
# AgDataBox-Map: Web Application for Spatial Analysis and Management Zone Delineation for Dynamic Fruit Harvest in Precision Agriculture

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**A paper from the Proceedings of the**
**17th International Conference on Precision Agriculture and 11th Brazilian Congress on Precision and Digital Agriculture**
**13-15 July 2026**
**Porto Alegre, Brazil**

***Abstract.***

*Yield maps are fundamental tools in precision agriculture, as they allow for the evaluation of whether corrective actions taken before and during the season achieved the intended effects by visualizing production heterogeneity within the cultivation area. However, in fruit farming, the manual nature of harvesting has historically made the generation of thematic maps problematic. In Brazil, initiatives developed by the Federal University of Technology – Paraná (UTFPR) in partnership with Embrapa resulted in national fruit harvest mapping systems, contributing to the adaptation of this technology to local conditions and expanding its application across different production chains. Nevertheless, early implementations required a partially static workflow, relying on fixed collection points within the orchard. This did not accommodate practices used in large-scale operations, where bins for unloading harvest bags are itinerant, moved by tractors and trailers. Given this context, the objective of this experiment was to evaluate methods for processing harvest data and generating thematic maps using non-fixed unloading points. The advancement toward an itinerant harvest data collection system enabled the broader application of yield maps to different fruit harvesting systems. Furthermore, the algorithm created for generating thematic maps of itinerant fruit harvesting can be applied in automated precision agriculture tools such as AgDataBox-Map (ADB-Map)—a web-based solution focused on the analysis and visualization of agricultural spatial data, with an emphasis on using yield maps for management support. The algorithm was applied in an experiment conducted in partnership with the company RASIP in apple orchards, utilizing an innovative data collection system during harvest with itinerant unloading points. Harvest workers operated along the rows carrying bags equipped with sensors capable of recording bag identification and GPS position every six*

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*seconds, among other relevant information. These bags, which were previously unloaded into fixed bins positioned within the orchard, are now unloaded into bins transported continuously by tractor-pulled trailers (itinerant bins). This shift from a static to an itinerant system required the recalculation of bin location centroids during map generation. The data obtained were processed via an algorithm developed in Python, to be implemented in AgDataBox-Map in the future, enabling the generation of detailed yield maps and their use in delineating result-based management zones. The results demonstrate that the algorithm is a practical and efficient tool for transforming harvest data into useful spatial information, contributing to more precise and sustainable decisions in fruit farming.*

***Keywords.***
*precision agriculture; yield maps; decision making; fruit farming; management zones.*

## Introduction

Precision agriculture comprises a set of technologies and tools designed to improve crop management through the collection of geographically referenced information that supports decision-making to optimize inputs for profitability, environment protection and better workplace (Gebbers and Adamchuk 2010). Due to increasing demand for food-chain traceability, since the materials used for production, transportation, storage and processing, retailers and regulations require more information to assure food security (Gebbers and Adamchuk 2010). In this context, precision agriculture consists of a network of information obtained from remote sensing such as satellite images to get surface of soils or vegetation parameters, and proximal approaches to obtain more precise and localized data from sensors to read nutrient status of the soil, leaf mass/chlorophyll content, soil moisture, or yield maps, and with a myriad of information it can be determined if the spatial variability is seasonal, e.g., caused by pests, diseases, weeds, or temporal, e.g., soil properties, sloping terrain (Gebbers and Adamchuk 2010).

Monitoring yield spatiotemporal variability is one of the most important tools to support decision-making of agricultural systems, as with this information, it is possible to determine whether or not a zone in the field is worthwhile to invest in additional inputs in a specific zone, make an economic analysis of the areas, and decide what is necessary to enhance productivity, meaning the final result of all decisions made throughout the growing season (Longchamps et al. 2022). While yield mapping is a well-established technology in grain crops, especially in cropping systems that are harvested with combines, in perennial crops, on the other hand, this is still an issue (Longchamps et al. 2022). To address this problem, a datalogger that recorded GPS coordinates every six seconds and an RFID sensor were attached to harvest bags. One method estimated harvest locations by calculating centroids along tree rows based on the coordinates recorded while workers harvested fruits and by calculating additional centroids at fixed discharge bins located between the rows. A second method divided the orchard into individual tree grid cells and used GPS coordinates together with the estimated weight of a full harvest bag to estimate the yield within each grid cell (Bazzi et al. 2022).

The methods above presented were made for harvesting conditions where the unloading point is fixed, as commonly found in smaller scale orchards where the bins are spread between the rows. Thus, this work proposed to use the same equipment in an apple harvest with itinerant discharge bins, and develop a Python algorithm to create yield thematic maps for larger scale orchards, in which the discharge bins are itinerantly transported with apple bin trailers coupled to the tractor.

## Material and methods.

The experiment was carried out at a commercial orchard belonging to Rasip company, located in the municipality of Vacaria, Rio Grande do Sul, Brazil with geographical coordinates -28.536775, and -50.834190, in an orchard area of one hectare and fully covered with white-color hail netting. The orchard was planted with apple cultivar Gala, with Fuji trees used as pollinizers. For this experiment, ‘Gala’ apples were harvested. The experiment was conducted on February 4, 2025. Seven workers were randomly selected to carry harvest bags equipped with the devices, so when unloading the bags into the apple bins RFID tags were attached to the sides of the bins, so every time the workers approached a bin to unload the harvest bags, a reading was made and saved in the datalogger. Throughout the day, the number of filled bins was also recorded to compare the estimated and the real amount of fruit harvested.

