Application of drone to aid in the evaluation of trials in cotton cultivation (*Gossypium hirsutum* L.) Malvaceae f.

Alexandre Barichello[1], Matheus Oliveira Rocha[1], Hugo Manoel de Souza[2], Igor Vinícius dos Santos Araújo[2] & Daniel Noe Coaguila Nuñez[1,3]

[1] Centro Universitário UniBRAS Rio Verde, Rio Verde, Goiás State, Brazil

[2] Oro Agri, Rio Verde, Goiás State, Brazil

[3] Universidad Nacional de San Agustin de Arequipa, Arequipa, Peru

Correspondence: Daniel Noe Coaguila Nuñez, Centro Universitário UniBRAS Rio Verde, Rio Verde, Goiás State, Brazil. E-mail: daniel.nunez@braseducacional.com.br

Received: November 14, 2023 DOI: 10.14295/bjs.v3i3.515

Accepted: February 28, 2024 URL: https://doi.org/10.14295/bjs.v3i3.515

Abstract

The use of drones to evaluate crops has become increasingly common. Among these uses, the drone helps in the cultivation of cotton a crop that is highly prone to intense attacks by pests and diseases. This study aimed to evaluate the use of drones in evaluating trials in cotton cultivation in the Southwest 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 the ExG vegetation index. ExG proved to be efficient in detecting differences between blocks. The use of drones provided a series of benefits in the assessment process in cotton cultivation. The ability to fly over the area quickly and accurately allowed detailed, and punctual images to be obtained which was essential for monitoring plant health and identifying problem areas such as pest or disease infestations.

Keywords: drone, *Gossypium* genus, agricultural area mapping, agricultural disease control, technology in agriculture.

Aplicação de drone no auxílio sobre avaliação de ensaios na cultura de algodão (*Gossypium hirsutum* L.) f. Malvaceae

Resumo

O uso de drones na avaliação de lavouras tem se tornado cada vez mais frequente. Dentre esses usos, o drone auxilia na cultura do algodão, cultura essa, altamente propícia ao ataque intenso de pragas e doenças. Este estudo teve por objetivo, avaliar o uso de drones em avaliação de ensaios na cultura de algodão no Sudoeste de Goiás, Brasil. Foi utilizado drone Phantom 4 Pro para realizar o mapeamento e o WebODM para realizar a fotogrametria e obtenção do índice de vegetação ExG. O ExG mostrou-se eficiente na detecção sobre diferenças entre os blocos. O emprego do drone proporcionou uma série de benefícios no processo de avaliação na cultura de algodão. A capacidade de sobrevoar a área de forma rápida e precisa, permitiu a obtenção de imagens detalhadas e pontuais, o que foi fundamental para o monitoramento sobre a saúde das plantas e identificar áreas com problemas, como infestações de pragas ou doenças.

Palavras-chave: drone, gênero *Gossypium*, mapeamento de área agrícola, controle de doenças agrícolas, tecnologia na agricultura

1. Introduction

Cotton (*Gossypium hirsutum* L.) family Malvaceae is one of the oldest and most important crops for humanity. Archaeological studies date back 4,000 years to the period in which this botanical species was domesticated in southern Arabia. As it is a vegetable and natural fiber, cotton is of great global importance, in addition to being widely used in the oil production, animal feed and textile industries (Rossi et al., 2020; Bender et al., 2020; Oliveira et al., 2021; Ferreira et al., 2022).

Cotton production is an activity with great economic and social relevance; therefore, it occupies approximately 2.5% of the world's arable land. There are approximately 81 countries that grow cotton, where the largest producers per tenth are represented by China, United States of America and India. For Prado Júnior (1987) and Agnelli (2022), cotton was one of the products that was exploited on a small scale since the colonial beginnings for the manufacture of fabrics and was thus widespread among indigenous tribes.

In Brazil, cotton cultivation is strategically important for the economy with this nation being the second largest exporter of processed cotton in the world. Brazilian cotton farming has undergone profound productive and technological transformations, making it more sustainable and efficient (Ferreira et al., 2022). New field management techniques, investments, research into genetic improvement and mechanization, and better processing have increased the quality and quantity of Brazilian cotton harvested making this production compliant for the cotton industry. Furthermore, cotton has historical importance in the country with the production of herbaceous cotton with shorter fibers and annual cycle beginning in the 18th century, in the state of São Paulo with the industrial revolution. The use of digital technologies, such as precision agriculture has led to encouraging results in cotton farming in Brazil and with high planting attractiveness for other regions of the country (Severino et al., 2019; Puia et al., 2020; Alcantara et al., 2021; Lavrati et al ., 2022).

