REVIEW

Application of drones in international and Cuban agriculture. A review

Aplicación de drones en la agricultura internacional y cubana. Revisión

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María Elena Ruiz Pérez[I*], Roberto García Reyes[II], Neili Machado García[I]

[I]Universidad Agraria de La Habana, San José de las Lajas, Mayabeque, Cuba.
[II]Ministerio de la Agricultura, Departamento Provincial de Suelos y Fertilizantes, provincia Holguín, Cuba.

ABSTRACT: The introduction of different technologies such as Geographic Information Systems, images obtained from satellites, airplanes, drones, various types of sensors as well as computer systems and tools have caused a revolution in Agriculture. The use of these technologies has always had the interest of using available resources effectively and efficiently, as well as humanizing agricultural work. This article reviews the benefits obtained with the use of drones internationally and also in Cuba. However, works that propose the use of Precision Agriculture in Cuba have also been cited. It is observed that there are still few published works that describe in detail the results obtained that allow their reproducibility and there are many that describe them qualitatively. It is considered that in the particular case of drones, the extension of their use is still very expensive since in a practical way only the GEOCUBA Enterprise has all the infrastructure and trained staff for their most complete use, so different enterprise, institutions and farmers that wish to use them must make large disbursements.

Keywords: UAV, Precision Agriculture.

RESUMEN: La introducción de diferentes tecnologías como los Sistemas de Información Geográfica, las imágenes obtenidas a partir de satélites, aviones, drones, los diversos tipos de sensores, así como los Sistemas y herramientas informáticas han provocado una revolución en la Agricultura. La utilización de estas tecnologías siempre ha tenido el interés de emplear de una forma eficaz y eficiente los recursos disponibles, así como humanizar el trabajo agrícola. En este artículo se hace una revisión de los beneficios obtenidos con el empleo de los drones a nivel internacional y también en Cuba. No obstante, se han citado también los trabajos que plantean la utilización de la Agricultura de Precisión en Cuba. Se observa que todavía son pocos los trabajos publicados que describan de forma detallada los resultados obtenidos que permitan su reproducibilidad y abundan los que describen los mismos de forma cualitativa. Se considera que en el caso particular de los drones, resulta muy costosa todavía la extensión de su utilización ya que de forma práctica sólo la Empresa GEOCUBA dispone de toda la infraestructura y el personal capacitado para su utilización más completa por lo que las diferentes empresas, instituciones y campesinos que deseen emplearlos deben realizar grandes desembolsos.

Palabras clave: Vehículos aéreos no tripulados, Agricultura de Precisión.

INTRODUCTION

Agriculture is the largest consumer of water globally and it is expected that the demand for food and water will increase dramatically in the near future (Rejeb *et al.*, 2022). Furthermore, the increasing consumption of fertilizers and pesticides, together with the intensification of agricultural activities, could generate future environmental challenges. Similarly, arable land is limited and the number of farmers is declining around the world. These challenges accentuate the need for innovative and sustainable agricultural solutions (Tzounis *et al.*, 2017; Elijah *et al.*, 2018; Inoue, 2020; Friha *et al.*, 2021).

The incorporation of new technologies has been identified as a promising option to address these challenges. The so-called Smart Agriculture Brewster *et al.* (2017); Tang *et al.* (2021) and precision agriculture Feng *et al.* (2019); Khanna & Kaur (2019) have emerged as a result of such issues. The first introduces Information and Communication Technologies (ICT) and other cutting-edge innovations in agricultural activities to increase efficiency and effectiveness (Haque *et al.*, 2021). For

*Author for correspondence: María Elena Ruiz Pérez, e-mail: mruiz@unah.edu.cu

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its part, precision agriculture focuses on site-specific management by dividing the land into homogeneous parts, and each part receives the exact amount of input it requires to optimize crop performance through novel technologies (Feng *et al.*, 2019; Khanna & Kaur, 2019). Among the technologies that have attracted the attention of scholars in this field are wireless sensor networks (WSNs) Zhou *et al.* (2016); Zheng & Yang (2018), Internet of Things (IoT) Gill *et al.* (2017); Liu *et al.* (2019); 2019; He *et al.* (2021), artificial intelligence (AI) techniques, including machine learning and deep learning Liakos *et al.* (2018); Shadrin *et al.* (2019); Parsaeian *et al.* (2020), information technologies (Jinbo *et al.* (2019); Zamora-Izquierdo *et al.* (2019); Hsu *et al.* (2020),, Big data Gill *et al.* (2017); Tantalaki *et al.* (2019) and blockchains (Khan *et al.*, 2020; Pincheira *et al.*, 2021).

