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IDENTIFICATION OF PLANTS IN CITRUS ORCHARDS USING REMOTE SENSING

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ABSTRACT
The use of Unmanned Aerial Vehicles (UAVs) or drones to capture images is increasingly common due to the physical and spatial resolution of this technology. In agriculture, one of the remote sensing methods that can be performed to characterize and monitor crops is Aerial Photography Analysis. In this context, the objective was to evaluate the potential of data collection with drones and the use of SAGA GIS software for the detection of trees in a citrus orchard in the municipality of Itabaianinha- SE. The flights were carried out on August 3, 2024, at different heights and with overlapping of different images. The time spent on processing in different qualities and different parameters to which the images

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Revista ARACÊ
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were subjected was evaluated to establish the best protocol for working with images obtained through remote sensing. The results generated were analyzed in Precision and Recall indices. All data generated were subjected to statistical analysis to prove their efficiency. Among the processing qualities analyzed, the low quality in flight at 120 meters in height with an overlap of 70 x 80, subjected to the parameters of radius of 10 and standard deviation of 2 in SAGA GIS, proved to be more efficient and closer to reality when compared to the others. It is concluded that remote sensing applied with drones enables more efficient management of crops.

Keywords: Digital Agriculture. Tree Counting. Aerial Photogrammetry.

INTRODUCTION

Fruit growing is a prominent activity in the Brazilian agricultural sector, providing a wide range of fruits throughout the year, due to favorable climate conditions, efficient agricultural practices, and investments in science and technology. The excellence and variety of fruit production in Brazil have stimulated the expansion of the sector on the global stage, making the country the third largest fruit producer in the world, with more than 40 million tons per year.

According to the July report by the United States Department of Agriculture (USDA), Brazil leads the global production of oranges and orange juice, while China dominates the production of tangerines and grapefruits, and Mexico is the main producer of lemons and limes.

In the establishment of orchards, the acquisition of seedlings plays a crucial role, being one of the main factors that influence the long-term success of production. According to a study by Pinheiro et al. (2019), the acquisition of inputs presented a higher cost in the year of implementation, where the purchase of certified seedlings is the most relevant item.

Given the great importance of fruit growing and the growth of cultivated areas, it is crucial to have accurate data on the number of fruit trees, both to calculate the survival rate of the plants and to monitor their productivity. The advancement of unmanned aerial vehicles (UAVs), also known as drones, and multispectral on-board sensors, presents a watershed for agriculture, as it defines new standards of remote sensing with greater accuracy, regularity, and quality of the information collected. With the use of UAVs, georeferenced data on crops can be collected, depending on the type of sensor used. It is also possible to investigate the different regions of the electromagnetic spectrum through digital image processing.

The effectiveness in identifying and quantifying fruit trees is linked to the spatial resolution of the image; the predominance of the tree in the orchard in terms of overlap, crown union, branch separation, and target geometry; the topography of the site and, mainly, the type of sensor used in the image acquisition process. All of these elements have the potential to facilitate or complicate tree counting.

The automated analysis of digital images is quite complex, especially in the identification of vegetation, when considering its morphometric parameters, which are often variable in natural conditions. OjedaMagaña et al. (2020) argue that individual detection is compromised precisely by the difficulty in defining the area of each tree, whether when the

Revista ARACÊ
ISSN: 2358-2472

shadow of a tree is projected onto itself or when it is projected onto the ground where the tree canopy and the shadows have similar colors, or even when the canopy of a tree has several areas. Thus, the present study aimed to develop a protocol for the remote identification and counting of trees in citrus orchards in the municipality of Itabaianinha, in Sergipe, based on images obtained by drone and processed in easily accessible software.

THEORETICAL FRAMEWORK

ORANGE CULTURE

The genus Citrus, belonging to the Rutaceae family, has its probable center of origin in Southeast Asia. However, its taxonomy is quite controversial, since some authors base their classification method on different aspects, such as Tanaka (1977) who considers morphological characteristics and proposes a total of 162 species, while the one suggested by Swingle & Reece (1967) encompasses only 16 species, focusing their thesis on the biological concept. Among the species belonging to this genus, the sweet orange tree, with the scientific name Citrus sinensis L. Osbeck, arose from the natural hybridization of the species Citrus maxima (grapefruit) and Citrus reticulata (tangerine) and was introduced to Brazil by the Portuguese at the beginning of the colonization of the lands, in the mid-1500s (Embrapa, n.d.b; Fernandes, 2010).

The adaptation of the orange nationally was so successful that over time, the country became a major producer and occupied the first position in the world ranking of production of this fruit according to the FAO (2022). Brazil managed to produce almost 20 million tons in 2023, double the production in 2019.

Although São Paulo is the largest national producer, Sergipe is the 4th largest orange-producing state in the country, even with a smaller territory and a harvested area about 10 times smaller than the first place, according to IBGE data from 2022.

The origin of Sergipe's citrus industry occurred with the arrival of grafted Bahia Orange (Navel Orange) seedlings on Sour Orange (Land Orange), brought by cattle drivers from Alagoinhas-BA. During the 1970s and 1990s, cultivation grew and expanded throughout the state, occupying areas previously destined for other activities and favoring the adoption of new technologies.

Currently, the citrus hub of the state of Sergipe has a production of approximately 13.82 t/ha, which characterizes it as the second place that produces the most oranges in the Northeast, behind only Bahia (IBGE, 2022).

Revista ARACÊ
ISSN: 2358-2472

PRECISION AGRICULTURE

Precision Agriculture (PA) can be defined as a system that assists in agricultural management, based on the temporal and spatial variation of the production unit, to contribute to sustainability, and reduce environmental impacts, in addition to adding economic gain to the property (BRASIL, 2012).

Given this concept, Bernardi et al. (2014) agree that because Brazilian agriculture is directed towards efficient production with practices to mitigate damage to the environment, precision agriculture is a good option to meet the proposed objective, including in the national fruit growing scenario.

Lamparelli, Rocha, and Borghi (2016) describe Precision Agriculture (PA) as a set of techniques that, when considering aspects such as location, soil fertility, and other factors, allow specific management in cultivated areas. This enables the optimization of the use of inputs and the achievement of better crop performance.

The application of PA in the production unit provides a broad knowledge of production, which contributes positively to decision-making (Pontes & Cavichioli, 2018). Among the steps to implement PA in the production system, the following can be mentioned: intensive monitoring, generation, and integration of maps, in addition to the systematization of agronomic modeling (De Oliveira, 2009).