The use of technologies for Brazilian trade represents a transfer of cotton production in our country from typical production areas to semi-arid regions and the Cerrado, where it contributes to the increase in imports and exports of high-quality fiber. A study found that cotton cultivation in the Brazilian Cerrado is being more productive when compared to the areas normally used for this already well-established culture. The Brazilian Cerrado has stood out as the main cotton producing area due to its high quality of labor, high level of technological level and crop management, which includes precision agriculture with the use of drones that assist in decision making (Embrapa, 2017; Ferreira et al., 2022).

The definition of Unmanned Aerial Vehicle's (UAVs) by the Brazilian Aeronautical Modeling Association (BAMA) is: "capable of flying in the atmosphere without influence from the ground, designed or modified to not accommodate a human pilot and/or remotely controlled or autonomously operated vehicles" (Yao et al., 2019; Oliveira et al ., 2020; Kolling; Rampim, 2021). The classification of a drone's functionality is made according to its type of control, and it can be autonomous (no human pilot is needed to control the drone from the ground, and it is powered by its own integrated systems and sensors) , requiring a human technician, whose job is to provide information and control the drone's responses, common in photogrammetry and precision agriculture (PA) work. Under supervision (some tasks are performed independently, but the operator commands). Pre-programmed (has a pre-prepared flight plan and cannot change it once executed) and remotely controlled (piloted directly by a technician through the console) (Pino, 2019; Pereira et al., 2021).

The development of drones has become an important PA tool. However, there is still a low content of information in the literature on the use of drone images and simple vegetation indicators as management adjustment tools, aiming to increase productivity and reduce production costs (Souza et al., 2019). The application of drones in agricultural areas and reconnaissance missions is facilitated by technological evolution, in addition to their lower cost than other equipment, they do not require a crew and do not require production optimization (Oliveira et al., 2020; Cerro et al., 2021).

Artioli & Beloni (2016) highlight that in Brazil, drones have become allies in the application of PA in crops. This is because drones can be precise and capable of detecting and monitoring large areas in real time through the images they produce, where it is possible to identify areas to combat pests and diseases or deficiencies in fertilization. The use of UAVs is a way of monitoring the development of different agricultural crops, including cotton. This makes it possible to produce aerial photographs of large surfaces at a low cost, highlighting the high resolution (2 or 4K resolutions) and allowing the instrument to be used on a large scale. The estimation of parameters related to biophysical and biochemical issues is of great importance for agricultural practices. It also helps in the assessment of genotypic behavior and the effects of biotic and abiotic stress, contributing to farmers' decision-making process, thus avoiding unnecessary expenses that can be avoided with UAVs (Souza et al., 2019). Furthermore, drones can be used for various purposes, such as monitoring crops, identifying problem areas, aerial spraying of pesticides, crop health, irrigation problems, among others (Villafuerte et al., 2018; Oliveira et al., 2022).

The Excess Green (ExG) vegetation index is an essential tool for analyzing the state of vegetation, widely applied in various areas, such as agriculture, forestry and environmental monitoring. Gao (1996) argues that this index highlights regions that present an excess of biomass or vegetative vigor, making it possible to identify areas of healthy growth in contrast to those that may be under stress due to factors such as phytopathogens, macro and micronutrient deficiencies or infestations. by agricultural pests. ExG's ability to provide detailed information about plant health is crucial for accurate decision-making and effective natural resource management, making it a valuable tool in PA and sustainable ecosystem management.

As a result, the application of digital technologies such as PA has enhanced results in Brazilian cotton farming, making it more sustainable and efficient and the use of UAVs in the evaluation of cotton trials can bring significant benefits to production, also allowing for a quick and targeted response. to solve problems and make production adequate and decisive associated with geographic coordinates (Bernardi et al., 2015; Viana et al., 2018; Silva & Silva-Mann, 2020; Bassoi et al., 2019; Pamplona; Silva, 2019; Ferraz et al., 2022).

