these goals, especially in the context of precision agriculture.

The delineation of management zones (MZs) is a cost-effective solution for precision agriculture since they function as operation units for the localized application of inputs and as an indicator for soil and crop sampling (Scheperset al., 2004; Milani et al., 2006; Ortega and Santibáñez, 2007).

Despite the wide range of methods and techniques that have been created to better understand the complex dynamics that involves the interaction between soil, water and crops, the farmers' knowledge of crops, although subjective, can efficiently determine constraints. The farmers know which areas of a plot have the highest and the lowest yields, considering that each area has different nutritional needs and/or physical characteristics that may restrict productivity. The use of this knowledge base can help to identify different management zones in a field based on the production history (Fleming et al., 2000; Morari et al., 2009). Fleming et al. (2004) compared prescription maps that were created according to the experience of the farmers with prescription maps and soil fertility analysis, in two corn crop fields in Colorado, United States. The results showed that the analysis of variance was similar when the authors compared both methods. Khosla et al. (2002) also delineated MZs using soil color obtained from aerial imagery, topography and the experience of farmers in the yield performance history of the area. They concluded that field variability was better managed with the treatment based on the MZs than with the conventional treatments.

Despite the importance of considering the empirical knowledge of farmers to define possible restrictions on crop yield, one of the impediments is the difficulty in surveying this variable since.With the growing popularity of information technology, especially mobile devices, farmers can use specialized management and data collection software in the field to support decision-making. Riquelme-López et al. (2016) stated that researchers must invest in agricultural management software using the cloud concept, which allows them to centralize management data seamlessly with various other devices.

The aim of this paper was to present an application for mobile devices that can be used to record and manage information of field operations, and to use the experiences of farmers in the delineation MZs based on a case study to validate the use of this tool.

Methodology

The app AgDataBox Mobile was designed to run on devices with the Android operating system. This platform was chosen because it is distributed free-of-charge and covers most of the mobile devices market. This app can be downloaded free of charge on the Google Play Store.

To operate the AgDataBox Mobile, users must first register the field they want to work with, insert data of the current agricultural crop (production history), and register the farmer experience variable used to delineate the MZs on the SDUM (Software for Delineation of

Management Zones) (Figure 1).

To evaluate the features of the AgDataBox Mobile application and confirm the applied methodology, data from an experimental area were used, with 15.5 ha, located in the municipality of Céu Azul, PR, Brazil, with a central geographical location 25º06'32" S and 53º49'55" W and an average elevation 620 m.

The soil in the study field was classified as Oxisol (Soil Survey Staff, 2010) and has been cultivated for more than ten years under the no-tillage system with a sequence of soybean, wheat, corn and oat crops. An irregular sample grid was established in the area, considering an imaginary central line between level curves, and a dense sampling grid with 2.58 points ha^{-1} was used to satisfy the restrictions of geostatistical analysis (Journel andHuijbregts, 1978).