Data collection for application in PA can be performed, among other ways, through remote sensing, without physical contact with the object of analysis (BERNARDI et al., 2014).

REMOTE SENSING

According to Arantes et al. (2019), Remote Sensing is a precision agriculture methodology that aims to detect and quantify problems spatially and enable targeted management that seeks to solve potential problems during the crop cycle. Through it, it is possible to establish planting lines to maximize the use of the area and the distribution of agricultural equipment. One of its advantages is the targeted application of herbicides, which considerably reduces costs and mitigates the effect on the environment.

One of the remote sensing tools used in precision agriculture are unmanned aerial vehicles (UAVs), also called drones. These devices have become more accessible with current technological progress that offers compact and low-cost equipment, in addition to meeting the demand for greater production efficiency, which has resulted in greater adoption of their use in the field (Oliveira et al., 2020).

Also according to Oliveira et al. (2020), the use of drones follows the steps of: flight planning, flight with overlap, obtaining georeferenced images, image processing, mosaic generation, analysis in a GIS tool, and report generation.

This corroborates what Pádua et al. (2020) state about the use of georeferenced images to obtain digital elevation models (DEM), orthophoto mosaics, and spectral indices, among other digital processing products.

AERIAL PHOTOGRAMMETRY

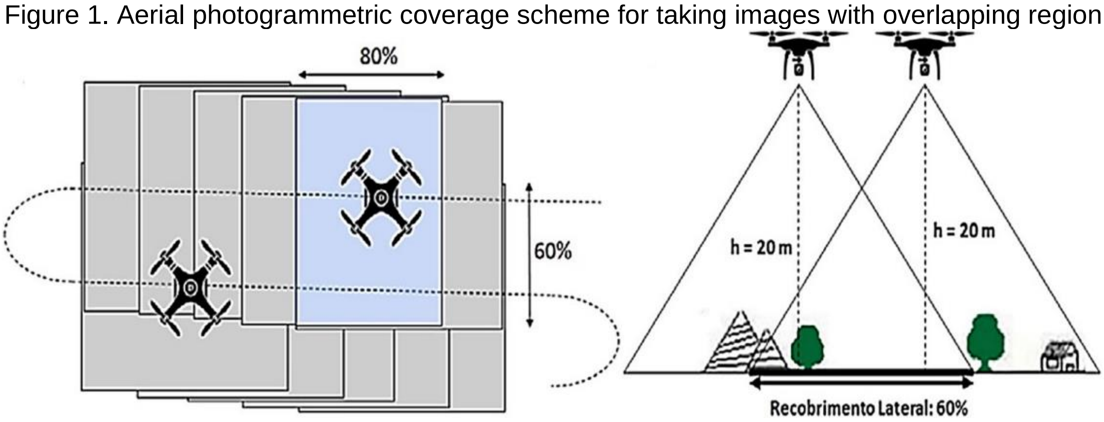
Aerial photogrammetry is a method of collecting geospatial data that uses aerial photographs obtained by sensors or cameras on board aircraft, such as drones or airplanes. This approach integrates remote sensing and enables the three-dimensional reconstruction of areas from a series of two-dimensional images. It is frequently used in several fields, including mapping, environmental assessments, and territorial planning (Cotomácio and Lima, 2020).

According to Wolf (1995), photographs of an object can be categorized based on their geometry, and are classified as high oblique, low oblique, and vertical. Vertical photography occurs when the optical axis of the camera of the photographic equipment is aligned perpendicularly with the terrain. However, photographs with a non-perpendicular axis are not appropriate for mapping due to geometric restrictions and accentuated distortions (Ruy, 2008).

According to Silva Júnior (2019), another factor in aerial photogrammetry is aerial photogrammetric coverage, which refers to the representation of the terrain through sequential photographic images obtained along a flight area. To ensure full coverage, a minimum longitudinal overlap of 60% between consecutive photographs and a lateral overlap of at least 30% between parallel strips is required. This ensures repeated photography of points on the surface, preventing failures and enabling the obtaining of three-dimensional measurements (Figure 1).

Revista ARACÊ
ISSN: 2358-2472

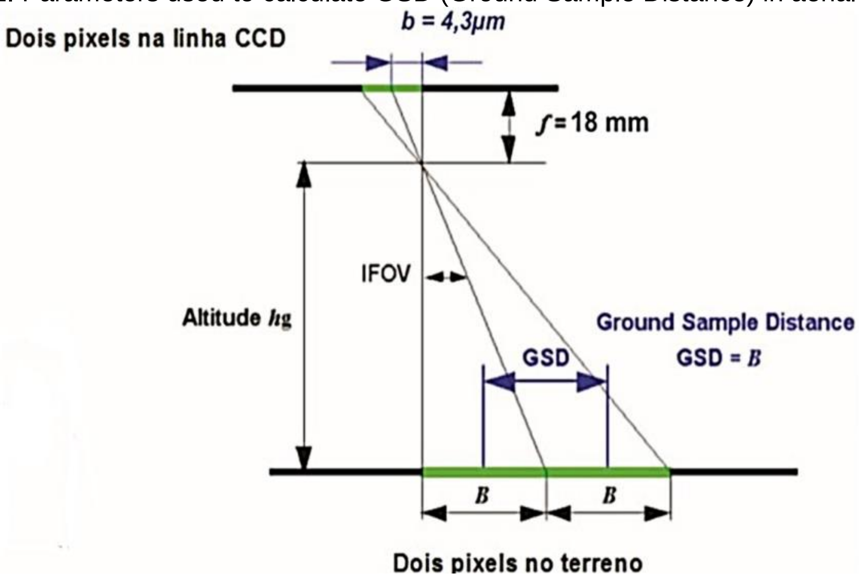
Figure 1. Aerial photogrammetric coverage scheme for taking images with overlapping region



Sá (2022)

According to Cunha et al. (2016), when linking the pixel to the scale of the photographed object, that is, when the pixel size represents a real distance on the ground, the image resolution is established, also called GSD (Ground Sample Distance). The height of the photograph about the ground, the focal distance of the camera, and the pixel size on the sensor are directly linked to the GSD, thus, there is a different GSD value at each flight height (Figure 2).