This study aimed to evaluate the use of drones as an aid in the evaluation of agricultural trials, especially in cotton (*Gossypium hirsutum*) cultivation.

2. Materials and Methods

2.1 Study area

The study with cotton cultivation was conducted at the Institute of Agricultural Sciences (ICA), located in the municipality of Montividiu, State of Goiás, Brazil (Figure 1). The region is predominantly characterized by Oxisol soils, although other variations can also be found, such as Haplic Gleisol, Argisol and Dystrophic Red-Yellow Argisol. Tropical climate with two distinct seasons, Summer and Winter and the geographic coordinates of the place are (17.4455 S and 51.1468 W) with 885 elevation.

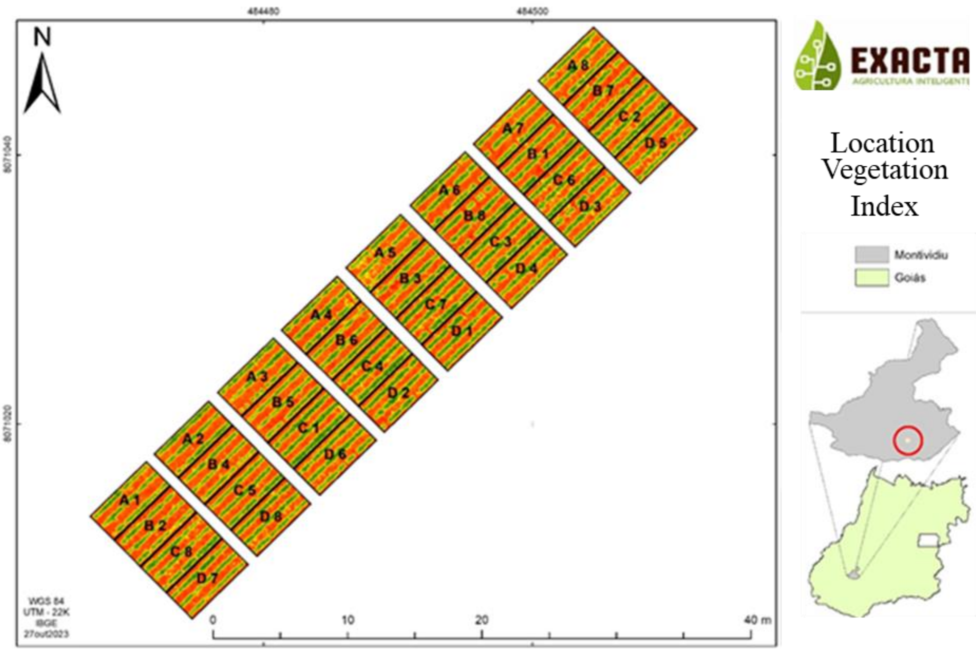

Figure 1. Location of the cotton crop experiment and plots. Source: Authors, 2023.

2.2 Flight planning and mapping

The Drone Deploy application was used to plan the flight at a height of 50 m with an overlap of 80% in the forward direction and 75% in the lateral direction. The mapping was conducted using a Phantom 4 Pro drone with an RGB camera (1” CMOS sensor and 20MP), following the recommendation to carry it out between 10 and 11 am. The flight plan was executed on February 10, 2023 (Figure 2).

