Mercator, Fortaleza, v. 22, e22001, 2023. ISSN:1984-2201

MERCATOR

ARTICLE

REMOTELY PILOTED AIRCRAFT SYSTEMS WITH RGB CAMERA TO MAP COMMERCIAL TABLE TOMATO NURSERIES

https://doi.org/10.4215/rm2023.e22001i

Furquim, M. G. D. [a]* - Nascimento, A. R. [b] - Costa, J. V. S. [c]
Ferreira, M. E. [d] - Corcioli, G. [e] - Borges, L. C. [f]

(a) PhD in Agribusiness.
ORCID: http://orcid.org/0000-0001-7823-9546. **LATTES:** http://lattes.cnpq.br/2681775689273863.
(b) PhD in Plant Production.
ORCID: http://orcid.org/0000-0002-7620-5681. **LATTES:** http://lattes.cnpq.br/4443496721863083.
(c) Master's student in Environmental Sciences.
ORCID: http://orcid.org/0000-0003-0765-3701. **LATTES:** http://lattes.cnpq.br/6706740706389830.
(d) PhD in Environmental Sciences.
ORCID: https://orcid.org/0000-0003-4516-6373. **LATTES:** http://lattes.cnpq.br/4498594723433539.
(e) PhD in Agronomy.
ORCID: http://orcid.org/0000-0002-3375-0700. **LATTES:** http://lattes.cnpq.br/5838446995807079.
(f) PhD in Agronomy.
ORCID: http://orcid.org/0000-0002-4288-206X. **LATTES:** http://lattes.cnpq.br/7105106788421440.

Article history:
Received 16 December, 2021
Accepted 17 November, 2022
Published 30 January, 2023

(*) CORRESPONDING AUTHOR
Address: Instituto Federal Goiano, Câmpus Iporá. Av. Oeste nº 350, CEP: 76200000 - Iporá (GO) - Brasil. Telefone: (+55 64) 36740400
E-mail: maria.furquim@ifgoiano.edu.br

Abstract

Remotely Piloted Aircraft Systems (RPAS) are already a reality in Brazil. They are used in different fields of knowledge to obtain digital products that contribute to the identification, monitoring, control, and precision of the agricultural decision process. However, the cost-benefit of applying this technology to produce seedlings in commercial tomato nurseries needs better evaluation. This research analyzes the use of an RPAS with RGB camera over areas of table tomato seedlings and compares the cartographic products with the information obtained through semi-structured interviews with rural property owners in the States of Goiás, Minas Gerais, and the Federal District (Brasília). The results were not divided into external area applications and internal (greenhouse) mapping, as adopting technology for monitoring the seedling production process inside greenhouses is still economically unfeasible compared to human identification, thus not justifying the investment. Nonetheless, images of the external area provide crucial information for planning a nursery, considering its structural aspects and adequate disposal.

Keywords: Seedling production; Digital Image Processing; UAV; Drones.

Resumo / Resumen

PLATAFORMAS AÉREAS REMOTAMENTE PILOTADAS COM CÂMERA RGB PARA O MAPEAMENTO DE VIVEIROS COMERCIAIS DE TOMATE DE MESA

As plataformas aéreas remotamente pilotadas, identificadas como RPAS (do inglês Remotely Piloted Aircraft System), popularmente conhecidas como drones, já figuram como uma realidade no Brasil, em diferentes áreas do conhecimento, para a geração de produtos cartográficos que contribuam na identificação, monitoramento, controle e precisão no processo de decisão agrícola. Todavia, o custo-benefício dessa tecnologia na produção de mudas em viveiros comerciais de tomates precisa ser melhor avaliado. Neste sentido, o presente trabalho objetiva analisar a viabilidade do uso de um RPAS, embarcado com sensor fotográfico RGB, em viveiros de mudas de tomate de mesa, comparando os produtos cartográficos gerados com esta tecnologia com as informações obtidas via entrevista semiestruturada com proprietários de empreendimentos localizados nos Estados de Goiás, Minas Gerais e Distrito Federal. Os resultados carecem ser divididos quanto às aplicações em mapeamento externo (viveiro) e interno (estufa), sendo que a adoção da tecnologia para o monitoramento do processo de produção das mudas, dentro de estufas, ainda se mostra economicamente pouco viável em comparação à identificação visual e operações manuais tradicionais, não justificando o investimento. Por sua vez, o imageamento externo fornece informações cruciais para o planejamento do viveiro, considerando os aspectos estruturais e sua adequada disposição.

Palavras-chave: Produção de mudas; Processamento Digital de Imagens; VANT; Drones.

PLATAFORMAS AÉREAS PILOTADAS A DISTANCIA CON CÁMERA RGB PARA MAPEO DE LOS VIVEROS COMERCIALES DE TOMATE DE MESA

Las plataformas aéreas pilotadas a distancia, identificadas como RPAS (Remotely Piloted Aircraft System), conocidas popularmente como drones, ya son una realidad en Brasil, en diferentes áreas del conocimiento, para la generación de productos cartográficos que contribuyan a la identificación, seguimiento, control y precisión en el proceso de decisión agrícola. Sin embargo, la rentabilidad de esta tecnología en la producción de plántulas en viveros comerciales de tomate debe evaluarse mejor. En este sentido, el presente trabajo tiene como objetivo analizar la factibilidad de utilizar un RPAS, embebido con un sensor fotográfico RGB, en viveros de plántulas de tomate de mesa, comparando los productos cartográficos generados con esta tecnología con la información obtenida a través de entrevistas semiestructuradas a empresarios. (identificados y visitados), ubicados en los Estados de Goiás, Minas Gerais y Distrito Federal. Es necesario dividir los resultados en cuanto a las aplicaciones en mapeo externo (vivero) e interno (invernadero), y la adopción de tecnología para monitorear el proceso de producción de plántulas, dentro de invernaderos, aún se muestra económicamente inviable en comparación con la identificación visual y tradicional. operaciones manuales, no justificando la inversión. Por otro lado, la imaginología externa brinda información crucial para la planificación del vivero, considerando los aspectos estructurales y su adecuada disposición.

Palabras-clave: Producción de plántulas; Procesamiento de imágenes digitales; UAV; Drones.

INTRODUCTION

Alongside other horticultural crops with national social and economic importance, the production chain of table tomatoes in Brazil requires studies that favor the sector and identify opportunities and obstacles. Tomatoes are among the principal crops in the state of Goias, which is the leading state in the national ranking for the production of *in natura* consumption and pulp processing. The fruit's destination illustrates the difference between the production chains of industrial or ground tomatoes and table tomatoes or piled tomatoes. Differences include the plant's natural architecture, management, production costs, producer profile, and marketing channels, which make the activity a high financial risk. Thus, reducing sources that affect performance in the field is indispensable to make the activity more viable (FURQUIM; NASCIMENTO, 2021).

However, studies that consider other aspects of analysis are still underexplored both for upstream segments (suppliers of inputs and technical assistance) and downstream of the production itself (distribution and commercialization), impacting the level of competitiveness of the production chain as a whole. Thus, different methodologies have emerged to verify the viability and efficiency of new technologies, taking into account the various agri-food chains and their specificities.