Figure 2. Parameters used to calculate GSD (Ground Sample Distance) in aerial images



Fonte: Sá (2022)

To determine the GSD, equation 1 is used with the following parameters::

$$GSD = \frac{(h_g \; x \; b)}{f} \qquad \text{(Eq.1)}$$

Revista ARACÊ
ISSN: 2358-2472

Where:

b - Sensor pixel size

f - Lens focal length

hg - Flight height

GSD - Ground Sample Distance - Distance between the center of two neighboring pixels

The value provided by the GSD is directly related to the degree of detail of the aerial survey; that is, the higher the GSD, the lower the degree of detail, and conversely, the lower the GSD, the higher the degree of detail. The GSD is directly related to the quality of processing to which the images are subjected, reflecting the final result of the digital products (Giovanni, 2021).

According to Herreros (2015), the digital results from aerial photogrammetric mapping can be two-dimensional or three-dimensional. In three-dimensional space, it is possible to create point clouds, as well as digital topography and terrain models. On the other hand, orthophotos and orthomosaics are examples of two-dimensional products.

Orthophotos are photographs of the terrain that have been corrected, showing the objects in their true orthographic positions (Wolf, Dewitt, and Wilkinson, 2014). In addition, from the processing of images obtained by satellites or drones, it is possible to create three main types of digital models: the Digital Elevation Model (DEM), which encompasses the elevation of the terrain and the plant canopy; the Digital Terrain Model (DTM), which reflects the elevation of the terrain, ignoring elements above the ground; and the Digital Surface Model (DSM), which records all existing elevations, such as buildings, roads and trees (Hyslop et al., 2020).

METHODS FOR DETECTING TREE

Normally, the process of counting plants is done manually by field workers. Although this method is very accurate in identification, it becomes quite inefficient due to the large number of man-hours required (Abidin et al., 2017).

Therefore, it is necessary to find ways to make this procedure more efficient. Therefore, software or plugins are used to perform this action more quickly and efficiently, requiring less labor to obtain the result. Among them is the SAGA System for Automated Geoscientific Analyses (SAGA GIS).

SAGA was created in C++ language and is compatible with Linux and Windows systems. In tree identification, the Gaussian filter is crucial, as it works as a smoothing operator that eliminates noise and details from the data. The smoothing level is adjusted using the standard deviation, where higher values require a larger search radius. The Standard Deviation variable, indicated as a percentage of the kernel radius, regulates the smoothing level of the data grid, with values ranging from 0.0001 to 1 (default). On the other hand, the Search Radius parameter determines the radius of the nucleus in the cells (Sá et al., 2021).

METHODOLOGY

The study was developed in a citrus grove located in the municipality of Itabaianinha-SE, in the south of Sergipe (11º16'39" S 37º47'11" W). The climate of the region is characterized by the concentration of rainfall during April and September, with the period between October and March marked by drought. It has a relative humidity of around 81% and an average temperature of 24 ºC (CINTRA, 2006).

In this location, Tahiti lime (Citrus latifolia Tanaka cv. Tahiti) and pear orange (Citrus Sinensis L.) are cultivated in an area of approximately 11 ha, aged 5 years after planting.

The images were obtained through flights in the area of interest, using the DJI Mavic 3 Multispectral RTK drone (DJI MAVIC, 2024) with an imaging system consisting of an on-board RGB camera with a 20 Mp 4/3 CMOS sensor, FOV 84° (24 mm equivalent format) and aperture of f/2.8 to f/11, and four multispectral cameras (green, red, red edge and near-infrared), with a 5 Mp 1/2.8" CMOS sensor, FOV 73.91° (61.2° x 48.10°) (25 mm equivalent format) and aperture of f/2.0.

The images of the property were collected on August 3, 2024, with flight plans by Brazilian legislation. The camera was angled at a 90º angle about the drone so that it was positioned directly towards the ground.

Table 1 shows the 12 treatments used for this study.

Table 1. Image processing quality (Low, Medium, or High), Flight Height (100 and 120m), and Image Overlap (70x80 and 80x80 - % x %), respectively

Treatment	Processing quality	Flight height (m)	Image overlap (% x %)
B1	Low	120m	70x80
B2	Low	120m	80x80
B3	Low	100m	70x80
B4	Low	100m	80x80

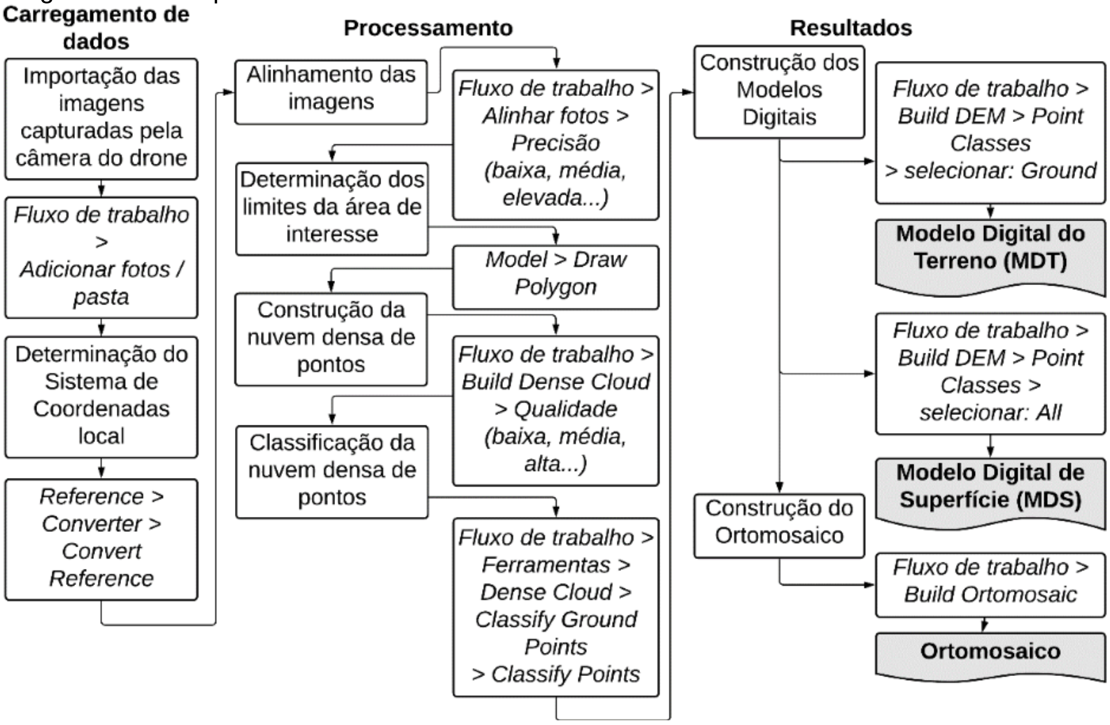
M1 Medium 120m 70x80
M2 Medium 120m 80x80
M3 Medium 100m 70x80
M4 Medium 100m 80x80
A1 High 120m 70x80
A2 High 120m 80x80
A3 High 100m 70x80
A4 High 100m 80x80