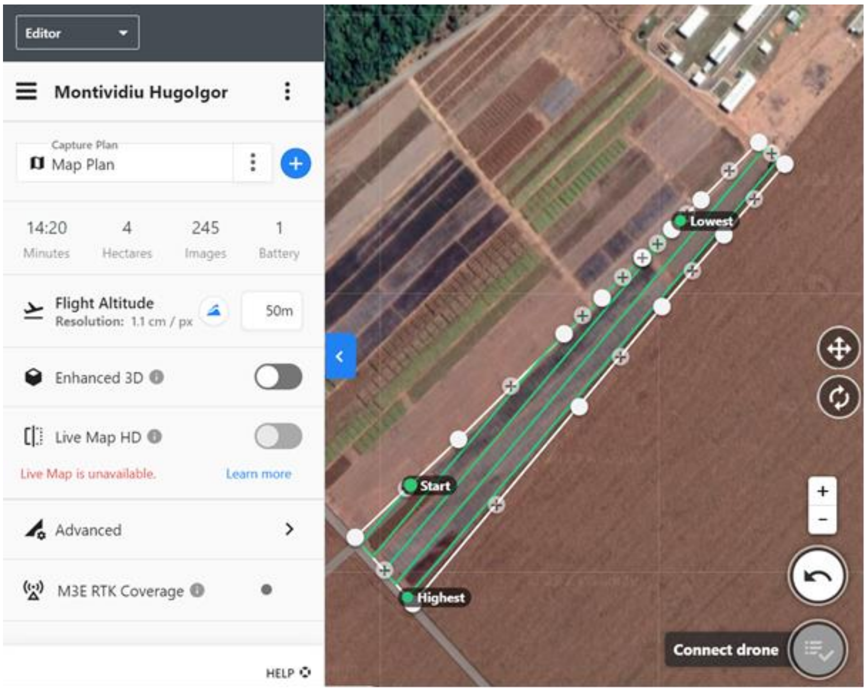

Figure 2. Flight plan in the DroneDeploy application. Source: Authors, 2023.

2.3 Image processing

For image processing, the Open Drone Map software (WebODM; https://opendronemap.org) obtained during the mapping phase was used. After completing this processing, the digital terrain model was obtained. For the geoprocessing of the orthomosaic and the digital terrain model, the ArcMap software (Esri®) was used (Figure 3).

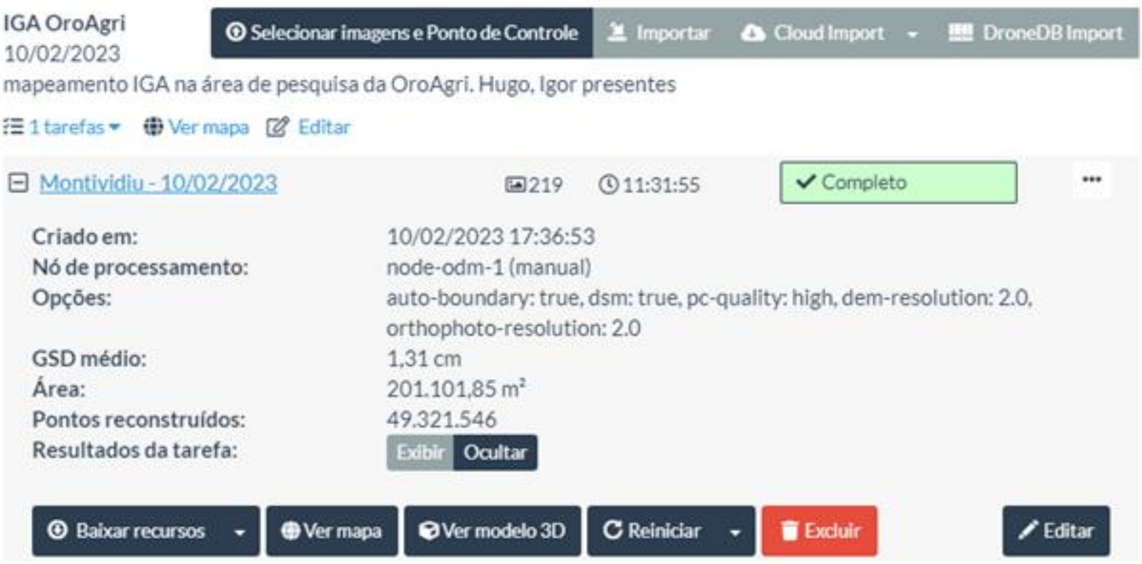

Figure 3. WebODM interface, photogrammetry program. Source: Mapping image processing report with WebODM and ArcMap, WebODM and ArcMap, 2023.

2.4 Experimental design

For the experiment in cotton cultivation, a randomized block design was used, consisting of 4 blocks and 8 treatments (Figure 4).

