Determining the height of cotton plants (*Gossypium hirsutum* L.) Malvaceae f. with the assistance of a drone

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Abstract

The use of drones in crop assessment has become increasingly common. The use of drones presents benefits for evaluating the height of plants in various crops, including cotton, checking nutritional, phytosanitary, genetic parameters, abiotic and biotic effects. The objective of this study was to evaluate the use of drones to aid in the evaluation of trials in cotton cultivation. The study was carried out at the Goiano Institute of Agriculture, located in the municipality of Montividiu, State of Goiás, Brazil. A Phantom 4 Pro drone was used to carry out the mapping and WebODM was used to carry out photogrammetry and obtain a digital model of the surface area in the cotton field. In the experimental design, 4 randomized blocks with 10 treatments were used. The results demonstrated that there was no difference between the four blocks for vegetative index. The digital surface model proved to be efficient in detecting possible differences between the analyzed blocks. This analysis is essential to understand variations in response to cotton cultivation in different blocks and identify possible factors that contribute to these differences.

Keywords: drone, geoprocessing, *Gossypium hirsutum*, genus *Gossypium*, vegetative morphological parameters.

Determinando a altura de plantas de algodão (*Gossypium hirsutum* L.) Malvaceae f. com auxílio de drone

Resumo

O uso de drones na avaliação de lavouras tem-se tornado cada vez mais frequente. O uso de drones apresenta benefícios para a avaliação na altura de plantas em diversas culturas, inclusive na cultura de algodão, verificando parâmetros nutricionais, fitossanitárias, genéticos, efeitos abióticos e bióticos. O objetivo desse estudo, foi avaliar o uso de drone no auxílio sobre a avaliação de ensaios na cultura de algodão. O estudo foi realizado no Instituto Goiano de Agricultura, localizado no município de Montividiu, Estado Goiás, Brasil. Foi utilizado drone Phantom 4 Pro para realizar o mapeamento e o WebODM para realizar a fotogrametria e obtenção do modelo digital da superfície de área na lavoura de algodão. No delineamento experimental, foram utilizados 4 blocos ao acaso com 10 tratamentos. Os resultados demonstraram que não houve diferença entre os quatro blocos para índice vegetativo. O modelo digital da superfície se mostrou eficiente na detecção entre possíveis diferenças entre os blocos analisados. Essa análise é essencial para entender as variações nas respostas à cultura do algodão nos diferentes blocos e identificar possíveis fatores que contribuem para essas diferenças.

Palavras-chave: drone, geoprocessamento, *Gossypium hirsutum*, gênero Gossypium, parâmetros morfológicos vegetativos.

1. Introduction

The cotton plant (*Gossypium hirsutum* L.) is a plant species belonging to the Malvaceae family with economic importance worldwide, whose fruit, in addition to being raw material for the production of vegetable oil and animal feed, is essential for the textile industry, which serves as the main commercial destination for cotton for the manufacture of fabrics, knitwear, among others (Vasconcelos et al., 2018; Puia et al., 2021; Oliveira et al., 2023).

The cotton crop is characterized by an annual herbaceous plant, belonging to the genus *Gossypium*, which has a complete life cycle, ranging from 5 to 8 months, depending on the variety and growing conditions. Cotton is widely cultivated in regions with a tropical and subtropical climate, being a crop of great economic importance in several countries (Constable; Roth, 2019; Silva et al., 2023). Cotton plants possess a number of distinct characteristics that contribute to their adaptability and productivity. The cotton plant is a shrubby plant, with variable height depending on the cultivar and growing conditions. It has a pivoting root system, with deep roots that allow good absorption of nutrients and water from the soil (Percy; Ulloa, 2020).

Cotton leaves are large and generally have three or five lobes. They are green and pubescent, covered in trichomes (small hairs) that give them a rough texture to the touch. Cotton flowers are solitary and are white, yellow or pinkish in color, depending on the variety. They are large and have a characteristic structure called a calyx, made up of bracts that surround the base of the flower (Smith; Cothren, 2019).

After pollination of the flowers, the cotton fruit, known as a capsule or apple, is formed. This oval or spherical structure contains several seeds surrounded by cotton fibers. The seeds are rich in oil and proteins and are used in the production of cottonseed oil and cottonseed meal. Cotton fibers are the most valuable part of the plant and are widely used in the textile industry. They are mainly composed of cellulose and have characteristics such as softness, resistance and water absorption capacity (Fang, 2015).