The variables analyzed were: Image processing time; GSD (Ground Sample Distance) of the MDS (cm/pixel) and the Orthomosaic (cm/pixel), which refers to the height of the photograph about the ground, in which higher values indicate a lower quality and detail in the processing of the images. In addition, the Percentage of Correct Points, which indicates the quantity in % of points read by the processing equivalent to the real points of the study site indicated by the template - in this case, each mapped point must represent a plant; the Degree of Precision and Degree of Recall, referring to the value of the radius and standard deviation applied in obtaining the image; and the True Positives (VP), points equivalent to the plants identified by the template of the real area; False Negatives (FN), that is, trees that exist in the area but were not detected by the software; and False Positives (FP), points identified by the software but that do not exist in the real area.

For the processing of the images and other steps necessary for the development of this work, a computer with an Intel Core i9-13900KF processor and NVIDIA GeForce RTX 3060 graphics card were used. The steps were carried out according to the methodology proposed by Sá et al. (2021) using the Agisoft Metashape® software version 2.1.0 to subsequently obtain the digital products: digital surface model (DSM), digital terrain model (DTM) and orthomosaic (Figure3).

Revista ARACÊ
ISSN: 2358-2472

Figure 3. Processing steps of images obtained with UAV in a citrus orchard to generate digital products in the software Agisoft Metashape®



Source Sá (2022)

Since we worked with a multispectral camera, images in “TIFF” format were imported. The coordinate system used was SIRGAS 2000 / UTM zone 24S.

After aligning the photos, the points outside the area of interest that presented a high amount of noise were manually cleaned using the Free-Form Selection tool and then removed. This step is important because it aims to eliminate any point considered to be an elevation that is not in the area of interest of the study so that they do not interfere with the generation of digital products (MDS and MDT).

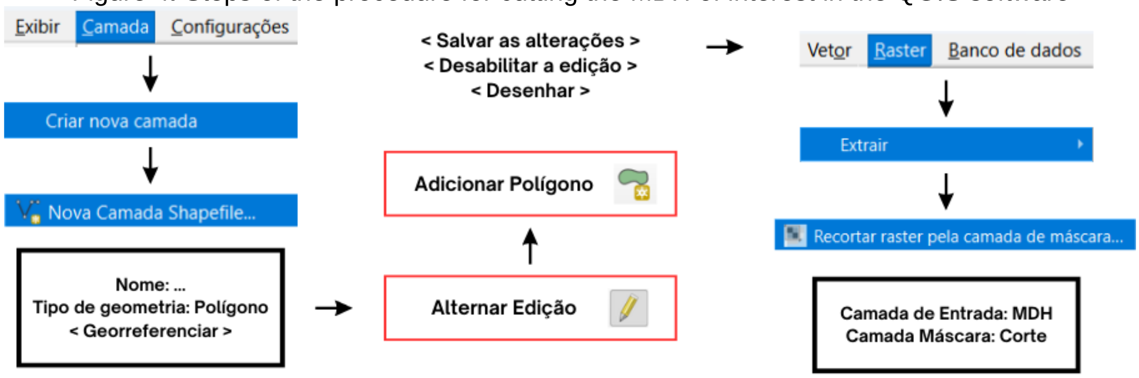
For the classification of the point cloud, the values of 15º for angle, 0.10 for maximum distance, and 50 m for cell size were used. According to the Agisoft software user manual, the "angle" parameter is related to the angle between a point on the terrain and the point to be classified - If the angle is less than 6º, the point is classified as part of the terrain, otherwise, it is not. The "maximum distance" parameter defines the distance limit between two points. If it is less than 1 meter, the point is classified as terrain; if it exceeds this distance, it is not. In turn, the "cell size" refers to the largest object that does not belong to the terrain, such as treetops, buildings, and vehicles, among others.

After acquiring the MDS and MDT, the QGIS software version 3.38.1 was used to create the Digital Height Model (DHM) using the “Raster” tool, and the equation DHM =

Revista ARAÇÊ
ISSN: 2358-2472

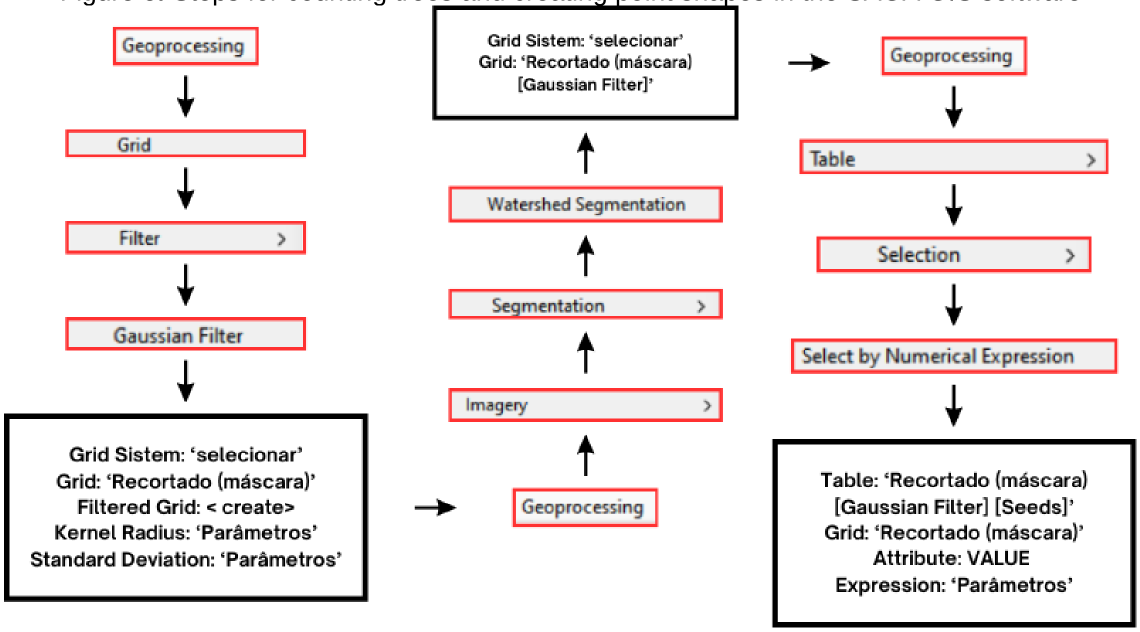
DHM - DHM was applied in the “Raster Calculator”. This resulted in the product of the subtraction of the DHM and MDT in GeoTIFF format, which was later subjected to the section of interest with an area of 5.5 ha. The targeted area was 5.5 ha. The cropped product was then exported in GeoTIFF format to be worked on in the SAGA GIS software version 9.3.1. (Figure4).