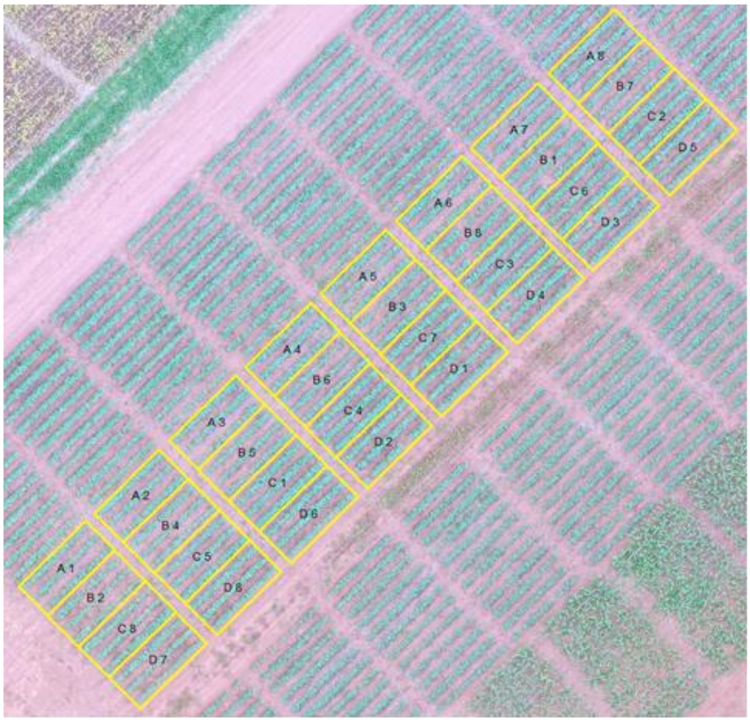

Figure 4. Statistical mapping of plots and treatments for the experiment with cotton cultivation in the IGA experimental area. Source: Authors, 2023. Note: Letters (A at D) and numbers (1 at 8) are blocks and treatments respectively.

2.5 Statistical analysis

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

3. Results and Discussion

In figure 3, it can be seen that the block with the highest ExG was block C and the one with the lowest ExG value was block B, with blocks A and D having intermediate performance. The ExG index has played a crucial role in assessing the health status of agricultural crops. In the study by Smith et al. (2022), researchers found the application of ExG to be highly effective in early detection of water stress in corn crops.

The results highlighted that areas with lower ExG values were correlated with an imminent need for irrigation, allowing farmers to take preventative measures to avoid plant damage. Furthermore, in an environmental monitoring context, Jones et al. (2021) explored the use of ExG to assess the health of tropical forests. Their findings demonstrated that this index was sensitive to changes in vegetation conditions, being a valuable indicator in identifying areas of deforestation and forest degradation, contributing to the conservation of these ecosystems.

The low performance of block B in relation to the ExG index (Figure 5) may be due to the intrinsic characteristics of the study area, given that the purpose of the block design is to distribute local heterogeneity. As observed by Silva et al. (2019), poor roads can cause a series of significant problems in soybean crops, ranging from soil compaction due to heavy vehicle traffic to erosion, which can result in the loss of nutrients and fertile soil, compromising productivity. of culture. Furthermore, the presence of roads in poor condition can make logistics and harvest transportation difficult, increasing production costs and negatively impacting farmers' profitability.

Another challenge highlighted by Pereira et al. (2020) in relation to roads close to soybean growing areas is the spread of pests and diseases. The movement of vehicles and agricultural equipment can facilitate the transport of pests and pathogens between different planting areas, contributing to the rapid spread of phytosanitary problems. To mitigate these problems, it is essential that producers and authorities pay attention to the adequate maintenance of roads and the implementation of phytosanitary control measures in order to protect soybean crops and maintain the sustainability of agricultural production.

In another study, carried out by Wang et al. (2020), the ExG index was used to assess the health of tea plantations in the Yunnan region of China. The researchers noted that ExG was able to identify areas of nutritional deficiencies in tea plants, allowing farmers to apply fertilizers in a targeted manner, optimizing resource use and increasing productivity. Therefore, ExG is a versatile and valuable tool in various applications, from precision agriculture to environmental conservation.

Therefore, the use of Unmanned Aerial Vehicles (UAVs), more commonly known as drones, represents an effective approach to monitoring the progress of various crops. These devices allow the capture of aerial images of vast expanses of land at a relatively low cost, highlighting the high resolution of the images, making their large-scale application possible (Souza et al., 2019).