In addition to the aforementioned technologies, remote sensing has been considered a technological tool with high potential to improve smart and precision agriculture. Satellites, human-manned aircraft, and drones are popular remote sensing technologies (Tsouros *et al.*, 2019). Drones, known as unmanned aerial vehicles (UAV), unmanned aircraft systems (UAS) and remotely piloted aircraft are of great importance as they have multiple advantages compared to other remote sensing technologies. For example, drones can deliver high-quality, high-resolution images on cloudy days (Manfreda *et al.*, 2018). Furthermore, its availability and transfer speed constitute other benefits (Radoglou-Grammatikis *et al.*, 2020). Compared to airplanes, drones are very cost-effective and easy to set up and maintain (Tsouros *et al.*, 2019).

In Cuba for several years, drone flights have been carried out with different objectives; however, the information obtained for agriculture has still been disseminated in most cases, more as an advertising impact than through reports or scientific publications that can be replicated by other researchers. The objective of this article is to provide summary information on the different uses that drones have had in agriculture internationally; their deficiencies and what they have been so far, their use in Cuba, as well as the challenges faced the extent of its use.

THE DRONES

A drone is a device that can fly on a preset course with the help of an autopilot and GPS coordinates. The device also has normal radio controls. It can be piloted manually in case of breakdown or dangerous situation. Sometimes the term drone is used to refer to the entire system, including ground stations and video systems, however, the term is more commonly used for fixed- or rotary-wing model airplanes and helicopters (Ahirwar *et al.*, 2019). Different types of sensors such as accelerometers, gyroscopes, GPS and barometers can be installed on drones to carry out georeferenced measurements. It is also very common for them to carry cameras to take aerial photographs and videos. The cameras can be of different types depending on the interest in the flight and can be very expensive. Ahirwar *et al.* (2019) states that drones are classified according to their weight, autonomy, altitude and the radius in which they operate; for civil use, the types shown in Table 1 can mainly be found.

TABLE 1. Classification of drones for civil use (adapted from Acharya *et al.* (2021))

Category	Weigh (kg)	Altitude (m) (asl[1])	Radius (km)	Autonomy (h)
Micro	<2	until 70	<5	<1
Mini	2-20	until 915	<25	1-2
Little	20-150	until 1524	<50	1-5

[1] above sea level

Despite the advantages that arise, the use of drones also has deficiencies associated among others, with the following aspects: the preparation of the pilot who flies it, the quality of the images obtained, the costs of implementation, its stability, maneuverability and reliability, the engine power that may be limited for certain tasks, the type of battery and its durability, the limitation in flight time, the limitations for data processing, its load capacity, the lack of regulations and the lack of experience (Laliberte *et al.*, 2007; Nebiker *et al.*, 2008; Hardin & Hardin, 2010; Hardin & Jensen, 2011; Laliberte & Rango, 2011; Zhang & Kovacs, 2012; Puri *et al.*, 2017; Lagkas *et al.*, 2018; Manfreda *et al.*, 2018; Dawaliby *et al.*, 2020; Velusamy *et al.*, 2021; Bacco, *et al.*, (2018)..

USE OF DRONES IN AGRICULTURE

Although they were initially used mainly for military purposes, drones can be used in agriculture, with the Japanese being the first to successfully use them for fumigation in the 1980s (Nonami, 2007). Their use has expanded as they can be linked with novel technologies, computing capabilities and integrated sensors to support crop management (e.g. mapping, monitoring, irrigation, plant diagnosis, disaster reduction, early warning systems, wildlife and forest conservation, to name a few (Negash *et al.*, 2019). Similarly, drones could be leveraged in various agricultural activities, including crop and growth monitoring, yield estimation , evaluation of water stress and weeds, pests and disease detection (Inoue, 2020; Panday *et al.*, 2020). They can not only be used for monitoring, estimation and detection purposes based on their sensory data, but also for precision in irrigation and the management of weeds, pests and diseases. In other words, drones are capable of applying water and pesticides in precise quantities according to environmental conditions.