From this perspective, acquiring uniform seedlings with good sanitary and physiological qualities is a crucial input in the sector. However, producing seedlings with these characteristics requires an adequate infrastructure, usually found in commercial nurseries, where environmental factors like temperature, solar radiation, relative air humidity, and water management can be controlled. Outsourcing seedling production is already a strategy to optimize the producer's time and resources (JORGE *et al*. 2016, p. 26).

The complementarity of the production/acquisition of seedlings with production reinforces the need for studies that promote advances in the production process (monitoring of planting failures, identification of pests and diseases, application of pesticides, among others), in addition to promoting greater efficiency and agility in the execution of activities.

Currently, one of the ways to obtain greater production control is through Remote Sensing data and techniques, especially those provided by aerial platforms, since the plantations in question cover small areas. Remotely piloted aerial platforms, identified by the acronym RPAS (*Remotely Piloted Aircraft System*), popularly known as drones, have been massively disseminated in Brazil, mainly to obtain agricultural information, such as productivity indices and disease and pest monitoring, or even to analyze soil preparation/topography. The wide-ranging variety of applications of this technology and favorable results reported in many studies have aided producers' decision-making.

Considering the particularities in the production chain of table tomatoes in Goiás, together with the importance of the input (i.e., plant seedlings) to promote the crop's performance in the field, this study aims to analyze the viability of RPAS or drones for mapping in commercial nurseries, aiming at increased control of production and quality. The study covers the main tomato production centers in Goiás, offering a comprehensive and diversified survey.

APPLICATION OF RPAS IN THE ERA OF DECISION: POSSIBILITIES IN THE AGRICULTURAL SCIENCES

Remotely piloted aerial platforms have a varied nomenclature in the literature, especially in English, including Remotely Piloted Aircraft (RPA), Remotely Piloted Aircraft Systems (RPAS), and Unmanned Aerial Vehicles (UAV) (PRUDKIN, 2016), or in Portuguese, *Veículos Aéreos Não Tripulados* (VANT) (ALVES JÚNIOR *et al*., 2018).

Although the equipment's history is military, the tool has multiple applications in the civil market. For this reason, RPAS have become popular in recent years, given their enormous potential in different sectors, ranging from the entertainment and media industry to the expressive agribusiness sector, where it is used to monitor and evaluate plantations, orchards, forests, and conservation areas. According to Prudkin and Mielniczuk (2019, p.72), "[...] the drone does not only symbolize a new technology but a process of continuity that is related to the history of perception and the ability to observe the world". After many years of improvement, this technology is indispensable in the contemporary era.

For the sake of user and airspace safety, this popularization has required new legal parameters to regulate crewless aircraft operations. The Brazilian Regulation of Special Civil Aviation (RBAC-E) No. 94 of 2015 defines "[...] (1) Model aircraft as any unmanned aircraft for recreation purposes; (2) Remotely Piloted Aircraft (RPA) intended for remotely piloted operation" (BRASIL, 2015, p. 4), with a payload like photographic sensors. The responsibility and authority are assigned to the remote pilot commanding the RPAS or model aircraft during its operation. In turn, the ordinance issued by the Department of Airspace Control – DECEA No.112/DGCEA (Director General of the Department of Airspace Control), of May 22, 2020, reissues IAC 100-40 - Instruction on "Unmanned Aircraft and Access to Airspace," governing the procedures and imperative responsibilities for safe access to Brazilian airspace by unmanned aircraft, as well as the penalties inherent in non-compliance with legal provisions. Therefore, they must comply with legal, ethical and regulatory factors in their operation, ensuring proper use.

It is noteworthy that in Brazil, RPAS are categorized into classes, depending on the Maximum Takeoff Weight (MTOW), as established in RBAC-E No. 94 of 2015: (1) Class 1: RPA with MTOW greater than 150 kg; (2) Class 2: RPA with MTOW greater than 25 kg and less than or equal to 150 kg; and (3) Class 3: RPA with MTOW less than or equal to 25 kg (this has two subdivisions: RPAS with up to 250 grams of maximum takeoff weight and those that exceed this weight).

The models available on the market are usually fixed-wing and rotary-wing (multi-rotor). With the aerodynamics of an airplane or glider, the former offer longer flight times and speed and cover extensive areas. The second group, with a rotary wing, is the most popular and allows flights in environments confined by buildings or trees, having greater maneuverability (FOGAÇA, 2020) as they take off and land vertically, like a helicopter. Both models can be coupled with other sensors, multispectral and RGB cameras that are used with aerophotogrammetry techniques to generate cartographic products, such as orthorectified digital mosaics and digital surface and terrain models (PRUDKIN, 2019).

Given that this technology has become an essential option in obtaining cartographic products, its adoption has acquired a strategic character in assisting the decision-making process and the conduct of different economic activities, especially those related to farming, having a relational character with precision agriculture and livestock. According to Matese *et al.* (2015, p. 2972), "Precision agriculture (PA) can be defined as the site-specific management of crop heterogeneity on a temporal and spatial scale, in order to increase the efficiency of agricultural inputs and yields, quality and sustainability of production."

From this perspective, Massruhá *et al.* (2020) clarify that the growing global demand for food, fiber, and clean energy to the detriment of the limited availability of natural resources and recurrent climate changes impute the need to increase productivity and optimize the use of productive resources. Adopting different technologies that effectively promote digital transformation in agriculture has become imperative. According to the authors, applying inputs at a variable rate and mapping with drones are the most popular technologies available in the face of these challenges. Santos *et al.* (2020) corroborate this view, pointing out that image capture permits continuous monitoring of planting or animal breeding, early identification of anomalies, and adequate intervention.

Writing about the development of RPAS and its relationship with precision agriculture, Barbedo (2019, p. 2) states that "[...] the application of new knowledge in rural areas helps producers to identify strategies that can increase agricultural management efficiency, maximizing crop profitability and making agribusiness more competitive". According to the author, aerial photo data enable the timely detection of problems with water availability, diseases, nutritional deficiencies, and pests. Huuskonen and Oksanen (2018) describe the use of RPAS combined with augmented reality technology, which assists in identifying sites for collecting soil samples and gathering information for adequate fertilization. According to these authors, RPAS have additional advantages over satellites as they can capture images in cloudy conditions and have a significantly higher spatial resolution, usually centimetric.

Likewise, Albuquerque *et al.* (2021) highlight the technical benefits of this technology in promoting efficient monitoring of forest restoration projects through the panoramic high spatial resolution view and georeferencing of the area of interest. Xavier (2013) includes the feasibility of applying the RPAS for environmental assessment for surveys and preventing imminent environmental risks.

According to Barbedo (2019), the multiple applications of RPAS, especially in the agricultural sector, promote technological progress; however, technical challenges, such as autonomy and flight safety, still need improvement. Usually, the devices are powered by electricity, with fast flights (average of 25 to 40 minutes, depending on the aircraft category), which still undermines their efficiency in large areas.