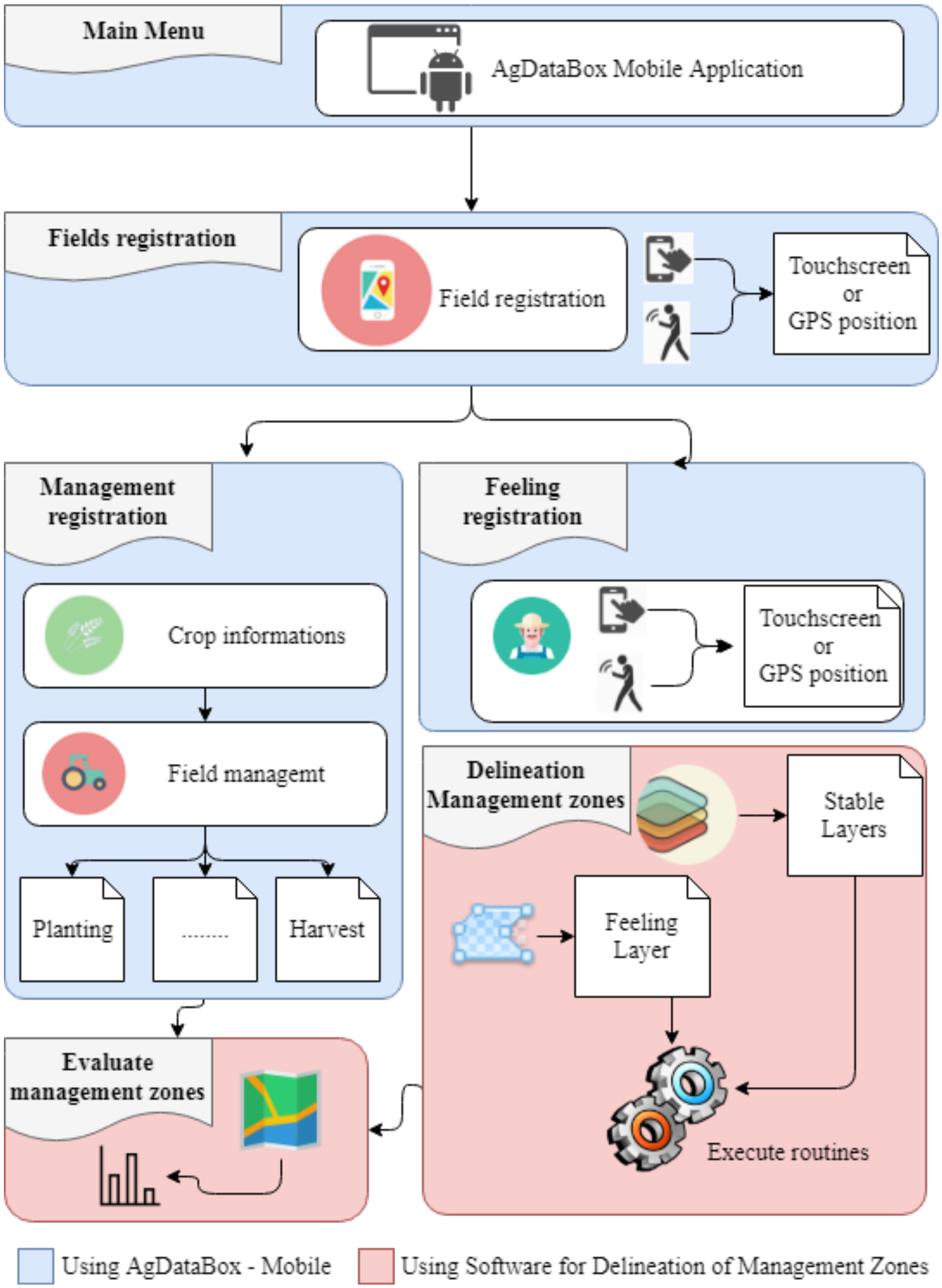


Fig. 1 - Operation flowchart of the AgDataBox Mobile application

According to the recommendations of Doerge (2000) and Fridgen et al. (2004), soil variables that were considered temporally stable were used in the process of defining the MZs (density, elevation (m), OM (%), sand (%), silt (%), clay (%), declivity (°), soil potential resistance - SPR 0-0.1 m (MPa), SPR 0.1-0.2 m (MPa), SPR 0.2-0.3 m (MPa) and soybean yield (Mg ha-1) and the farmer experience variable. The intention is for the variables considered in this process to conduct the delineation of the valid MZs for several years.

The farmer determined the experience variable through the AgDataBox Mobile app installed on a smartphone. The site was divided by him into three yield classes(high, medium and low) based on previous crop years, and the average yield was inserted in each class to create the numeric variable of farmer's experience.

To select the variables required to define the MZs using clustering methods, Cordoba et al. (2013) and Gavioli et al. (2016) compared some techniques by considering multivariate data sets for areas with spatial dependence. They demonstrated that the multivariate analysis technique based on the Moran´s PCA index (MULTISPATI-PCA) (Dray et al., 2008) provided the best results in most cases. Therefore, we used the approach proposed by Gavioli et al. (2016), called MPCA-SC, which is based on Moran's bivariate spatial autocorrelation statistic (Ord, 1975) together with MULTISPATI-PCA.