A polygon was made around the whole area with QGIS with extension .gpkg, so in Python software version 3.10.11 (van Rossum 2023) it was left only the data within the area. The script identified each RFID reading and divided 15 Kg with the number of GPS coordinates until the previous RFID reading. Thus, each coordinate was assigned a corresponding weight (Kg), which fell inside each grid of 10×10 meters. The sum of the weights inside each grid was calculated and ordinary kriging was performed.

## Results and discussion

After the conclusion of the experiment, all devices were collected from the workers, and data stored in the MicroSD was retrieved to be analyzed with the script. Figure 1 depicts the location of the unloading points where each harvester approached the device onto the RFID tag attached to each bin. Some regions of concentration can be observed, likely due to high fruit load and many refills and unloads of the harvest bags. A total of 375 RFID readings (unloads) were recorded, which corresponded to 5625 Kg of calculated harvest, whereas the estimated real harvest was 5120 Kg, considering 16 bins harvested and an average of approximately 320 Kg per full bin.

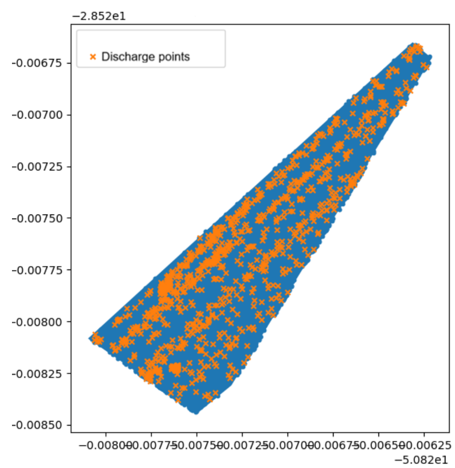


**Figure 1** Geographical depiction of the discharge points in the itinerant harvest bins.

The 15 kg corresponding to the approximate capacity of a fully filled harvest bag was divided by the number of GPS coordinates recorded between two RFID readings. This procedure allowed a weight value to be assigned to each coordinate and subsequently aggregated (summed) within each 10 × 10 m grid, as seen in Figure 2. A total of 97 grids were formed. Apple harvesting is usually performed in two or three passes. With this single pass it was possible to identify variability in the area, which could be because of high number of fruits per tree, taller trees, requiring more bag refills and unloadings, a microregion in which fruits ripened earlier, etc.

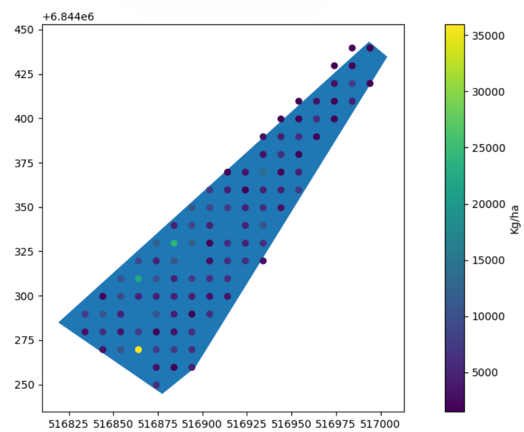


**Figure 2** Sum of weights inside each 10×10 meters grid. Data converted to Kg per hectare.

After calculating the sum and the yield of each grid data was subjected to ordinary Kriging to generate a thematic map as depicted in Figure 3. The thematic map displayed basically two regions of high yield and a region of low yield. Yet a thematic map was generated, the pipeline has to be improved, as the calculated yield by the ordinary kriging was 6154 Kg, being 20.2% overestimated.

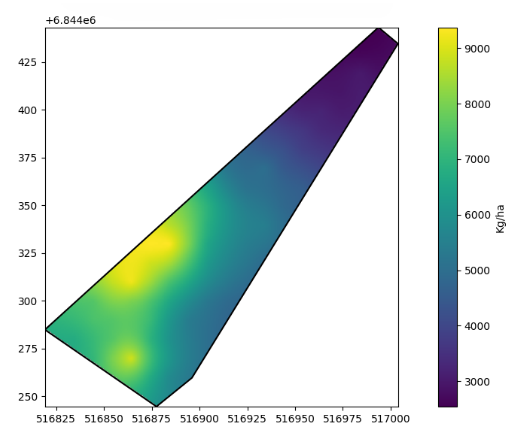


**Figure 3** Thematic map depicting yield variability of an orchard of 'Gala' apples

## Conclusion

The creation of yield thematic maps for perennial crops adds an additional layer of information, which along with other layers of information such as soil moisture, slopes, fertility, NDVI, etc., could support the delineation of management zones and support decision-making at a local level, rather than an average of whole plots, as done nowadays. The system proved to be functional with fixed harvest bins in the middle of the rows, and has now been shown to be applicable to harvest systems using itinerant bins that are commonly used in large orchards. When ready, the algorithm will be implemented in the freely available online software AgDataBox (Franz et al. 2026) for use by farmers.

## Acknowledgments

This research was funded by FAPESP – São Paulo Research Foundation (Proc. 2022/09319-9 for funding and Proc. 2025/28583-7 and Proc. 2025/05910-2 for scholarship grant), under the CCD-AD/SemeAr Project. The authors also acknowledge Embrapa Grape and Wine for their institutional support..

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