METHODOLOGICAL PROCEDURES

This study's objective is a qualitative and descriptive mapping of nurseries producing table tomato seedlings in the state of Goiás. The intention is to analyze the feasibility of RPAS use in activities associated with this type of enterprise. According to Zanella (2013, p. 100), "[...] qualitative research is descriptive, as it is concerned with describing phenomena through the meanings manifest by the environment".

The author adds that the results of the relationship between the environment and social actors can be represented in different ways, including the transcription of interviews, narratives, statements, photographs, and other forms of data collection and exposure of information.

Initially, the nurseries were identified based on information provided by Agrodefesa/Plant Health Management, the agency responsible for implementing the state policy on animal and plant health, which indicated the municipalities in which the nurseries are located since other nursery registration information is confidential. In total, ten nurseries meeting the inclusion criteria were identified, eight located in the state of Goiás, in the municipalities of Pires do Rio, Catalão, Morrinhos, Goianápolis, Leopoldo de Bulhões, and Anápolis, with one nursery each, and Hidrolândia with two nurseries. One was located in Brazlândia/DF, and another was in Araguari-MG.

All the nurseries were contacted in advance; aerial mapping was carried out in six properties according to their availability to participate in the research. These were located in Araguari/MG and Brazlândia/DF, and in Catalão, Pires do Rio, Goianápolis, and Leopoldo de Bulhões in Goiás. In the presentation of the results, the nurseries are identified by letters A to F, randomly distributed. In the Pires do Rio enterprise, the production serves producers and people interested in cultivating for their own consumption, reaching a maximum volume of 12,000 seedlings per year.

The flights were conducted in accordance with Brazilian legal regulations. The equipment used was the *Parrot Anafi Work 4K* (rotary wing) model with a 4k RGB standard camera (3 bands, covering the visible light spectrum, in the blue, green, and red bands), 21 MP, with camera stabilizer cradle in a 180° vertical orientation axis, to generate images in selected nurseries. The flight plan was prepared in the free *Pix4D Capture* software for smartphones/tablets, with the following flight parameters: 50 m height and overlap between the photos of 70% in the longitudinal and 60% in the lateral direction.

Once the flight plans had been prepared in the office, programmed with the "target's" coordinates, in the field, the RPAS traveled the programmed path autonomously, following the flight lines. In addition, this programming allows the photos to have a controlled overlap, in this case, 60% laterally and 70% longitudinally, allowing the creation of an aerophotogrammetric mosaic without coverage failures, as exemplified in Figure 1.

The image processing in the laboratory employed Pix4DMapper software, which is widely used in RPAS 3-D mapping and reconstruction services, especially for commercial purposes, due to the quality of the products generated (SANTOS *et al*., 2020).In addition to the orthorectified mosaic (a set of photographs joined by homologous points between two or more photos, with minimized geometric deformation when prioritizing photos obtained with an angle of 90º, i.e., an orthogonal projection), this processing generates point clouds with altimetry information.

The results include digital surface and terrain models that obtain the targets' elevation (height) on the surface, the terrain's topography, and the calculation of distances, areas, and volumes.

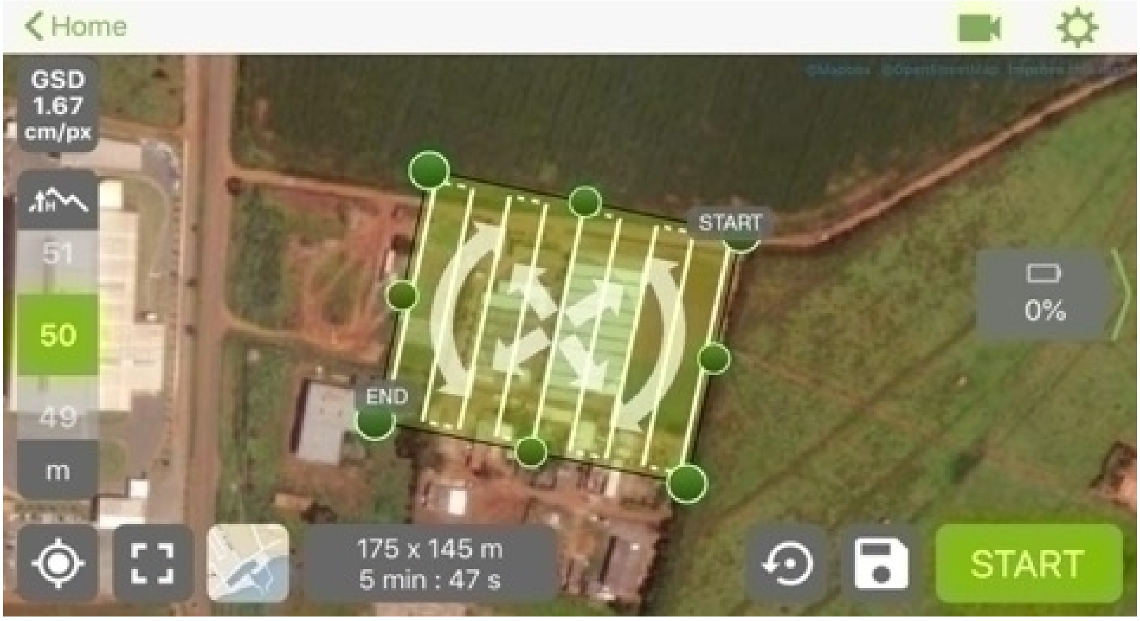

Figure 1 - Flight plan of the area of interest to be mapped in Goianápolis, programmed in the Pix4D Capture software, with the flight lines adjusted according to the lateral and longitudinal overlap suitable for this project (60 x 70%) at a flight height of 50 m.

Corresponding semi-structured interviews were conducted with the nurseries' owners about their enterprise, pointing out aspects that could be analyzed comparatively with the aerial imaging products. According to Zanella (2013, p. 116), this data collection instrument follows a "script" or "guide" created by the interviewer without being rigidly tied to the sequence of questions. "The conversation follows according to the interviewee's statements, without rigidly obeying the interview script." The methodological procedures adopted in the development of this work are summarized in the flowchart in Figure 2.