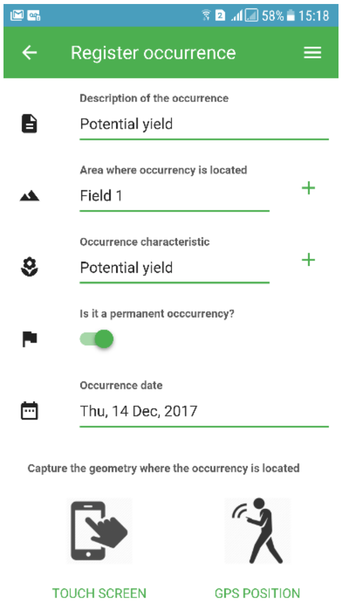
After interpolating the data using kriging, the data that resulted from the MSC1 and MSC2 variables were used as input of the Fuzzy c-means clustering algorithm in the SDUM software (Bazzi et al., 2013), considering the parameters of error = 0.0001 and weighted index 1.3, which delineated two, three and four MZs. Those MZs were evaluated quantitatively using the following indexes:Variance Reduction (VR) (Doberman et al., 2003; Xiang et al., 2007); Fuzziness Performance Index (FPI); Modified Partition Entropy (MPE); Smoothness Index (SI); and Analysis of Variance (ANOVA).

Results and discussion

The AgDataBox Mobile allows users to register fields, crop data, field operations (planting, harvesting and other applications carried out in each crop), machinery used in these operations, workers, and the definition of the farmer's experience variable.

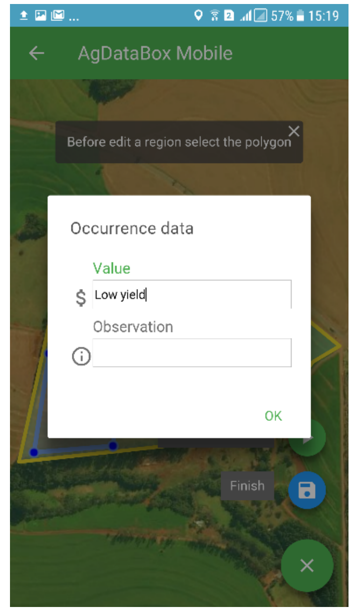
Recording the farmer experience variable can indicate different features, such as the estimated yield of a crop area, which is the variable used in the case study. But the farmer has the possibility to register information about regions where occurred erosion, diseases, pest-infest places and regions with plantation gaps or with climate problems that interfere with field operations, so they can keep track of the crop for future reference.

The trailing or selection method on the screen can be used to record the farmer's experience variable (Figure 2), define problem areas or expected outcomes, such as areas with low, medium or high yield. A description of the experience is recorded by selecting the type of practice, date in which this record was generated, and the field that will be recorded (Figure 2a). Once the experience is saved, users can view the area and start dividing the site into yield classes (Figure 2c). After selecting a sub-area of the plot (Figure 2d), users must enter the value of yield and a field of observation (Figure 2e). Users must define all the yield classes while dividing the plot. In this case, the divisions of expected yield were high (5000 kg ha^{-1}), medium (4500 kg ha^{-1}), and low (4000 kg ha^{-1}).



a)Recording the farmer's experience

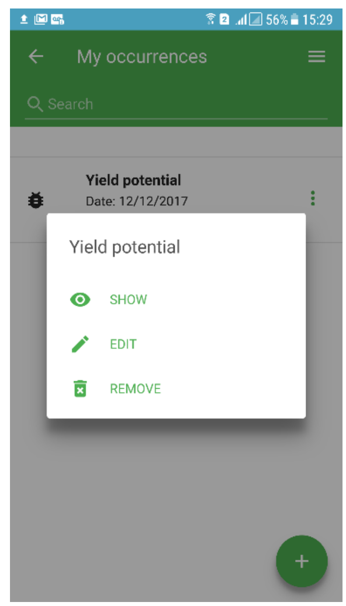
b) Defining the first yield level



c) Defining yield level

d) Division of the field

e) Delineation the third yield class



f) Experience recorded

Fig. 2 - Defining the farmer's experience

The MZ delineation methodology that uses the farmer's experience variable was tested in a case study in a commercial farming field. This layer corresponds to an estimate of high, medium and low yield defined by farmer demarcated using the AgDataBox Mobile app, as shown in Figure 3.