Cotton is a crop that adapts well to high temperatures, being able to withstand long periods of heat. However, extreme temperatures can negatively affect its development and fiber quality and its anatomical and physiological system requires an adequate supply of water throughout its growth cycle. Water deficit can negatively affect fiber productivity and quality (Stewart et al., 2018). As for pest attack, *G. hirsutum* is susceptible to a series of pests and diseases, such as boll weevil, aphids, caterpillars and powdery mildew. Integrated pest and disease management is essential to ensure healthy and sustainable production. Cotton plays a significant role in the Brazilian economy and is an important crop for the country, including Brazil, which is one of the largest producers and exporters of worked cotton in the world, standing out as one of the main players in the international market (Gabieri; Asmus, 2016).

Several morphological analyzes are carried out on the main crops, and the determination of plant height is among several, of great importance for a cultivar. In cotton cultivation, measuring plant height is a crucial task, since accurate knowledge of plant growth is essential for the adequate management of this crop of great economic relevance throughout the world. The height of cotton plants is closely linked to their development, health and productivity. Therefore, the ability to accurately and efficiently measure the height of cotton plants is fundamental for farmers, researchers and professionals in the agricultural sector (Silva; Lima, 2023). Detailed understanding of cotton plant height is crucial for decision-making such as scheduling irrigation, applying fertilizers and pesticides, harvesting at the optimal time, and evaluating the performance of cotton varieties under different growing conditions (Brito, 2020).

The growing demand for greater efficiency in agriculture has driven the adoption of advanced technologies at various stages of the production process. In this context, the use of Unmanned Aerial Vehicles (UAVs), also known as drones. The use of this technology has stood out as a promising tool for monitoring and optimizing the cultivation of various agricultural crops. The application of this technology to determine the height of cotton plants is of paramount importance (Zhang; Yang, 2018).

Thus, drones can help in carrying out this task, and there are two types: multirotors and fixed wings. Multirotor drones are characterized by having several propellers that provide support and control. They are able to take off and land vertically, fly in confined spaces and maneuver in different directions. These drones are ideal for operations that require short duration flights at low altitudes, such as infrastructure inspections, mapping small areas and monitoring events (Hassanalian; Abdelkefi, 2017; Torres-Sánchez, 2018).

Fixed-wing drones are similar to conventional airplanes, with a single wing that provides lift. They fly more efficiently over large areas, covering greater distances in a single flight. Fixed-wing drones are most used in applications involving mapping large areas, agricultural monitoring and topographic surveying. As for sensors on board drones, there are mainly two types: RGB (Red, Green, Blue) cameras and multispectral cameras (Khan et al., 2019).

RGB cameras capture images in the visible spectrum, similar to conventional cameras used for aerial photography, 2D mapping, surveillance and visual inspections. These cameras are more affordable in terms of cost and offer good image quality (Sankaran et al., 2015). Multispectral cameras are capable of capturing images in several spectral bands in addition to the visible spectrum, such as near infrared and thermal infrared. These cameras are particularly useful in agricultural applications as they can provide information about plant health, identify areas of stress or disease, and monitor crop growth (Albetis et al., 2016).

Finally, the Digital Elevation Model (DEM) and the Digital Surface Model (DSM) are products resulting from the processing of data captured by drones or other sources. The DEM represents the elevation of the terrain, providing information about topography, such as reliefs and altitudes. DSM includes not only the elevation of the terrain, but also the height of objects such as trees, buildings and structures. These models are widely used in mapping applications, urban planning, environmental monitoring, and civil engineering studies (Yang et al., 2018).

The choice of types of drones, sensors and digital models depends on the specific needs of each application, considering the desired information, the necessary precision, the available budget and other technical requirements. It is important to carefully evaluate these aspects to obtain the best results and make the most of the capabilities of these technologies (Li et al., 2017).

Therefore, this study aimed to explore the capabilities of drones in measuring the height of plants in cotton crops in the field, providing crucial information for monitoring development and decision-making in agricultural management.

