

Agriculture Drones

Market Scenario and Competitive Landscape

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Context

This report provides data about the **agriculture drones market**, focusing on trend and dynamics in the period 2023-2028, on the market segmentations by application, component, farm produce, offering, payload and region and on the competitive landscape of the European region.

1 Agriculture Drones

Unmanned aerial vehicles (UAVs)/drones are remotely piloted aerial vehicles. Agriculture drones are the UAVs used in various agricultural applications, such as precision farming, livestock farming, smart greenhouse, precision fish farming, horticulture, and forestry. Agriculture drones are also used in precision farming applications such as **field mapping**, variable rate application (VRA), crop scouting, and crop spraying.

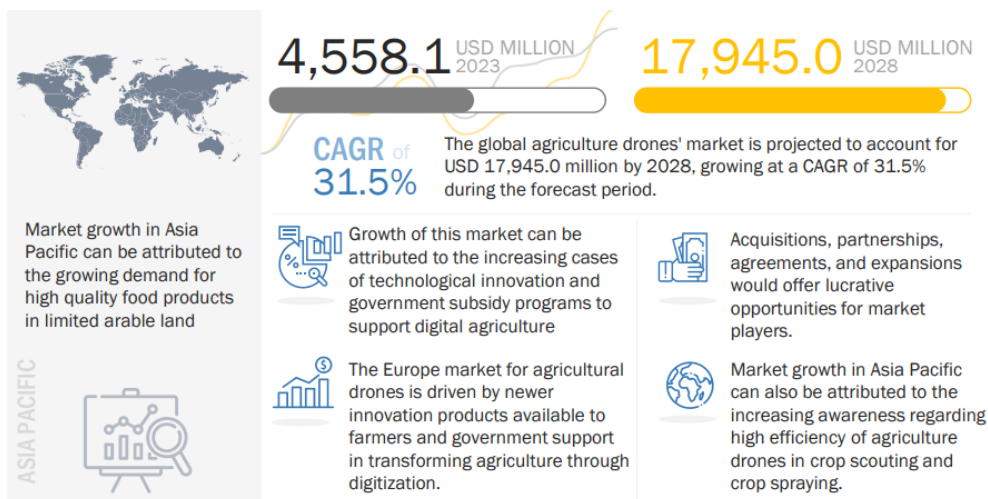
Agriculture drones enable precision farming techniques, which have become increasingly crucial in meeting the global food demand. With a rapidly growing population and huge arable land, farmers need to maximize their productivity while minimizing resource wastage. Agriculture drones provide real-time data on crop health, soil conditions, and **irrigation needs**, allowing farmers to apply targeted interventions such as optimized fertilization, pest control, and water management. This precision approach leads to increased yields, reduced input costs and improved farm efficiency.

1.1 Global Market and Market Dynamics

The global **demand** for agriculture drones is experiencing significant growth due to various factors driving the adoption of this technology worldwide. Agriculture drones enable farmers to enhance productivity and efficiency by providing real-time data on crop health, soil conditions, and irrigation needs, enabling precise and targeted interventions. This data-driven approach leads to improved yields, reduced costs, and optimized resource allocation. The growing awareness of these advantages has fueled the global demand for agriculture drones as farmers seek innovative solutions to optimize their operations and meet the demands of a rapidly changing agricultural landscape.

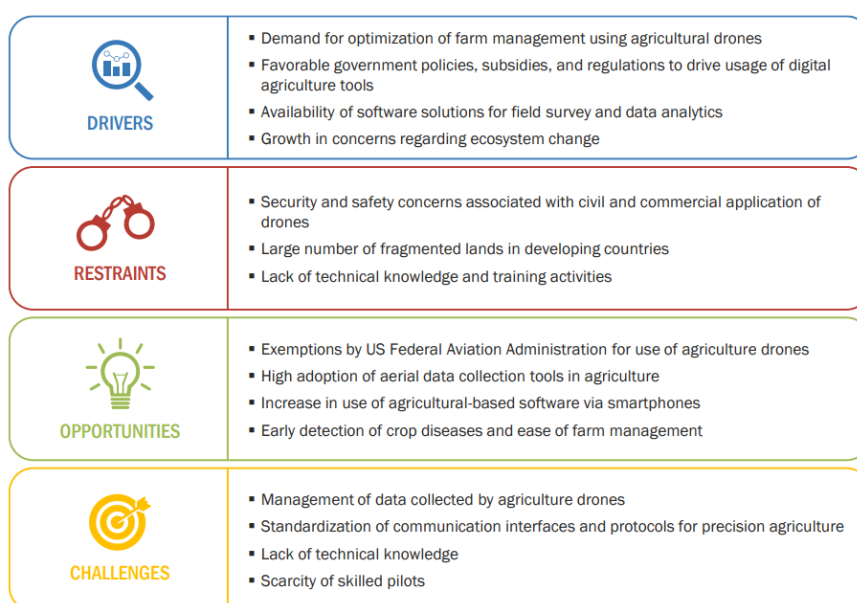
The **global agriculture drones market** is expected to reach the value of USD 17,945.0 million by 2028, growing at a Compound Annual Growth Rate (CAGR) of 31.5% in the period 2023 – 2028 (Figure 1).