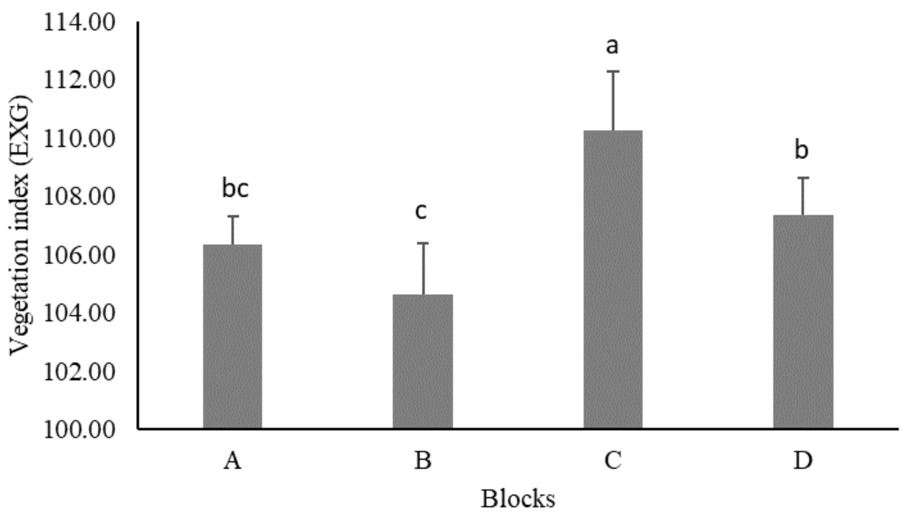

Figure 5. Graph referring to the Vegetation Index – excess green vegetation index - ExG. Source: Authors 2023.

In Figure 6, it can be seen that treatment 1 had the worst performance from a numerical point of view in relation to the EXG index. According to the study by Silva et al. (2021), pests pose a significant threat to cotton plantations, with the boll weevil being a major concern. Integrated pest management, which includes the use of selective pesticides and the implementation of biological control practices, has been shown to be effective in reducing damage caused by these pests. Furthermore, genetic research has contributed to the development of pest-resistant cotton varieties, reducing dependence on chemical pesticides and making production more sustainable.

Another challenge in treating cotton crops is controlling diseases such as Fusarium wilt. As pointed out by Torres et al. (2020), the adoption of crop rotation practices and the use of seeds treated with fungicides have been important strategies for controlling Fusarium wilt. Furthermore, the application of soil management techniques, such as improving drainage and adopting appropriate irrigation practices, can contribute to reducing the incidence of this disease. Together, these approaches aim to ensure sustainable cotton production while minimizing the risks of crop losses due to pests and diseases.

As observed by Oliveira et al. (2022), drones play a crucial role in capturing images, facilitating the producer's task in mapping failures in planting and fertilization, while at the same time enabling the monitoring of crop development. Furthermore, drones enable soil analysis and the identification of pests and diseases.

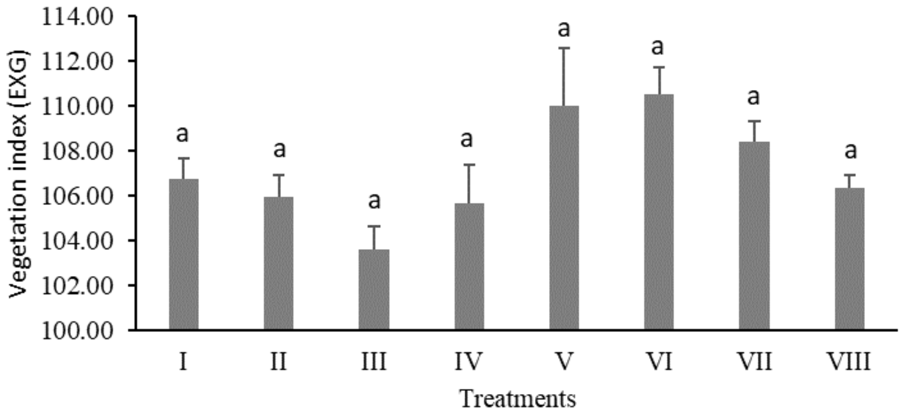

Figure 6. Graph relating to treatment – ExG. Source: Authors, 2023.

4. Conclusions

The use of drones in cotton farming is an important fundamental tool for the modernization and optimization of agriculture, bringing significant benefits to farmers and the agricultural sector. The ExG vegetation index demonstrated efficiency in aiding cotton test evaluations, managing to perceive some differences, albeit between blocks.

Furthermore, the use of drones in cotton farming reduces dependence on traditional monitoring methods, such as manual inspection, which is laborious and time-consuming. In addition, the ability of drones to cover large areas of land in a short space of time means that distant and difficult-to-reach areas can be monitored with ease, ensuring that no critical points are overlooked.