Hunt Jr & Daughtry (2018) state that agricultural tasks with drones can be grouped into three lines: (1) problem exploration, (2) monitoring to prevent yield losses and (3) planning management operations. Each of these lines has different requirements regarding the type of sensor to be used and its calibration, which defines the operating costs. According to this author, line (3) is the most economical, however, in the United States, the majority of farmers still do not obtain benefits from the use of drones for planning management operations. Table 2 shows the requirements for each of these lines.

According to Rejeb *et al.* (2022) Table 3 summarizes some of the benefits of drones in agriculture.

USE OF DRONES IN CUBA

Although at an international level, there is already a distinction between Smart Agriculture and Precision Agriculture, the terminology most used in Cuba has been Precision Agriculture and different papers use tools that are part of it, such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), tractors with computer and sensory equipment for their management, satellite images of different types and drones. However, there are not many scientific articles that have been published, as well as participation in scientific conferences. In the particular case of the use of drones, the articles have been mainly informative with a view to promoting the advantages of using them. The press releases promoting precision agriculture tools are numerous, but logically no technical details of these applications are given. However, their growing popularity, both internationally and nationally, requires frequent reviews of their applications. Although the main objective of this work is a review of the use of drones, publications that use the term Precision Agriculture have also been incorporated with a view to giving a more complete idea of the gradual incorporation of new technologies in Cuban Agriculture.

Hernández *et al.* (2006) has been the first publication found in which elements of precision agriculture are applied. The investigation was carried out on farm No 101; belonging to the Basic Cooperative Production Unit (UBPC) "La Julia" of the

TABLE 2. Drone requirements for the three lines of use for agriculture (Hunt Jr & Daughtry, 2018)

Characteristic	Exploration	Monitoring	Planning
Sensors	Camera (visible, Thermal)	Multispectral	Multispectral, Hyperspectral
Sensor calibration	Not required	Sight	rigorous
Covered area	Specific locations	Entire field	Entire field
Output	Georeferenced photos	Geographic information system of the Field	Decision-making system
Spatial precision	low	medium	high
Orthomosaic is required	no	It depends on the product	yes
Time	immediate	1 or 2 days	From 3 days to 3 months
Cost	low	medium	high
Economic benefit	Not considerable	Depends on the action taken	Better economic rates
Environmental benefit	Not considerable	Depends on the action taken	Greater reduction of agrochemicals
Aplicacions	Check problem locations in the field	Potential yield, occurrences of pests, diseases and weeds	Variable rate applications

TABLE 3. Some of the benefits of using drones in Agriculture Rejeb *et al.* (2022)

Benefit	References
Improve spatial and temporal resolution	(Gago *et al.*, 2015; Niu *et al.*, 2020; Srivastava *et al.*, 2020)
Facilitate Precision Agriculture	(Maimaitijiang *et al.*, 2017; Deng *et al.*, 2018; Kalischuk *et al.*, 2019)
Crop classification and exploration	(López-Granados *et al.*, 2016; Moharana y Dutta, 2016; Maimaitijiang *et al.*, 2017; Kalischuk *et al.*, 2019; Melville *et al.*, 2019; Inoue, 2020).
Fertilizer use	(Deng *et al.*, 2018; Guan *et al.*, 2019)
Drought monitoring	(Su *et al.*, 2018a; Fawcett *et al.*, 2020; Panday *et al.*, 2020)
Biomass estimation	(Bendig *et al.*, 2014)
Yield estimation	(Inoue, 2020; Panday *et al.*, 2020; Tao *et al.*, 2020)
Disaster reduction	(Negash *et al.*, 2019)
Wildlife and forest conservation	(Negash *et al.*, 2019; Panday *et al.*, 2020)
Water stress assessment	(Su *et al.*, 2018a; Zhang *et al.*, 2019; Inoue, 2020)
Detection of pests, diseases and weeds	(Su *et al.*, 2018b; Zhang *et al.*, 2019; Gašparović *et al.*, 2020; Inoue, 2020)