2. Material and Methods

2.1 Study area

The cotton crop trial was conducted at the *Instituto Goiano de Agricultura* (IGA), municipality of *Montividiu*, *Goiás* State, Brazil (Figure 1). The region is predominantly characterized by Oxisol soils, although variations can also be found, such as Haplic Gleisol, Argisol and Dystrophic Red-Yellow Argisol. As for the climate, it is tropical with two distinct seasons, Summer and Winter. The geographic coordinates of the study site are (17.4455 S and 51.1468 W) with an elevation of 885 M.

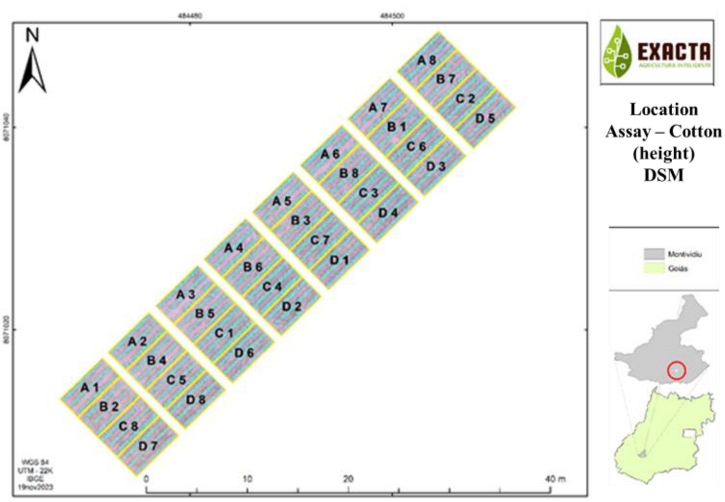

Figure 1. Location of the cotton test. Source: Exacta Smart Agriculture, 2023.

2.2 Experimental design

Four randomized blocks with 10 treatments (T1 to T10) were used in cotton cultivation as described in (Figure 2).

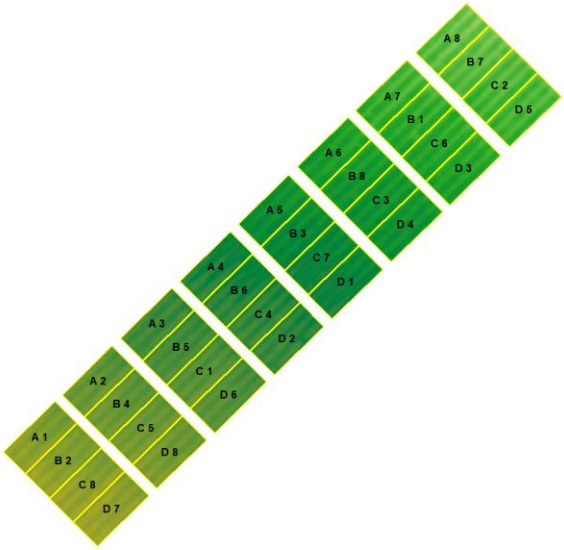

Figure 2. Sketch of the cotton trial in the experimental area of the *Instituto Goiano de Agricultura*. Letters and numbers are blocks and treatments respectively. Source: Authors, 2023.

2.3 Flight planning and mapping (flight plan)

Drone Deploy was used in the test version, the flight plan was carried out at 70 m height with frontal and lateral overlap of 75 and 70% respectively. The mapping was carried out with Phantom 4 Pro at the recommended time between 10 and 11 am (am) (Figure 3).