Figure 4. Steps of the procedure for cutting the MDH of interest in the QGIS software



With the SAGA GIS interface open, the generation of the tree count product in shapefile format was worked on, in which each tree was represented by a point, where 2 procedures were carried out with different variables to verify the performance of the method in the different processing qualities (Figure 5).

Figure 5. Steps for counting trees and creating point shapes in the SAGA GIS software

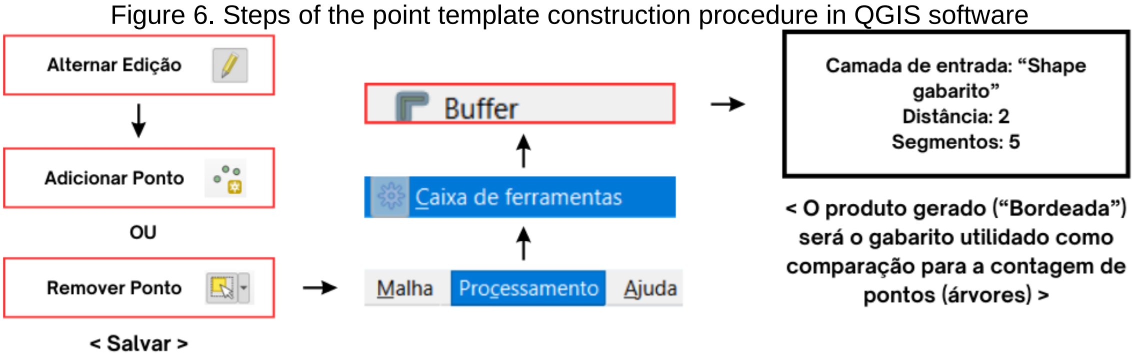


In procedure 2, values of 10 and 2 were used for the Kernel Radius and Standard Deviation parameters, respectively. In procedure 2, these values were 30 and 6,

Revista ARACÊ
ISSN: 2358-2472

respectively. The parameters for cleaning points outside the area of interest (between lines) were “a > 3” and “a < 0.5”, where the Select by Numerical Expression tool was applied, a step that selects points based on the height values identified by the software in the VALUE attribute. Then, the respective points in selection were deleted and the product was exported in shapefile format to be worked on in QGIS. To compare the points generated in SAGA GIS, a layer was created with all the real trees represented by point. For this, one of the shapes generated in SAGA GIS was duplicated and points were added or removed in order to have a representation closer to reality, using the Buffer tool in QGIS, where an expansion of each point was made (Figure 6).

Figure 6. Steps of the point template construction procedure in QGIS software



This layer, called “bordered”, served as a comparative template for evaluating the Percentage of Correct Points.

Then, the respective shape of each treatment was imported into QGIS and compared based on the template. For this, the “Polygon Point Count” tool in the toolbox was used. In “Polygons”, the template generated in QGIS was used, and in “Points”, the shape generated by SAGA GIS. Soon after, the product of this step, called “Count”, was exported in CSV format (comma separated value) in order to be worked on in EXCEL, in which the NUMPOINTS column represents the number of points arranged in each Buffer. The efficiency of each variation for counting trees in a citrus orchard was verified based on the Precision, Recall and F1 - Score indexes (Equations 2, 3 and 4 respectively). In order to find these values, the CSV data generated by QGIS were imported into an EXCEL spreadsheet and equations 5, 6 and 7 were applied to VP, FN and FP, respectively, with “X” being the data range of interest (NUMPOINTS).

Precision = TP / (TP + FP) (Eq. 2)
Recall = TP / (TP + FN) (Eq. 3)
F1-Score = 2 × (Precision × Recall) / (Precision + Recall) (Eq. 4)

Revista ARACÊ
ISSN: 2358-2472

=COUNTIF(X, “=1”) (Eq. 5)
=COUNTIF(X, “=0”) (Eq. 6)
=COUNTIF(X, “>1”) (Eq. 7)

The data was loaded and processed using the pandas library (version 3.6). Descriptive statistics were calculated using the numpy library (version 1.24.0) for exploratory data analysis. The graphs were created using the matplotlib.pyplot library (version 3.9.10) for data visualization and pattern identification. All data analyses were performed using the Python programming language (version 3.9.13) in the Visual Studio Code (VSCode) environment (version 1.86.2), a popular IDE for software development that provides an intuitive interface and features for Python programming.

RESULTS AND DISCUSSIONS

PROCESSING TIME AND GSD

Below are the processing time and GSD values of the digital products obtained for each processing quality (Table 1).

Table 1. Parameters of digital image processing obtained by UAV over an orange orchard in the municipality of Itabaianinha-SE

Treatments	Processing Time	GSD of DSM (cm/pixel)	GSD of Orthomosaic (cm/pixel)
B1 - Low/120m/70x80(mxm)	03 min 18 sec	41.6	5.76
B2 - Low/120m/80x80(mxm)	04 min 35 sec	46.0	5.75
B3 - Low/100m/70x80(mxm)	04 min 18 sec	38.6	4.83
B4 - Low/100m/80x80(mxm)	07 min 24 sec	38.6	4.83
M1 - Medium/120m/70x80(mxm)	09 min 05 sec	23.0	5.76
M2 - Medium/120m/80x80(mxm)	10 min 18 sec	23.0	5.76
M3 - Medium/100m/70x80(mxm)	08 min 29 sec	19.3	4.83
M4 - Medium/100m/80x80(mxm)	14 min 43 sec	19.3	4.83
A1 - High/120m/70x80(mxm)	17 min 10 sec	11.5	5.76
A2 - High/120m/80x80(mxm)	24 min 51 sec	11.5	5.76
A3 - High/100m/70x80(mxm)	22 min 42 sec	09.7	4.84
A4 - High/100m/80x80(mxm)	35 min 56 sec	09.7	4.83