Finally, the use of drones in cotton farming is an important evolution towards precision agriculture, in which the application of inputs such as fertilizers and pesticides can be adjusted according to the specific needs of each area of the plantation. This not only results in resource savings, but also reduces the environmental impact of agriculture, making it more sustainable in the long term. Therefore, the adoption of drones in cotton farming is not just a trend, but a necessity to meet the growing demands for food and fiber in a more efficient, economical and environmentally responsible way.

5. Acknowledgments

To the UniBRAS University Center Rio Verde, Rio Verde, Goiás, Brazil.

6. Authors' Contributions

Alexandre Barichello: study design, writing, imaging, data search and presentation of results. *Matheus Oliveira Rocha*: study design, drone manipulation, writing and reading the study. *Hugo Manoel de Souza*: data collection and data analysis. *Igor Vinícius dos Santos Araújo*: drone flights and data collection. *Daniel Noe Coaguila Nuñes*: statistical collection and analysis, guidance and supervision, writing, reading, translation and publication.

7. Conflicts of Interest

No conflicts of interest.

8. Ethics Approval

Not applicable.

9. References

Abbade, E. B. (2014). O papel do agronegócio brasileiro no seu desenvolvimento econômico. Journal of

Sistainable *Production, Operations and Systems Management*, 9(3), 149-158. https://doi.org/10.15675/gepros.v9i3.1053

Agnelli, H. P. (2022). A economia do algodão no Brasil, 1930-1945: industrialização, crise cambial e política externa. (2022). Tese de Doutorado pela Universidade de São Paulo, São Paulo, Brasil.

Alcantara, I. R., Vedana, R., & Vieira Filho, J. E. R. (2021). Produtividade do algodão no Brasil: uma análise da mudança estrutural. Texto para Discussão, Instituto de Pesquisa Econômica Aplicada (ipea). https://doi.org/10.38116/td2682

Almeida, R. B. (2009). Traços da história econômica da Bahia no último século e meio. *Revista de Desenvolvimento Econômico*, 19, 82-101.

Bender, E. P., Batista, J. N., Lyra, G. B., Polidoro, J. C., Jantalia, C. P., & Lyra, G. B. (2020). Modelagem do crescimento e produtividade do algodão em cultivo comercial no cerrado baiano. *Nativa*, 8(3), 403-412. https://doi.org/10.31413/nativa.v8i3.10029

Box, G. E. P., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society*, 26(2), 211-252. https://doi.org/10.1111/j.2517-6161.1964.tb00553.x

Cerro, J., Ulloa, C. C., Barrientos, A., & Rivas, J. L. (2021). Unmanned aerial vehicles in agriculture: A survey. *Agronomy*, 11(2), 203. https://doi.org/10.3390/agronomy11020203

Dutta, G., & Goswami, P. (2020). Application of drone in agriculture: A review. *International Journal of Chemical Studies*, 8(5), 181-187. https://doi.org/10.22271/chemi.2020.v8.i5d.10529

Ferreira, E. B., Cavalcanti, P. P., & Nogueira, D. A. (2014). ExpDes: An R Package for ANOVA and Experimental Designs. *Applied Mathematics*, 05(19), 2952-2958.

Ferreira, A. B. R., Toledo, M. R., Pereira, G., & Resende, F. C. (2019). O agronegócio no Brasil: uma breve revisão histórica e conceitual. *Revista Interdisciplinaria de Estudios Agrarios*, 50, 67-91.

Ferreira, I. C., Silva, J. C. L., Neto, L. B. F., Santos, T. J. L., & Carvalho, J. C. A. (2022). A contribuição e relevância do agronegócio para o Brasil. *Revista CEDS*, 2(10), 1-21. https://periodicos.undb.edu.br/index.php/ceds/article/view/16

Gao, B. C. (1996). NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. *Remote Sensing of Environment*, 58(3), 257-266. https://doi.org/10.1016/S0034-4257(96)00067-3

Gomes, C. S. (2019). Impactos da expansão do agronegócio brasileiro na conservação dos recursos naturais. *Cadernos do Leste*, (19)19, 63-78. https://doi.org/10.29327/248949.19.19-4