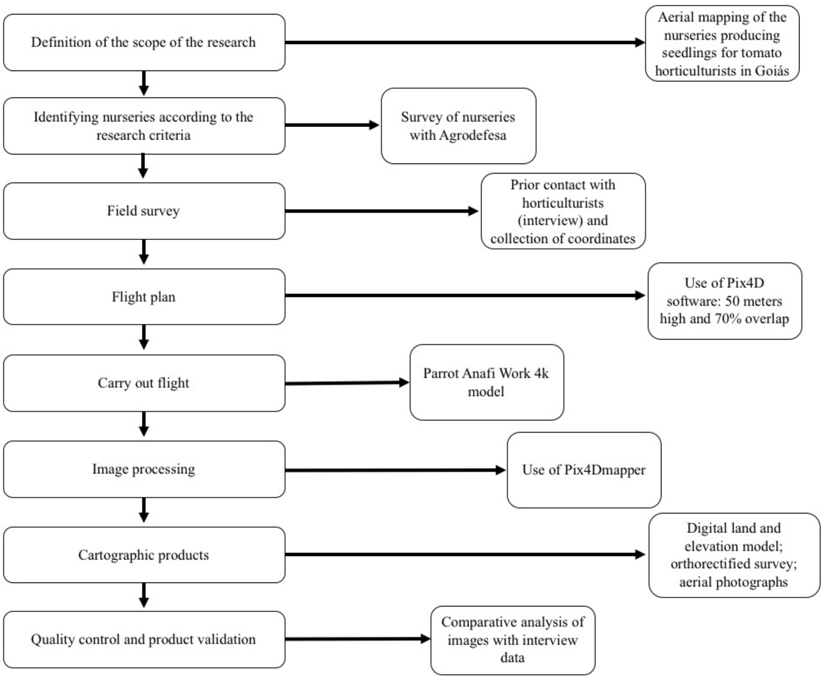

Figure 2 - Flowchart of the activities developed in this research.

RESULTS AND DISCUSSION

Using seedlings with adequate nutritional, sanitary, and physiological qualities are conditioners for the adequate performance of table tomato crops in the field. Thus, acquiring them from commercial nurseries allows the horticulturist to optimize the production process stages since in-house production of seedlings is unfeasible due to the legal requirements, as established by Agrodefensa Normative Instruction - IN No. 06 of 2011. Moreover, other inhibiting factors include necessary investments in physical infrastructure and labor and the commitment of land destined for production. According to Jorge *et al*. (2016, p. 26), "The trend, proven in the field, is that due to the high technological investment, the production of vegetable seedlings is separate and is a service provider for producers who then start their investments from transplantation in the field."

Thus, based on the cartographic products generated, it was possible to extract information about the characteristics of the projects analyzed; Figure 3 shows the infrastructure variations from one nursery to another. Data includes the difference in the number and dimensions of the greenhouses, the access roads, and whether the greenhouse models are twin arch or individual (a ceiling height of 2.5 m) and covered with plastic material. In Goiás, in particular, nurseries that produce creeping or staked tomato seedlings must be under screens with a maximum mesh of 0.239 mm, as provided in paragraph 4 of Article 11 of IN No.06 of 2011. However, the images do not confirm if the screened material used in the nurseries in question complies with these technical specifications. Subsequent on-site observation substantiated that all the projects comply with the regulations.

According to Lima *et al*. (2016), professional nurseries for the production of commercial vegetable seedlings should include three structural categories, namely: basic structure (roads, energy distribution network, water availability, flatter topography, windbreak); production structure (greenhouses, storage for inputs and equipment, sowing sheds, germination chambers, and an area for washing and disinfecting trays); support structure (office, kitchen, bathroom, locker room, wheel disinfection facilities, and others). All of these categories are visible on the images.

Furthermore, Nunes and Santos (2007) recommend that an area's levels of sunlight and ventilation should be checked before a screened nursery is installed. They suggest building on flat ground, which receives the most solar radiation throughout the day and is associated with good ventilation, contributing to controlling the nursery's internal temperature. They suggest implementing a windbreak to protect against strong winds that may potentially damage the nursery's structure. These structural factors are also observable in aerial images.

Imaging also makes a complementary analysis possible, using the Digital Surface Model (DSM) and the Digital Terrain Model (DTM), generated in this order by the same processing software, as shown in Figures 4 and 5, to represent altimetry data of areas overflown with the UAV, including the terrain topography. While the DSM shows the height of vegetation and buildings above the surface, adding to the altitude of the terrain itself, the DTM details the altimetric variation of the terrain in an attempt to exclude natural or artificial above-ground objects. By subtracting the DSM by the DTM, a third altimetric product is generated, called the Digital Elevation Model (DEM), which only calculates the height of the selected targets without interference from the terrain (ALBUQUERQUE *et al*., 2022).

According to Oliveira and Tommaselli, the digital representation of the surface makes it possible (2012, p. 194) "[...] to perform a detailed topographic analysis and modeling, generate slope or geological maps, extract terrain profiles, perform calculations for engineering projects and serve as a data source for geographic information systems". Herein, the DSM and DTM models were obtained by drone flights over the nurseries' area, in which the altimetric differences of the relief are associated with a variation in colors. Table 1 shows the recorded altitudes of the farmland of the nurseries to sea level.

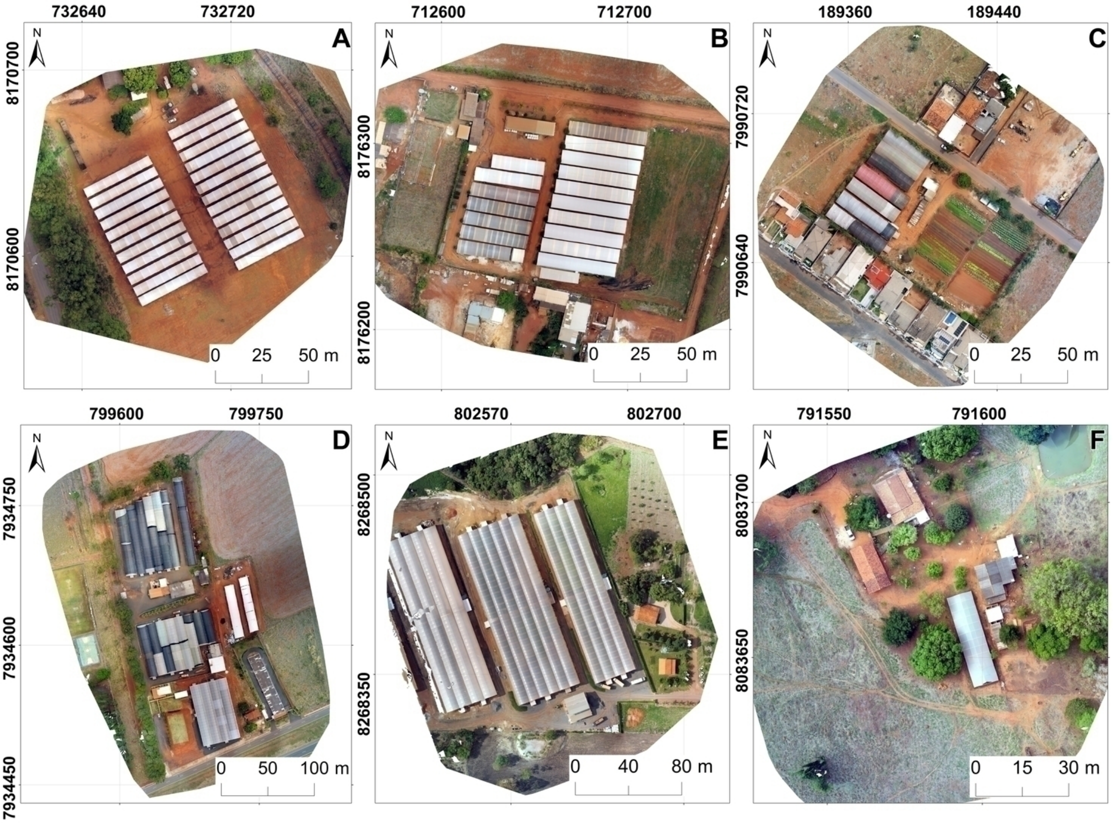

Figure 3 - Aerial images of the nurseries in Leopoldo de Bulhões - GO (A), Goianápolis - GO (B), Catalão - GO (C), Araguari - MG (D), Brazlândia - DF (E), Pires do Rio - GO (F), Brazil, with flights carried out in October 2020.