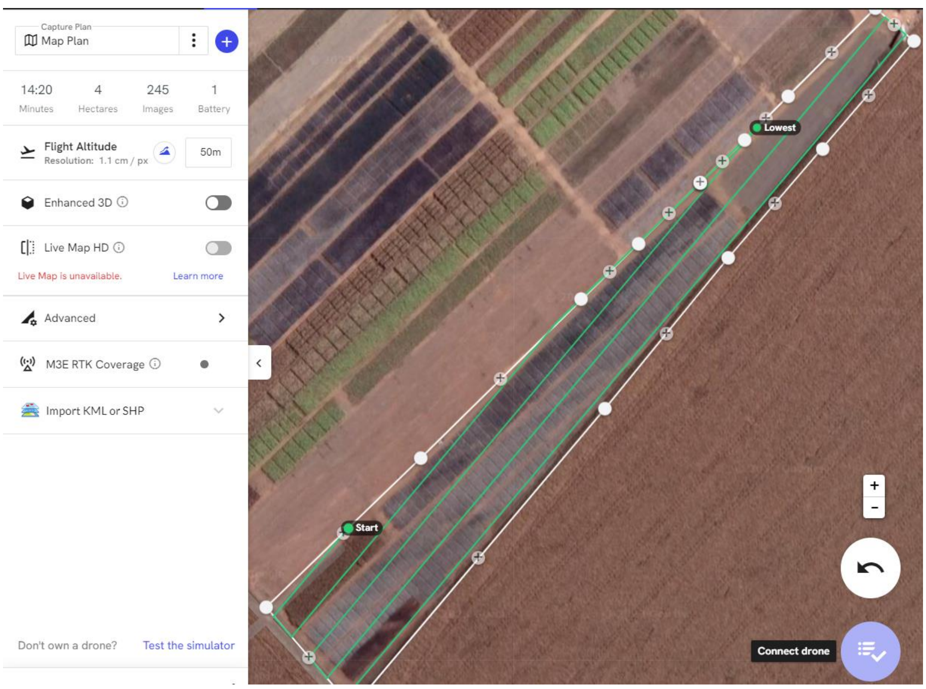

Figure 3. Flight plan in the Drone Deploy application. Source: Authors, 2023.

2.4 Image processing

We use WebODM to process the photos acquired during aerial mapping. Immediately after processing, the orthomosaic and DMS were acquired. We also use ArcMap to perform geoprocessing of the orthomosaic/DMS (Figure 4).

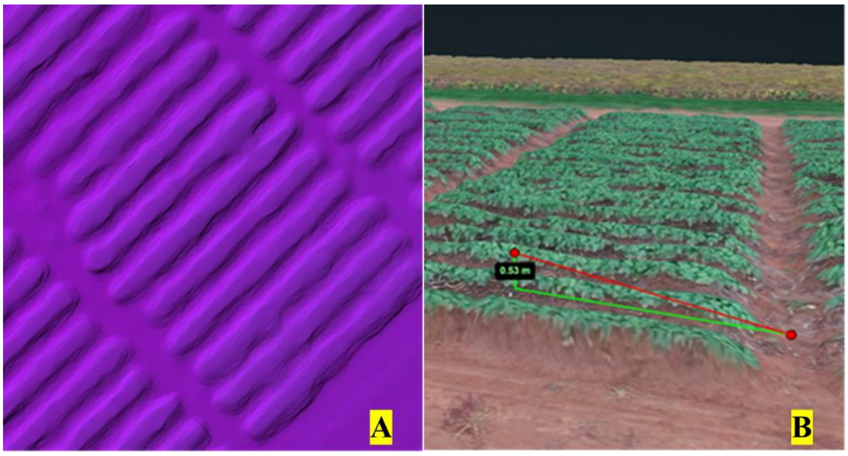

Figure 4. Digital surface model (**A**) and orthomosaic superimposed on the digital surface model (**B**). Source: Authors, 2023.

2.5 Statistical analysis

The original data were subjected to the Shapiro-Wilk normality test (5% significance) and the Bartlett homogeneity test (5% significance). Data that did not present normal distribution and/or homoscedasticity were transformed using the Box-Cox family of transformations (Box and Cox, 1964). Then, the data were subjected to analysis of variance using the F test ($p < 0.05$) and, when significant, the Tukey test ($p < 0.05$) was used in the qualitative analysis to compare the means. All analyzes were carried out using the statistical software R, version 4.2.0 (Ferreira et al., 2014; Team, 2018).

3. Results and Discussion

Figure 5 shows the four block treatments for sunflower plants using drone imaging. It is observed that there was no statistical difference between the four blocks analyzed for the height of sunflower plants in this study. The blocks presented the following values in plant height A (0.79), B (0.80), C (0.84) and D (0.82) m. Several reasons may contribute to this similar performance. One possibility is that the test was subjected to the same climatic conditions, due to its size as discussed by Anderson et al. (2018).

The climate in the municipality of *Montividiu*, *Goiás*, is characterized by a dry season in winter and a rainy season in summer. Variations in weather conditions, such as intense rain or strong winds, can affect sowing quality. In the same sense, Shil (2018) in his review article describes that abiotic and biotic factors, variable to extreme, influence positively or negatively on agriculture. Furthermore, according to authors Sankaran et al. (2015), soil-related factors may have influenced the performance of the blocks, where differences in soil texture, organic matter content or nutrient levels may affect seed germination and plant establishment. It is important to consider soil quality and adequate land preparation to optimize sowing. There is also the possibility of deviations in calibration that could result in variations in seeding density (Shakir et al., 2018), which could also explain the lack of variation between treatments.