Guimarães, D. M. N. (2019). Avaliação dos impactos do plano nacional de agroecologia e produção orgânica nos serviços de assistência técnica no âmbito da reforma agrária nos estados do Acre e Pará. Dissrtação de Mestrado em Agricultura Orgânica, pela Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brasil. https://tede.ufrrj.br/jspui/handle/jspui/5183

Kolling, C. E., & Rampim, L. (2021). Agricultura de precisão e digital: perspectivas e desafios dos produtores rurais do Estado do Paraná. *UNINGÁ Review Journal*, 36, 1-13. https://doi.org/10.46311/2178-2571.36.eURJ3981

Lavrati, G. (2022). Tendência global de desenvolvimento sustentável e a cadeia produtiva do algodão orgânico. Trabalho de Conclusão de Curso em Engenharia Têxtil pela Universidade Federal de Santa Catarina, Santa Catarina, Brasil. https://repositorio.ufsc.br/handle/123456789/234036

Oliveira, V. L. C., Marinho, M. R., Oliveira, D. C., Pestana, M. S., Silva Filho, S. S., Sperotto, L., & Obana, F. (2021). Estudo dos agronegócios 4.0 - Tecnologias, desafios e beneficios nos Agronegócios. *Research, Society and Development*, 11(13), 1-13. https://doi.org/10.33448/rsd-v11i13.35379

Oliveira, J. T., Maradini, P. S., Borges, A. C., & Gava, R. (2021). Viabilidade da fertirrigação por pivô central com uso de efluentes tratados em diferentes níveis. *Nativa*, 9(1), 23-29. https://doi.org/10.31413/nativa.v9i1.10884

Pereira, M. A., Silva, N. M., Barbosa, D. S., Pessi, D. D., Souza, A. P., & Filho, A. C. P. (2021). Identificação de sítios de reprodução de Aedes aegypti com aeronave remotamente pilotada (ARP). *Nativa*, 9(4), 344-351. https://doi.org/10.31413/nativa.v9i4.12094

Puia, J. D., Martins, B. R., Borsato, L. C., & Vigo, S. C. (2020). Comportamento diferencial de linhagens de algodão a Cercospora gossypina. *Nativa*, 9(2), 163-166. https://doi.org/10.31413/nativa.v9i2.10834

Severino, L. S., Rodrigues, S. M. M., Chitarra, L. G., Lima Filho, J. R., Contini, E., Mota, M. M., Marra, R., & Aragão, A. A. (2019). Produto: Algodão-Parte 01: Caracterização e Desafios Tecnológicos. Série desafios do agronegócio brasileiro (NT3). https://www.alice.cnptia.embrapa.br/alice/handle/doc/1109655

Silva, A. F. C. (2022). Pragas, patógenos e plantas na história dos sistemas agroecológicos. *Boletim do Museu Paraense Emílio Goeldi*, *Ciências Humanas*, 17(1), e20210023. https://doi.org/10.1590/2178-2547-BGOELDI-2021-0023

Souza, D.C., (2019). Auxílio de tomada de decisão no manejo e planejamento do plantio de soja com o processo de segmentação de imagens. *Revista Eletrônica Agentina-Brasil, ReABTIC*, 1(11), 11-23. http://dx.doi.org/10.5281/zenodo.3601202

Team, R. D. C. (2018). A language and environment for statistical computing, R foundation for statistical computing, Vienna, Austria. https://www.r-project.org/

Viana, L. A., Zambolim, L., Sousa, T. V., & Tomaz, D. C. (2018). Potencial uso de câmera termal acoplada a VANT para monitoramento de culturas. *Brazilian Journal of Biosystems Engineering*, 12(3), 286-298. https://doi.org/10.18011/bioeng2018v12n3p286-298

Villafuerte, A., Valadares, F. G., Campolina, G. F., & Silva, M. G. P. (2018). Agricultura 4.0 – Estudo de inovação disruptiva no agronegócio brasileiro. *In*: 9th International Symposium on Technological Innovation, 9(1), 150-162. https://www.api.org.br/conferences/index.php/ISTI2018/ISTI2018/paper/viewFile/567/276

Yao, H., Qin, R., & Chen, X. (2019). Unmanned aerial vehicle for remote sensing applications – A review. *Remote Sensing*, 11(12), 1443. https://doi.org/10.3390/rs11121443

Funding

Not applicable.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Copyrights