Based on the obtained data, it is possible to observe that the GSD values of the orthomosaic were very similar across all processing qualities, with variations occurring only at different flight altitudes. Treatments with lower flight heights (100 m) showed lower GSD values, indicating higher quality due to the expected increased level of detail from being closer to the ground. In their research, Zaghuini et al. (2023) found a similar GSD behavior

Revista
ARACÊ
ISSN: 2358-2472

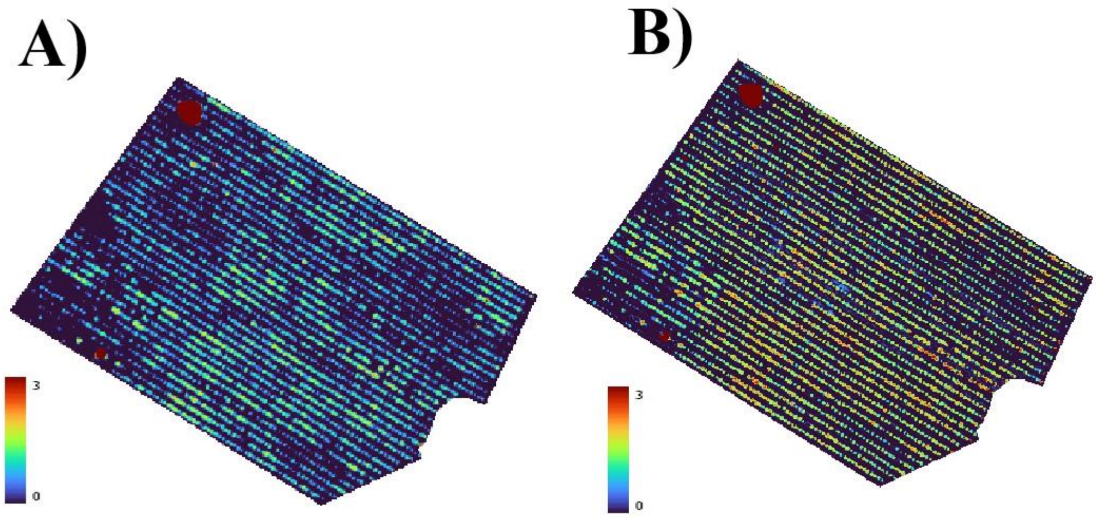
when processing images from flights at different altitudes to identify and measure defects in flexible pavements, where higher flights resulted in proportional GSD values that were unable to detect certain ground details.

However, regarding the time required to obtain digital products, the results showed significant differences. Compared to the low-quality treatments, the medium classification required three times more processing time. Meanwhile, for high-quality treatments, this value was five times higher due to the degree of detail in the images subjected to higher-quality processing. Regarding the GSD of the DSM, processing quality had a nearly 100% reduction between each applied quality, meaning that treatments with higher quality stood out for this variable.

Thus, considering time efficiency, treatments B3 and B4 proved to be the best alternatives for obtaining orthomosaics, as they deliver images with lower GSD values and are seven times faster than high-quality processing.

There were no changes regarding overlap, a result similar to that obtained by Berci et al. (2023), who concluded that increasing overlap does not necessarily improve quality to justify using a better pixel resolution. However, increasing the GSD resulted in lower-quality images (Figure 7).

Figure 7. MDH obtained by processing low (A) and high (B) quality images, from flights at 120 meters with 70 x 80 overlap and 100m with 80 x 80 overlap, respectively



For heights, in High quality, the value of 11.5 cm/pixel (A1 and A2) drops to 23.0 cm/pixel on average (M1 and M2), and 41.6 cm/pixel on low in the 2 overlaps analyzed at a flight height of 120 m (B1 and B2). In the 100 m flight, these values went from 9.67

Revista ARACÊ
ISSN: 2358-2472

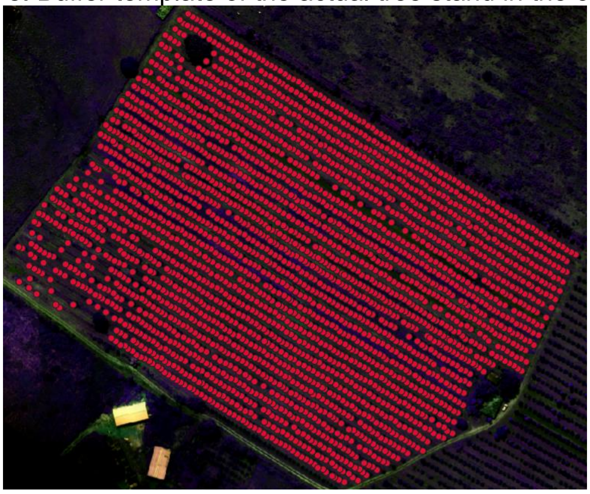
cm/pixel in High quality (A3 and A4) to 19.3 cm/pixel on average (M3 and M4), and 38.6 cm/pixel on the lowest (B3 and B4). These differences should be taken into account because they affect the plant identification capacity, since it is expected that the lower the flight height, the greater the detail and, consequently, the lower the GSD values. This corroborates what was said by Giovanini (2021), who states that the value provided by the GSD is directly related to the degree of detail of the aerial survey; that is, the higher the GSD, the lower the level of detail, while the opposite is also true. The result presented shows that there is a better representation of the real elevation of the area due to the lower GSD value.

From this, it can be said that B1 was the treatment that stood out the most in the time evaluation, which was expected due to the smaller amount of pixels processed. A4 stood out in the GSD variables of both the MDS and the Orthomosaic, however, when it comes to time, treatment A3 stands out, as it presents image quality that is as superior as A4 in less processing time. Evaluating only the GSD of the Orthomosaic and time, treatments B3 and B4 stand out, however, they are among the lowest quality, in relation to the GSD of the MSD.

PERCENTAGE OF CORRECT POINTS

After demarcating the points and constructing the template with the Buffer tool, the real stand was determined with the presence of 2,761 trees in the area of interest of the orchard (Figure8).