Various Crops Company (ECV), "Batabanó", in the area of an electric central pivot irrigation machine planted with potatoes. The general objective of the research was to propose recommendations for the differentiated application of fertilizers by quadrants for potato cultivation. In the area under study, it was necessary to carry out a study of the fertility and chemical environment of the soil. The applied methodology allowed us to determine the main chemical characteristics of the soil, demonstrating the differences that exist from one quadrant to another. The differentiated fertilization doses for potato cultivation on the aforementioned farm were also calculated, which if implemented, would guarantee a saving of 16.21 t of NPK (9-13-17) and 1.16 t of UREA (46 -0-0), meaning a decrease in the production cost for the ECV by $4,988.53 (MN) and a saving for the Cuban Ministry of Agriculture (MINAG) of $3,278.51 (USD). It is not known if the results were applied.

Lago-González *et al.* (2011) give an explanation of what precision agriculture is and what its main components are. The authors developed a System for the Generation of Performance Maps that, according to them, was one of the first at an international level. In addition, they explain how the proposed application can be used. Curiously, the system test was carried out in 2007 in Australia due to the existence of machines there where the System for generating performance maps created could be tested. The obtained maps are shown.

Lora (2015) applies GPS and GIS to evaluate the energy consumption of agricultural machinery in the “Niña Bonita” Livestock Company, obtaining that total energy expenses decrease by 16%

Almeida-Maldonado *et al.* (2017) developed a website with a view to efficiently managing irrigation. Python language was used for its implementation, mainly because it is very flexible; Its code is readable and well organized, which makes maintenance work and further development easier; In addition, it allows the use of libraries in C and C++, which can be used to offer complex functionalities for which creating a library from scratch could be very expensive. Web2Py was used as the development framework, among other reasons, because it offers a very organized structure and syntax.

Sosa-Escalona *et al.* (2017) present AgroAlert, a tool for predicting the effects of climate change on agriculture. Which provides early warnings of drought in specific crop fields three to six months in advance. AgroAlert is responsible for the organization, storage, handling, analysis and modeling of agroclimatic conditions. Describes the most vulnerable crop areas in terms of soil water conditions and level of salinization. Likewise, it offers the possibility of varying the criteria under which these areas are identified and carrying out the analysis and prediction of the risks.

Guillén *et al.* (2020) provides a comprehensive review of the origin of drones in the North American military industry. Subsequently, it defines Precision Agriculture and how drones are a tool that allows many of its applications to be carried out. Provides information on types of drones and cameras, as well as the type of images obtained, citing examples of applications abroad. It also establishes the advantages and disadvantages of its use. Among the latter, the cost, interference in airspace, climate and the need for specialized personnel to analyze the images obtained. Finally, the role of the GARP (Automation, Robotics and Perception Group of the Faculty of Electrical Engineering) at the UCLV (Central University “Marta Abreu” of Las Villas) who have carried out the construction of drones as well as the development of the necessary software.

Ríos-Hernández (2021) makes a review of some of the technologies used in Precision Agriculture such as satellite images, autonomous driving machinery, drones, the location of sensors in plots, soil maps, Geographic Information Systems and offers qualitative examples of the results obtained. It states that drones and other tools have been used to identify pests in Cuban sugarcane fields since 2009 in the Jesús Rabí base business unit (UEB) in Matanzas. It is reported that GEOCUBA (Business group formed by the integration of the Cuban Institute of Hydrography and the Cuban Institute of Geodesy and Cartography), INICA (Sugar Cane Research Institute) and CENPALAB (National Center for Production of Laboratory Animals) have participated in these works). However, no bibliographic references are offered where the quantitative results have been published.