City	Minimum MDS (m)	Maximum MDS (m)	Minimum MDT (m)	Maximum MDT (m)	Amplitude(m)
Leopoldo de Bulhões	999.93	1011.68	999.93	1009.3	15
GOIANÁPOLIS	968.61	987.78	968.61	982.45	15
Catalão	887,05	902.90	887.07	897.05	20
Araguari	918.69	956.71	918.69	938.70	40
Brazlândia	1039.26	1115.61	1039.26	1107.83	25
Pires Do Rio	648.82	678.02	648.84	665.30	15

Table 1 - Land altitudes obtained with the DSM and DTM in the study areas.

Figures 4 and 5 show that the color differences reflect the altitude in a given area, which vary according to topographic characteristics. It is also noteworthy that in the locations of the greenhouses, there is a predominance of hot colors, which refer to the targets' higher altitudes.

The DTM data, which seeks to eliminate all targets above ground, such as trees and buildings, do not have a specific application for business planning in this research because the nurseries had previously been installed on suitable or adapted land; moreover, this application is emphasized in future studies.

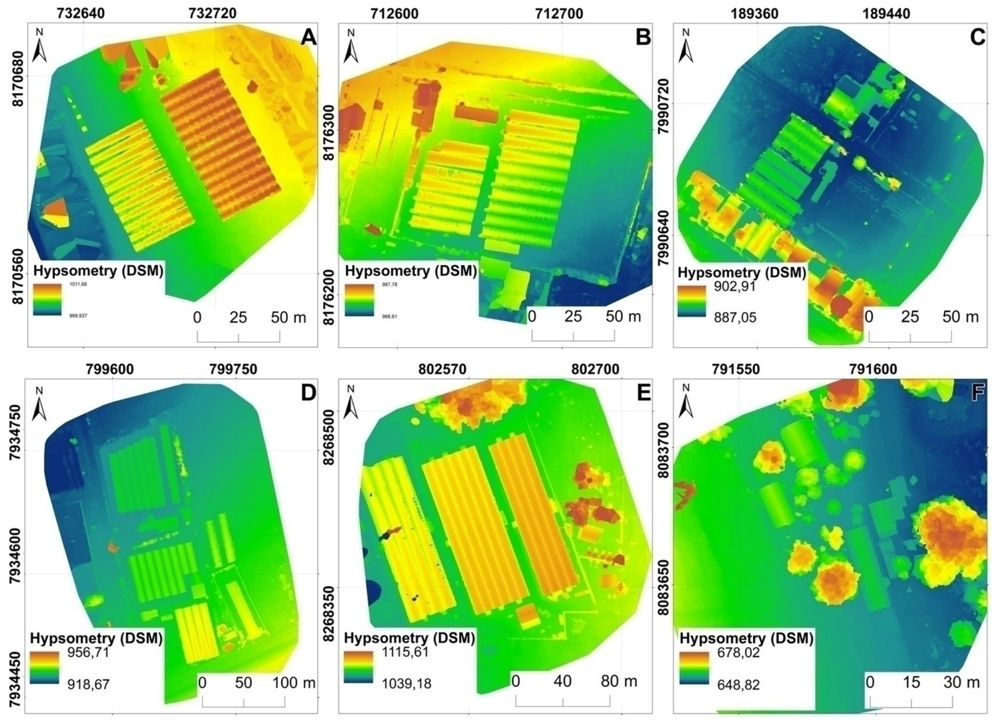

Figure 4 - Representation of the Digital Surface Model for nurseries in Leopoldo de Bulhões (A), Goianápolis (B), Catalão (C), Araguari (D), Brazlândia (E) and Pires do Rio (F), Brazil.

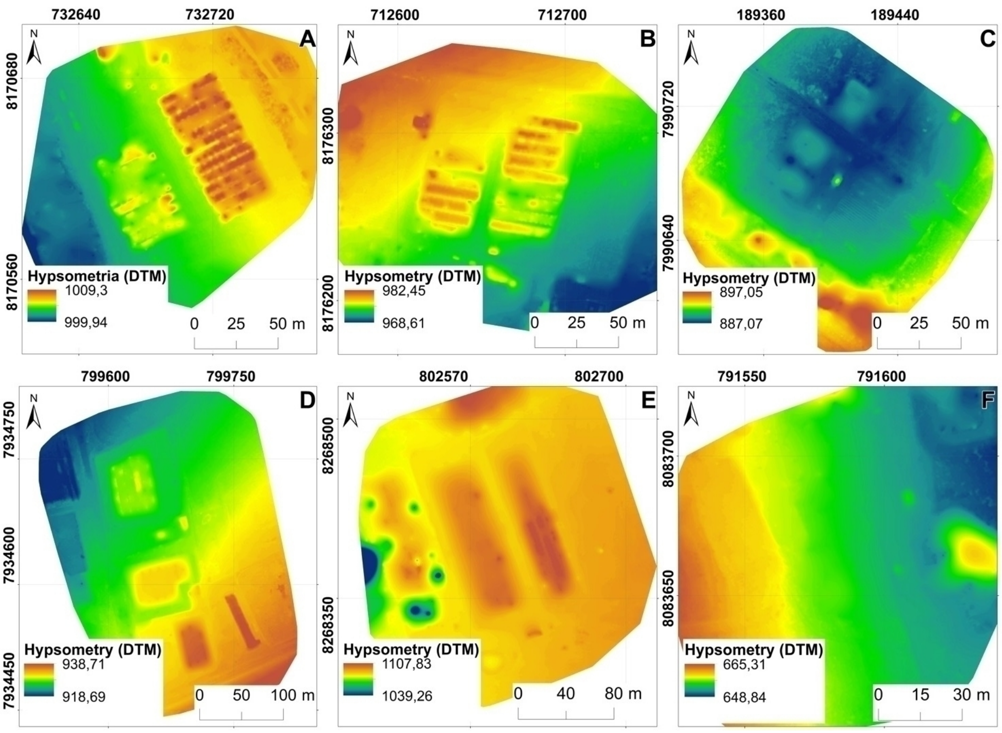

Figure 5 - Representation of the Digital Land Model for nurseries in Leopoldo de Bulhões (A), Goianápolis (B), Catalão (C), Araguari (D), Brazlândia (E) and Pires do Rio (F), Brazil.