Figure 8. Buffer template of the actual tree stand in the orchard



In view of this, the percentages of detected points were determined for the values of

Revista ARACÊ
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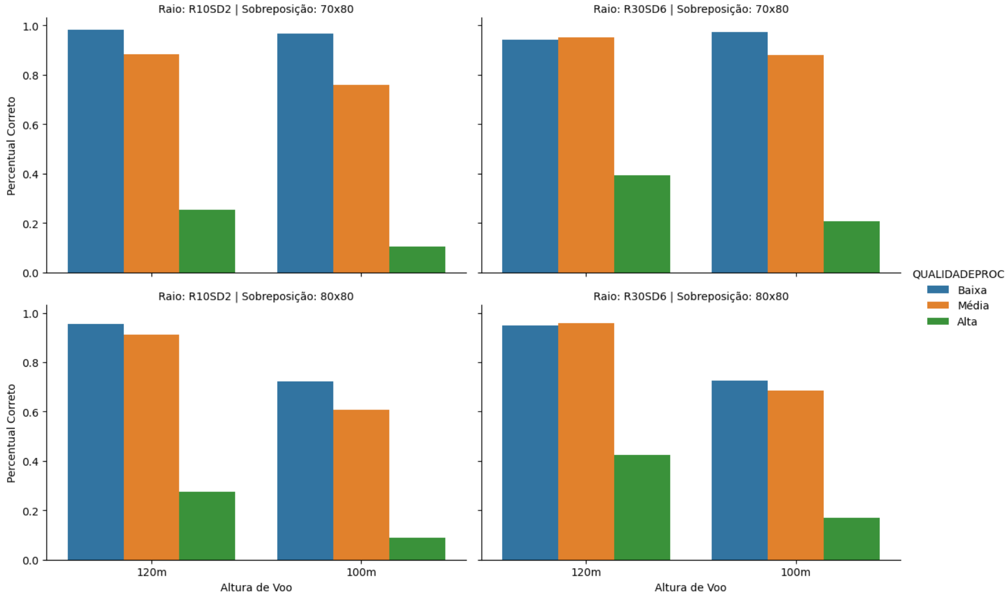
flight height, radius and standard deviation and overlap, in different processing qualities (Figure 9).

Figure 9. Percentages of correctly detected points for: flight height, radius and standard deviation and overlap, for different processing qualities



Based on the percentages analyzed, it can be stated that low-quality processing showed a greater number of correctly demarcated points in all variables analyzed, except in treatments with a flight height of 120 meters subjected to parameters of 30 and 6 for Kernel Radius and Standard Deviation, respectively, in which the average quality demonstrated slightly better performance.

On the other hand, high-quality treatments did not obtain the expected performance, since they presented the lowest values for all parameters. This may have occurred due to the greater number of cells in the same space due to the GSD value, that is, the higher the processing quality, the lower the GSD and, consequently, the greater the number of points demarcated in the same area.

It is also evident that the results of the flight height of 100 meters and image overlap of 80x80 presented the lowest percentages of correctly detected points in all processing qualities. This differs from what was found by Reis (2020), who concluded that a lower flight height proved to be more efficient in detecting planting failures in sugarcane. In other words, images with a higher degree of detail, such as treatment A4, are more recommended for detecting grasses, while for identifying tree species they proved to be ineffective due to interference from weeds around the canopy.

Revista ARACÊ
ISSN: 2358-2472

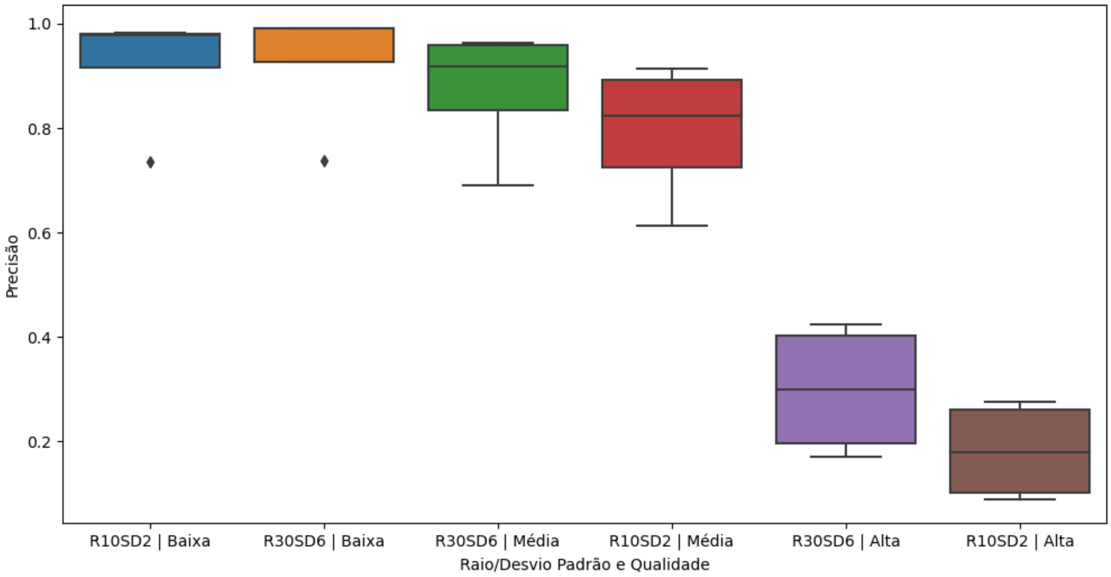
DEGREE OF PRECISION, RECALL, AND VP, FN, AND FP

The evaluation of the distribution of Precision in the processing quality of UAV images obtained in an orange grove showed better performance when values of 30 were applied for the radius and 6 for the standard deviation (Figure 10).

This behavior can be explained by the fact that the larger the radius, the larger the coverage area for demarcating the point. This avoids the presence of incorrect points in the area (FP). The Degree of Precision showed similar behavior to that previously mentioned regarding the processing qualities, with the high quality demonstrating lower precision in both treatments submitted in the SAGA GIS software. This phenomenon can be explained due to the fact that the equation for determining the degree in question considers false positive points in its calculation. Thus, the low performance of the highest quality is consistent with the greater presence of points detected by the software that do not exist in the studied area..