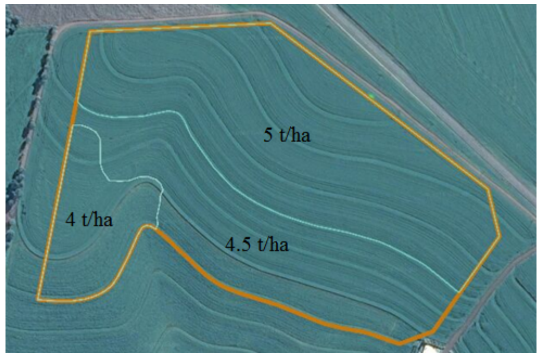


Fig. 3 - Variable farmer's experience obtained using AgDataBox Mobile

In addition to the farmer's experience variable, the variables MSC1 and MSC2 were generated using the variables altitude, clay, sand and SPR 0.0-0.1 m that were the variables that correlated with soybean yield and showed autocorrelation.

The MZs with two, three, and four classes (Figure 4) were delineated using variables MSC 1 and MSC 2.

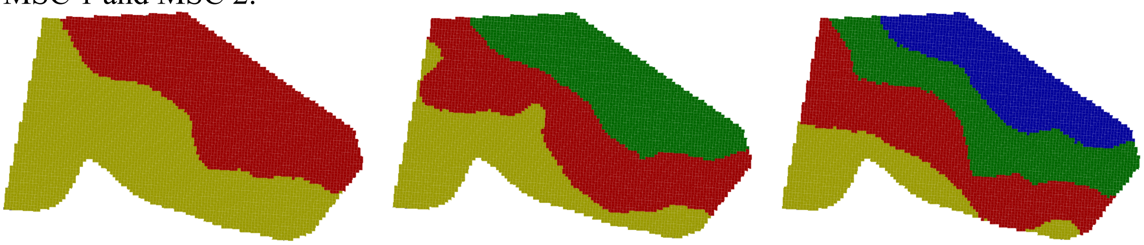


Figure 4. Management zones delineated using the main spatial components MSC1 and MSC2

The best statistical results for the MZs assessed using VR, FPI, MPE and SI (Table 1) correspond to the division into two MZs, since a higher SI (98.4%) and the lower FPI (0.14) and MEP (0.03) were obtained, with 55% reduction in the VRin each cluster in relation to total variance. However, when the field was divided in four classes it allowed the reduction of a greater percentage of data variance, which is expected when the fields are divided into more management classes. In addition, when two and three MZs were delineated, ANOVA indicated a different yield potential for each zone.

Table 1 **-** Evaluation statistics of the delineated management zones (MZs)

Number of MZ	MZ 1	MZ 2	MZ 3	MZ 4	VR (%)	FPI	MPE	SI
2	a	b			55.2	0.14	0.027	98.4%
3	a	b	c		53.7	0.25	0.050	96.8%
4	a	a	b	b	58.0	0.24	0.052	95.9%

VR – Variance reduction, FPI, Fuzziness Performance Index, MPE, Modified Partition Entropy, SI Smoothness Index.

Conclusion

The AgDataField-Mobile app is a user-friendly tool to record and manage information of field operations and can easily catch the farmer's experience and use it to delineate management zones for any crop. The farmer's experience layer can be easily obtained. So, the methodology, using this software may help the farmers to delineate management zones and use precision agriculture concepts at very low costs.

The gratuity of this software also makes the tool easier to be access by the farmers.

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