Matamoros *et al.* (2022) present perhaps the most complete work where the use of different types of drones and also other types of images has been decisive for the development of a computer platform for image processing, specialized cartography and Artificial Intelligence algorithms that are applied to satellite and drone images. The main investigations were carried out in the Sur del Jíbaro rice complex located in the La Sierpe municipality of the Province of Sancti Spíritus. Based on prior knowledge of the crop sowing plans, these were incorporated into the cartography to spatially know the entire distribution of fields, their sowing dates and planned tasks with a view to planning drone flights. Three types of drones were used (Phantom 4 Advanced, Delta Sky Walker X8 and Agras MG-1P Drone) with flight ranges of 30 minutes, 1h 30 minutes and 15 minutes respectively. To process the data, the Agisoft Metashape, Pix4dMapper and IA Tierra software were used, developed by specialists from the GEOCUBA Scientific and Technical Research and Consulting Unit. The authors of the research suggest that systematic monitoring of large areas of rice-planted area through the use of drones is complex due to the flight capacity and processing required. This led to the proposal of combined use of 10 meter resolution Sentinel images and greater exploitation of vegetation indices. The images from this satellite allow the evaluation of the state of the crop every 5 days and the detection of anomalies due to the state of humidity or vegetation. In this way, drone surveys are carried out at certain times of the phenological state of the crops and for the detailed study of areas of anomalies. A service that was widely accepted by producers was fumigation using drones. It is noteworthy that Geo Cuba has already created a drone infrastructure, access to satellite images and computer specialists that make the application of all these technologies possible. However, its use by other companies and private producers would imply prohibitive costs.

Finally, Sosa-Franco *et al.* (2023) discusses the necessary tools of what could be a "smart farm" in the future, creating a computer system that allows automated management through a GIS, images, data of different formats, the information produced by an agricultural farm, as well as such as the possibility of making inquiries about it by non-specialized personnel.

CONCLUSIONS

There is a dizzying growth at the international level in the use of technologies such as Geographic Information Systems, images from satellites, airplanes and lately, very numerously, drones, as well as the link to computer tools and sensors of different types. The above has led to benefits such as improving the spatial and temporal resolutions of agricultural studies, facilitating Precision Agriculture, classifying and exploring crops, applying fertilizers and water efficiently, monitoring drought, estimating biomass and yields, detection of pests, diseases and weeds, disaster reduction and conservation of wildlife and forests. In Cuba, it is observed that there are still few published works that describe in detail the results obtained that allow their reproducibility and there are many that describe them qualitatively. It is considered that, in the particular case of drones, the extension of their use is still very expensive since in a practical way only the GEOCUBA Company has all the infrastructure and trained personnel for their most complete use, so different companies and institutions those who wish to employ them must make large outlays.

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María Elena Ruiz-Pérez. Dr.C., Profesora Titular, Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez". Carretera Tapaste y Autopista Nacional km 231/2, San José de Las Lajas, Mayabeque, Cuba. CP 32700, e-mail: mruiz@unah.edu.cu
Roberto Alejandro García-Reyes. Ing., Inv., Ministerio de la Agricultura, Departamento Provincial de Suelos y Fertilizantes, provincia Holguín, Cuba, e-mail: ralejandro9409@gmail.com
Neili Machado-García. Dr.C., Profesora Titular, Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez". Carretera Tapaste y Autopista Nacional km 23 1/2, San José de Las Lajas, Mayabeque, Cuba. CP 32700, e-mail: neili@unah.edu.cu

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CONTRIBUCIONES DE AUTOR: Conceptualización: María Elena Ruiz. **Curación de datos:** María Elena Ruiz, Roberto García, Neili Machado. **Análisis formal:** María Elena Ruiz, Roberto García, Neili Machado. **Investigación:** María Elena Ruiz, Roberto García, Neili Machado. **Metodología:** María Elena Ruiz. **Supervisión:** María Elena Ruiz, Roberto García, Neili Machado. **Validación:** María Elena Ruiz, Roberto García, Neili Machado. **Visualización:** María Elena Ruiz, Roberto García, Neili Machado. **Redacción–borrador original:** María Elena Ruiz, Roberto García, Neili Machado. **Redacción–revisión y edición:** María Elena Ruiz, Roberto García, Neili Machado.
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