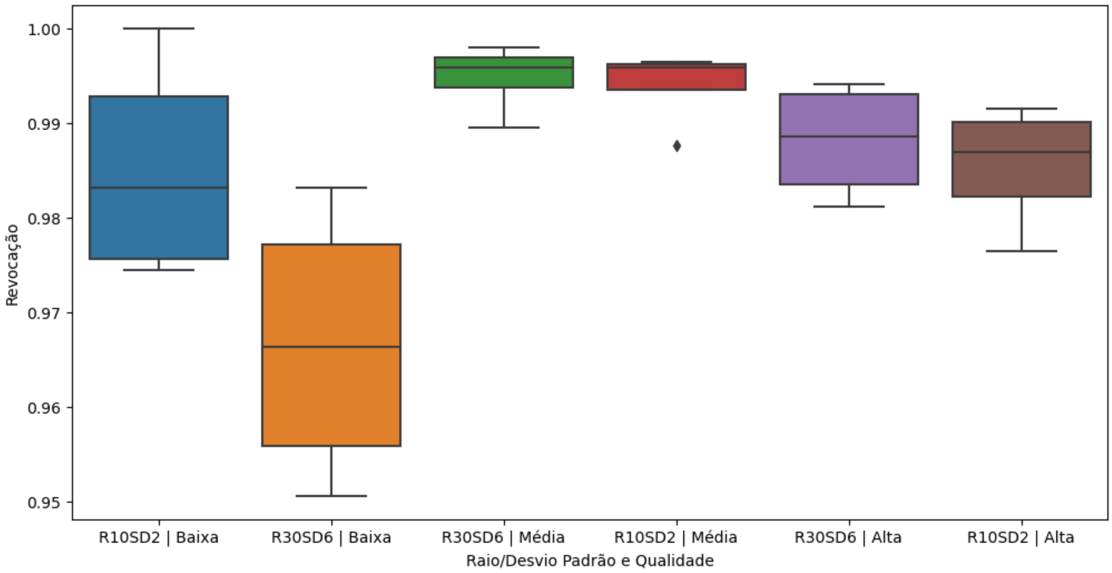
Revista ARACÊ
ISSN: 2358-2472

Figure 10. Boxplot of the distribution of Precision for assessing the quality of processing of UAV images obtained in an orange orchard



Regarding the Recall Degree, the medium and high qualities presented the best performances, respectively, with very close results regardless of the radius and standard deviation values used in SAGA GIS (Figure 11).

Figure 11. Boxplot of the Recall distribution for evaluating the quality of processing of UAV images obtained in an orange grove



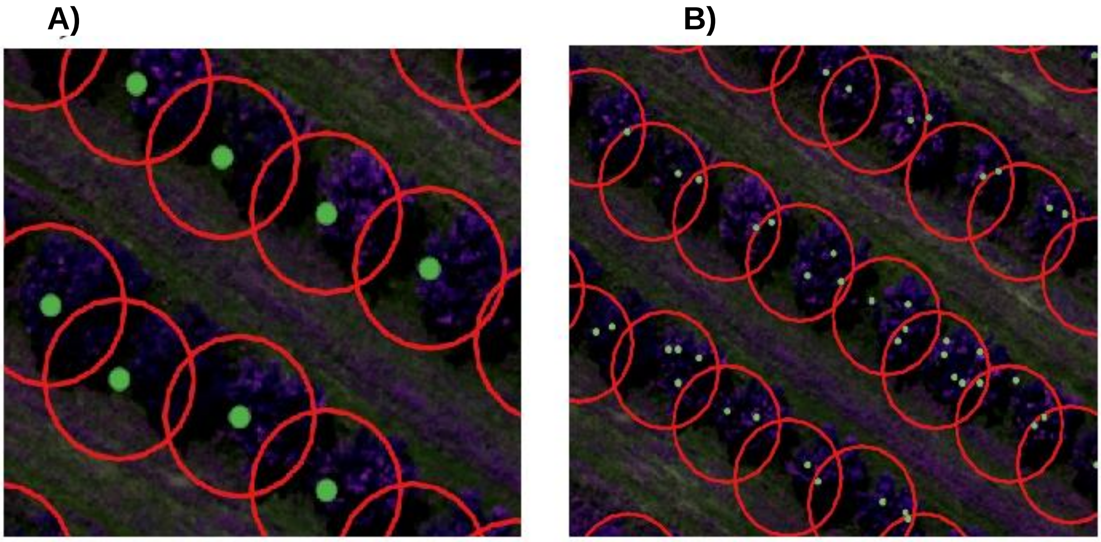
However, the low quality had a lower performance when compared to the others, and even higher when using a radius of 30 and a standard deviation of 6. This may have occurred due to the higher GSD of the MDS and caused two or more trees to be grouped into a single cell, which causes False Negatives, that is, trees that actually exist in the area

Revista ARACÊ
ISSN: 2358-2472

but were not detected by the software. In this way, the software recognizes them as just one unit that marks a single point in the highest part of the canopy.

In view of this, the differences in points detected in the image correctly and incorrectly for each treatment are clear, where the red circles represent the reference trees of the flight count products at 120 meters with overlapping images of 70 x 80 in low quality (A) and 100 meters with overlapping images of 80 x 80 in high quality (B), where the presence of many false positives is verified in figure B compared to A. (Figure12).

Figure 12. Points marked on the circumference of the Buffer, VP (A) e FP + VP (B)



Therefore, Low quality showed satisfactory performance when subjected to the different parameters of radius and standard deviation in SAGA GIS to obtain the number of orange trees present in an orchard. It is possible to affirm its viability for use in counting plants in the field, especially when considering the shorter time required for its processing.

CONCLUSIONS

Among the image processing options, low quality processing showed the best performance in the GSD of the orthomosaic, offering superior results to those obtained with high quality, but in less time. This allows for faster delivery of aerial imaging products with UAVs, benefiting users and decision makers in the management of agricultural properties.

A high GSD value provides a large number of points marked for the same area, which results in a greater recurrence of FP in images with high processing quality and occurrence of FN in images with lower quality.

Revista ARACÊ
ISSN: 2358-2472

The best performance for tree detection was obtained by SAGA GIS when flying at an altitude of 120 meters, with overlapping images of 70 x 80 using values of 10 for radius and 2 for standard deviation.

The tool evaluated for tree detection still requires the intervention of an operator to perform processing at different stages. However, depending on the characteristics of the flight and the areas imaged, such as low-density orchards and taller trees, processing can be facilitated and the results obtained more quickly, requiring less action on the part of the operator..

Revista ARACÊ
ISSN: 2358-2472

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