Other products obtained refer to the dimensioning of greenhouses through image processing, making it possible to estimate the production capacity, the number of employees involved in operationalizing productive activities, and the raw materials required. These include the arrangements of the benches according to technical guidance, the number of trays per greenhouse, the substrate, pesticides, and the irrigation system, according to image analysis and prospecting of the enterprise (Figure 3). Thus, based on the area and number of greenhouses, conclusions are drawn regarding the general aspects of the business. One example is the Leopoldo de Bulhões nursery, where 7 to 8 million seedlings of different cultures are produced annually (cabbage, pepper, pepper, cauliflower, cucumber). The nurseryman reports that 300 to 400 thousand are table tomato seedlings, making a 20% profit for each thousand produced.

Although in an open environment, the image analysis allows aspects related to the activity to be inferred, it is noteworthy that this information's accuracy lacks a database that cannot be validated by aerial imaging alone. The internal layout varies according to the greenhouse model and how the producer defines the internal space's optimization, such as installing the countertops supporting trays and corridors for internal displacement and the movement of the trays on the countertops.

Lima *et al*. (2016) clarify that in a greenhouse for vegetable seedling production, the "trellis" system is often adopted; a smooth, resistant wire is stretched and supported on metal, wood, or masonry structures. Preferably, they should be 1.20 m wide, built longitudinally inside the greenhouse, in order to include two trays per row per bench. They should be an appropriate height from ground level to address ergonomic issues and facilitate treatments. Specifically, tomato seedling production in nurseries uses returnable or disposable rigid plastic trays with 72, 128, or 200 cells. According to Jorge *et al*. (2019), the length x width x height (in cm) of the trays available on the market are 54 x 28 x 4.8 and 54 x 28 x 4.5 for flexible black plastic trays with 128 and 72 cells, respectively.

It is estimated that two people are employed on average per greenhouse, depending on its dimensions and the level of technology adopted. However, due to IN No. 06 of 2011, which establishes a cultivation schedule in Goiás, temporary labor is also hired to meet the increase in demand in specific periods.

As shown in Figure 6, another cartographic product created was the weighted or Euclidean distance from the point or coordinate of each nursery visited, considering the state of Goiás itself as the maximum limit. Then, the spatial distribution of the nurseries was identified based on the distance between the points, considering the distance limits established for these points (50 km) and the reference municipalities (primary producers of table tomatoes in the state).

According to the Central de Abastecimento de Goiás – CEASA, in 2020, the principal municipalities producing table tomatoes in Goiás were Anápolis, Bonfinópolis, Corumbá de Goiás, Goianápolis, Leopoldo de Bulhões, and São João d'Aliança; three of these municipalities have commercial nurseries. This result is consistent with the findings of Sousa Neto (2019) and Quintanilha *et al*. (2019), which signal a concentration of the table tomato production chain in the state, with the microregions of Goiânia, Anápolis, and Entorno de Brasília prominent in the supply of the product. The authors report that the proximity to large populations and distribution centers contributes to the configuration of the table tomato production chain, as it favors the commercialization of the product with the attributes required by the consumer market, including firmness, color, and lack of damage from handling.

Therefore, adopting RPAS technology in commercial nurseries producing vegetable seedlings with a focus on the cultivation of table tomatoes can contribute to the project elaboration phase in this type of enterprise. It offers a broader and more strategic view of the area, guiding the decision to install greenhouses and other nursery structures, considering the access routes, the nursery's internal logistics, solar lighting, and other technical and marketing factors. As Bezerra (2003, p. 17) corroborates, "When planning a nursery, socioeconomic factors such as the availability of labor, energy, access roads, distances from the place of consumption, and suppliers of inputs and seeds with proven quality must also be considered."

However, currently, the aerial survey of the internal environment of the greenhouses to identify anomalies in seedling production is unfeasible due to the considerable investment required in equipment and people trained to carry out these activities. For the time being, it is not possible to replace manual operations, such as the visual identification of diseases or failures in the cycle of production of seedlings, with automation, especially for small nurseries. As Lobo *et al.* (2020, p. 786) point out, data collection through Remotely Piloted Aerial Platforms is not adequate for every situation, considering the cost-benefit of using such systems. Studies by McLean (2015) and Matese *et al.* (2015) corroborate these conclusions. They calculate the costs of acquiring the equipment in an associated manner, as well as organizing and conducting the collection of images (professional costs/hour) to obtain the orthorectified and georeferenced mosaic (with Latitude and Longitude coordinates), including the steps for processing aerial photos. However, the authors clarify that economic performance evaluations should be analyzed in line with the research objectives and the necessary spatial scale, given the different remote sensing platforms applicable to the various contexts.

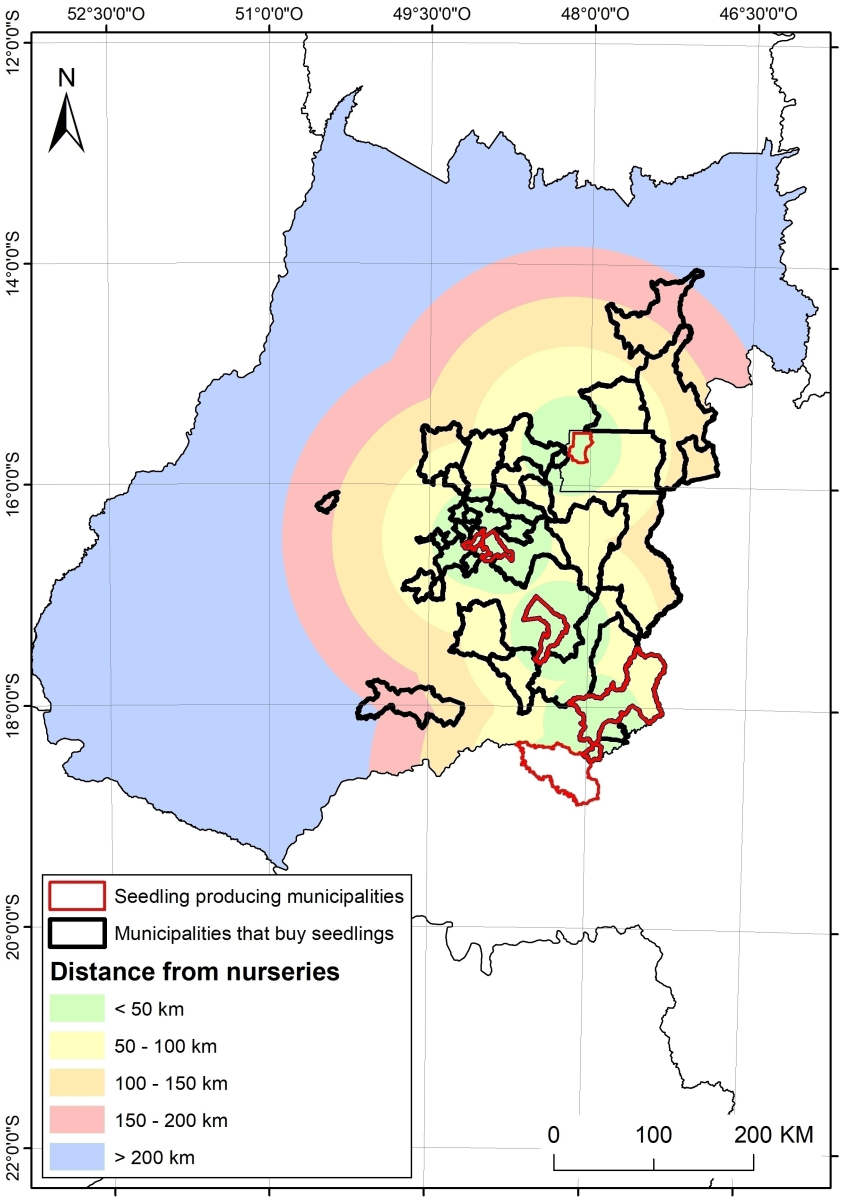

Figure 6 - Weighted or Euclidean distance between the main municipalities producing table tomatoes in the state of Goiás, Brazil, in relation to the location of the nurseries visited.