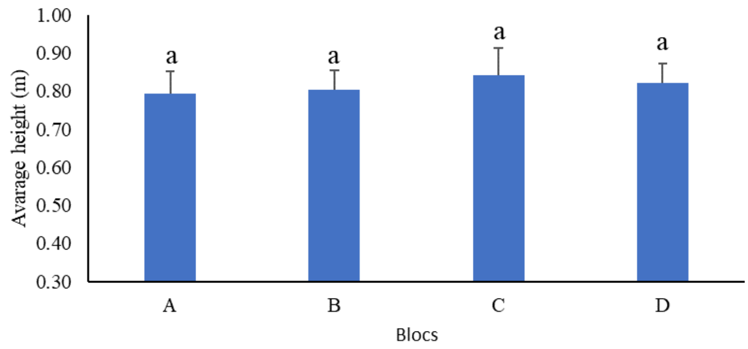

Figure 5. Performance of the blocks in relation to the average height of sunflower plants analyzed by drone image. Source: Authors, 2023.

In Figure 6, our treatment (block 1) was significantly higher than 0.90 m when compared to the other means of treatments 2 to 8. This disparity suggests that treatment 1 provided more favorable conditions for plant development, resulting in significantly greater cotton height. The use of the mean comparison test is essential to make multiple comparisons between the means of different treatments, enabling a detailed analysis of statistical discrepancies. Based on the results obtained in our study, it is possible to draw crucial conclusions about the relative performance of the treatments and their impacts on the development of cotton plants in the field.

Highly relevant studies were carried out by Thenkabail et al. (2000), Li et al. (2001) and Bronson et al. (2005), on growth in the vegetative phase and productivity in the reproductive phase in cotton crops, comparing these data through spectral reflectance measurements in broad and narrow bands with the aid of spectral imaging.

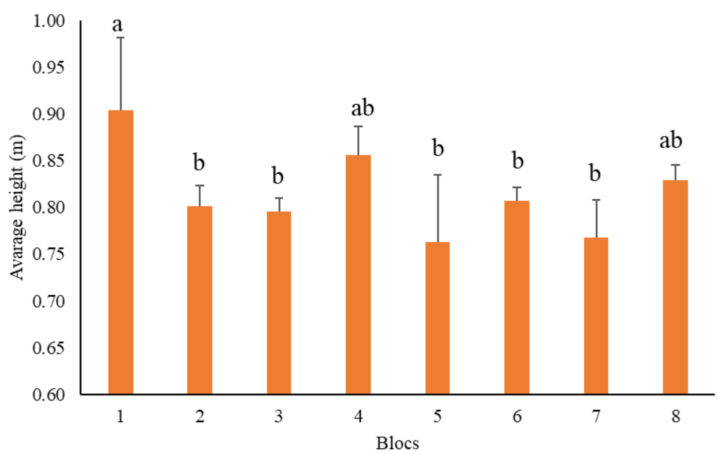

Figure 6. Performance of treatments in relation to the average height of sunflower plants. Source: Authors, 2023.

4. Conclusion

The use of a drone to assess the height of cotton plants presented potential for analyzing plants still in the vegetative phase. The Phantom 4 Pro drone proved to be an important Agriculture 4.0 tool, differentiating treatments, plant heights and thus, forming data on the variation between plots. Thus, the capacity of the digital surface model generated by mapping was effective in identifying average plant height values for cotton cultivation and in forming theories between the results achieved.

5. Authors' Contributions

Jeremias Silva de Sousa: study design, data collection, writing, review. *Adriano Guimarães Pereira*: flight plans, writing, corrections. *Hugo Manoel de Souza*: flight plans, program analysis, image analysis, data description.

Igor Vinicius dos Santos Araújo: data description, image analysis, flight plans and discussion. *Daniel Noe Coaguila Nuñez*: advisor, action plan, flight plans, statistical analysis, corrections, submission and publication.

6. Conflicts of Interest

No conflicts of interest.

7. Ethics Approval

Not applicable.

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