Notably, adopting this technological tool in regular plant monitoring will depend on each project's specificities and the horticulturalists interest in digitally and automatically conducting seedling management. An example of a pioneer using this technology is the company Veracel Celulose, which manages all stages of production of eucalyptus seedlings digitally, guiding the application of pesticides and reducing the loss of seedlings. However, eucalyptus seedlings' production meets agribusiness's demands, which integrates forestry with industrial and logistic operations (VERACEL, 2021).

Thus, given the structure of some of the nurseries in this study, which have a mobile bar irrigation system, we suggest an adaptation in the existing structure, coupling a digital camera similar to that used in the RPAS, to capture internal images (RGB, multispectral and thermal standard), facilitating monitoring and support for decision making.

Significantly, this method can be adopted by public inspection agents to analyze enterprises' compliance with regulations, not only in nurseries but in other inspection activities related to plant production, which would justify the investment in equipment, image processing software, and technical training.

CONCLUSION

The use of Remotely Piloted Aircraft Systems (RPAS) in Brazil to obtain accurate and updated images and maps of rural environments is not recent. However, the multifunctionality of technology, initially designed for military purposes and widely adopted in the civilian market, has provided different applications in several sectors.

Particularly in the area of Agricultural Sciences, the technology contributes to monitoring cultivated land, especially in identifying and controlling pests, diseases, nutritional status, and soil and water management. In addition, it allows the survey of forest areas, and actual and potential environmental impacts, among other applications that promote greater effectiveness in conducting actions. This study evaluated the use of an RPAS or drone in commercial nurseries that supply the state of Goiás with table tomato seedlings, considering the results of studies that signal the benefits of this type of technology in field production as an example of precision agriculture.

The results indicate the high employability of drone technology, shipped with standard RGB and/or multispectral imaging sensors, for example, in the project preparation phase for tomato seedling production enterprises. The high spatial and temporal resolution aerial images with flights on demand give an enlarged and strategic view of the area. These guide decisions regarding the installation of greenhouses and other nursery structures and show the characteristics of the terrain and the area surrounding the nursery that may need intervention.

On the other hand, the technology to monitor the internal environments of the nurseries is not feasible due to the high operational costs of such systems at the rate required to monitor the development cycle of greenhouse seedlings, including the acquisition of the equipment and human resources qualified for such activities. Thus, maintaining a visual analysis to identify failures in the crop or indicators of diseases/nutritional deficiencies is also an appropriate management technique for seedling production, regardless of the nursery's infrastructure and the technological level of each enterprise.

Furthermore, we sought to identify other ways of capturing images in the internal environment of the greenhouses, an application that has, until now, required more experienced RPAS operators. In this case, we suggest adapting existing structures in the nurseries by coupling digital cameras to monitor cultivation, alternatives that need technical, scientific, and economic validation studies.

ACKNOWLEDGMENTS

The authors are grateful to the Fundação de Amparo à Pesquisa do Estado de Goiás – FAPEG, for the resources allocated to the acquisition of drones used in this research.

To the Federal Institute of Education, Science and Technology of Goiano (IF Goiano), Campus Iporá, for granting leave for training. M.E.F. is a CNPq research productivity fellow (process 315699/2020-5).

REFERENCES

ALBUQUERQUE, R. W.;FERREIRA, M.E.; OLSEN, S. I.; TYMUS, J. R. C.; BALIEIRO, C. P.; MANSUR, H.; MOURA, C. J. R.; COSTA, J. V. S.; BRANCO, M. R. C.; GROHMANN, C. H. **Forest Restoration Monitoring Protocol with a Low-Cost Remotely Piloted Aircraft: Lessons Learned from a Case Study in the Brazilian Atlantic Forest.** Remote Sensing, v. 13, p. 2401, 2021.

ALBUQUERQUE, R. W.; MATSUMOTO, M. H.; CALMON, M.;FERREIRA, M. E.; VIEIRA, D. L. M.; GROHMANN, C. H. **A protocol for canopy cover monitoring on forest restoration projects using low-cost drones.** Open Geosciences, v. 14, p. 921-929, 2022.

ALVES JR., L. R.;FERREIRA, M. E.;CORTES, J. B. R.; JORGE, L. A. C. **High accuracy mapping with cartographic assessment for a fixed-wing remotely piloted aircraft system**. Journal of Applied Remote Sensing, v. 12, p. 1-22, 2018.

BARBEDO, J. G. A. **A review on the use of unmanned aerial vehicles and imaging sensors for monitoring and assessing plant stresses**. Drones, v. 3, n. 2, 2019.

BEZERRA, F. C. **Produção de mudas de hortaliças em ambiente protegido**. Fortaleza: Embrapa Agroindústria Tropical, 2003. 22 p. (Embrapa Agroindústria Tropical. Documentos, 72).

BRASIL. ANAC. **Requisitos gerais para veículos aéreos não tripulados e aeromodelos**. RBAC – E nº 94. Brasília, 2015.

BRASIL. Ministério da Defesa. Comando da Aeronáutica. Departamento de Controle do Espaço Aéreo. **Portaria DECEA No 112/DGCEA, de 22 de maio de 2020**. Aprova a reedição da ICA 100-40, Instrução sobre "Aeronaves não tripuladas e o Acesso ao Espaço Aéreo". Brasília, 2020.

FOGAÇA, A. **Drones, leis e regulamentação: tudo o que você precisa saber antes de voar**. 2020. Disponível em: https://tecnoblog.net/379593/drones-leis-e-regulamentacao-tudo-o-que-voce-precisa-saber-antes-de-voar/

FURQUIM, M.G.D.; NASCIMENTO, A. dos R. Aspectos relevantes para o entendimento da cadeia do tomate de mesa no Brasil. In: Estudos em Agronegócio: participação brasileira nas cadeias produtivas - V. 5. - Medina, G. da S.; Cruz, J. E. (orgs.). - Goiânia / Kelps, 2021.

HUUSKONEN, J.; OKSANEN, T. **Soil sampling with drones and augmented reality in precision agriculture.** Computers and Electronics in Agriculture, v.154, p.25-35, 2018.

JORGE, M. H. A.; ANDRADE, R. J. de.; COSTA, E. **O mercado de mudas de hortaliças.** In: NASCIMENTO, W. M.; PEREIRA, R. B. Produção de mudas de hortaliças. Brasília, DF: Embrapa, 2016.

JORGE, M. H. A.; MELO, R. A. de C. e; HABER, L. L.; REYES, C. P.; COSTA, E.; BORGES, S. R. dos S. **Recomendações técnicas para utilização de bandejas multicelulares na produção de mudas de hortaliças**. Brasília, DF: Embrapa Hortaliças, 2019. 30 p.

LIMA, G. G. da S.; NASCIMENTO, A. dos R.; ÁZARA, N. A. de. **Estruturas de um viveiro profissional para produção de mudas de hortaliças.** In: NASCIMENTO, W. M.; PEREIRA, R. B. Produção de mudas de hortaliças. Brasília, DF: Embrapa, 2016.

LOBO, F. C.; FERREIRA, M. E.; UCHOA, C.;COSTA, J. V. S.**Uso de Plataformas Aéreas Não Tripuladas no Brasil? um Panorama de Dez Anos (2008-2018) de Publicações Acadêmicas.** RBC. Revista Brasileira de Cartografia, v. 72, p. 807-828, 2020.

MASSRUHÁ, S. M. F. S.; LEITE, M. A. de A.; LUCHIARI JUNIOR, A.; EVANGELISTA, S. R. M. **A transformação digital no campo rumo à agricultura sustentável e inteligente.** In: MASSRUHÁ, S. M. F. S.; LEITE, M. A. de A.; OLIVEIRA, S. R. de M.; MEIRA, C. A. A.; LUCHIARI JUNIOR, A.; BOLFE, E. L. Agricultura Digital: Pesquisa, desenvolvimento e inovação nas cadeias produtivas. – Brasília, DF: Embrapa, 2020.

MATESE, A.;TOSCANO, P.;DI GENNARO, SF;GENESIO, L.;VACCARI, FP;PRIMICERIO,

J.;BELLI, C.;ZALDEI, A.;BIANCONI, R.;GIOLI, B. **Intercomparison of UAV, Aircraft and Satellite Remote Sensing Platforms for Precision Viticulture.**Remote Sensing. v.7*,* p. 2971-2990, 2015.

MCLEAN, C. **Aerial Mapping Techniques and Technologies: A cost benefit analysis.** Apresentação para o simpósio de engenharia, realizado pelo Departamento de Geodésia e Geomática da Universidade de New Brunswick (Canadá), 2015. Disponível

em: http://www2.unb.ca/gge/News/2015/STC/McLean.pdf

NUNES, M. U. C.; SANTOS, J. R. dos. **Tecnologia para produção de mudas de hortaliças e plantas medicinais em sistema orgânico.** Embrapa Tabuleiros Costeiros - Circular Técnica, v. 48, p. 1-8, 2007.

OLIVEIRA, R. A. de.; TOMMASELLI, A. M. G. **Geração automática de modelo digital de superfície utilizando múltiplas imagens.** Anais do III Simpósio Brasileiro de Geomática, Presidente Prudente - SP, 26-28 de julho de 2012. v.1. p. 193-198.

PRUDKIN, G. **El periodismo** *drone*. Contextualización histórica y posibles usos periodísticos. Revista Communicação & Inovação, v. 33, p. 7-21, 2016.

PRUDKIN, G. **Drones: su origen y aplicación en el periodismo contemporáneo para generación de contenidos em 3D.** In: DRONES E CIÊNCIA: Teoria e aplicações metodológicas – V. I. - PRUDKIN, G.; BREUNIG, F. M. (orgs.) – Santa Maria, RS: FACOS – UFSM, 2019.

PRUDKIN, G.; MIELNICZUK, L. P. **El periodismo** *drone*: ¿innovación, disrupción ocontinuidad? Un estudio teórico retrospectivo sobre la captación de imágenes aéreas en el contexto de una cultura visual. Contemporanea - Comunicação e Cultura, v.17, n.01, p.70-98, 2019.

QUINTANILHA, K.T.;TAVARES, É. B.;CORCIOLI, G. **Mapeamento do escoamento do tomate comercializado no CEASA - Goiás em 2017 e 2018.**Pesquisa, Sociedade e Desenvolvimento, v. 8, n.10, p.e138101199, 2019.

SANTOS, T.T.; BARBEDO, J. G. A.; TERNES, S.; CAMARGO NETO, J.; KOENIGKAN, L. V.; SOUZA, K. X. S. de. **Visão computacional aplicada na agricultura.** In: MASSRUHÁ, S. M. F. S.; LEITE, M. A. de A.; OLIVEIRA, S. R. de M.; MEIRA, C. A. A.; LUCHIARI JUNIOR, A.; BOLFE, E. L. Agricultura Digital: Pesquisa, desenvolvimento e inovação nas cadeias produtivas. – Brasília, DF: Embrapa, 2020.

SOUSA NETO, R. de. **O mercado de tomate em Goiás: estudo sobre o comportamento da cadeia e a evolução da atividade produtiva no setor in natura**. Dissertação (Mestrado em Agronegócio) - Universidade Federal de Goiás, Goiânia, 2019.

VERACEL CELULOSE. Disponível em: https://www.veracel.com.br/processo-digital-monitoramento-pragas-e-doencas-viveiro-mudas-eucalipto/ Acesso em: 10 de out. 2021.

XAVIER, R. **A utilização do VANT em levantamentos ambientais**. DSPACE. Paraná, 2013. Disponível em: >. Acesso em: 15 out. 2021.

ZANELLA, L. C. H. **Metodologia de pesquisa** – 2. Ed. Reimp. – Florianópolis: Departamento de Ciências da Administração/ UFSC, 2013.

Author's Affiliation

Furquim, M. G. D. - Professor at Instituto Federal Goiano, Iporá (GO), Brazil.
Nascimento, A. R. - Professor at the Federal University of Goiás, Goiânia (GO), Brazil
Costa, J. V. S. - Member of the Research and Training Program with Unmanned Aerial Vehicles, Goiânia (GO), Brazil.
Ferreira, M. E. - Professor at the Federal University of Goiás, Goiânia (GO), Brazil.
Corcioli, G. - Professor at the Federal University of Goiás, Goiânia (GO), Brazil
Borges, L. C. - Professor at the University Center of Goiás, Goiânia (GO), Brazil.

Authors' Contribution

Furquim, M. G. D. - The author contributed to the elaboration, realization and manipulation of the date and writing.
Nascimento, A. R. - The author contributed to the elaboration, realization and manipulation of the date and writing.
Costa, J. V. S. - The author contributed to the elaboration, realization and manipulation of the date and writing.
Ferreira, M. E. - The author contributed to the elaboration, realization and manipulation of the date and writing.
Corcioli, G. - The author contributed to the elaboration, realization and manipulation of the date and writing.
Borges, L. C. - The author contributed to the elaboration, realization and manipulation of the date and writing.

Editors in Charge

Alexandra Maria Oliveira
Alexandre Queiroz Pereira