Figure 1. Global Agriculture Drones Market, in the Period 2023 - 2028



The agriculture drones' market is experiencing **growth** owing to the benefits offered in terms of technology, crop protection, and yield enhancement (Figure 2). Various R&D initiatives conducted globally have led to the development of agriculture drone industries that now produce more than 90% of the market's demand. Agricultural drones have emerged as groundbreaking tools in modern agriculture. The impact of agricultural drones on agriculture cannot be overstated. They provide invaluable insights into crop health, optimize resource allocation, and contribute to sustainable farming practices. As farmers embrace this technology, they are empowered to make data-driven decisions, increase productivity, and address the challenges posed by a growing global population and the need for efficient food production. Agricultural drones are revolutionizing the agrarian landscape, paving the way for a more sustainable and productive future.

Figure 2. Agriculture Drones Market Dynamics



Drivers

Smart farm optimization and resource usage efficiency are poised to drive the market for agricultural drones by addressing key challenges the agriculture industry faces. With the growing global population and increasing demand for food, farmers are under pressure to maximize productivity while minimizing resource wastage. Agricultural drones provide a cutting-edge solution to achieve these goals. By leveraging advanced sensors, artificial intelligence, and data analytics, agricultural drones enable farmers to optimize their farming operations. These drones can gather real-time data on crop health, soil moisture, temperature, and other crucial parameters. Farmers can gain valuable **insights** into their fields through sophisticated analytics, enabling them to make data-driven decisions and take proactive measures.

Precision agriculture practices are made possible with this technology, allowing for the accurate application of inputs such as water, fertilizers, and pesticides in the appropriate amounts. The agricultural drone market is further propelled by integrating drone technology with other smart farm systems. Drones can be seamlessly connected to farm management software, weather stations, and IoT devices, creating a comprehensive ecosystem for farm optimization. This integration allows farmers to automate tasks, monitor multiple parameters simultaneously, and receive real-time alerts and recommendations.

The production of a specific commodity or system has always been influenced by **government policies and regulations**. Recently, farmers have been embracing technology, including the use of agriculture drones, which is a relatively new concept. This trend has been accelerated by increasing awareness and the impact of COVID-19. The pandemic has led to greater adoption of digitalization worldwide, as it is convenient and does not disrupt daily operations. Governments

worldwide are increasingly promoting adopting modern farming practices, offering incentives and guidance programs to produce high-quality seeds and increase food production and storage capacity.

When it comes to drones, the **software** plays a crucial role in facilitating communication between the user and the aircraft, as well as managing the hardware. Selecting the wrong software platform for a drone can result in significant costs if one needs to switch to another software in the future, much like with smartphones and tablets. Drone software is divided into two categories: open source and proprietary software. Open-source software is accessible to anyone and can be modified to add new capabilities that were not originally intended by the creators, making it the preferred option. PX4 is one of the leading opensource, auto-piloting software offered by Pixhawk (Switzerland) in the agriculture drones market. The software provides flexible tools for drone developers to share technologies and create tailored solutions for drone applications. The farm surveying plays an important role in precision farming, along with proper analysis of field data collected by drones. Trimble Inc. (US) and DroneDeploy (US) are the leading software solution providers in the agriculture drones market.

The growing global population and changing diet patterns of consumers are driving the demand for food exponentially. According to FAO, the **food security challenge** will become more difficult, as the world will need to produce about 70% more food by 2050 to feed an estimated 9 billion population. Production is struggling due to declining ocean health and natural resources like soils and water. On farms, climate change is reducing crop yields and the nutritional quality of major cereals and lowering livestock productivity. Different technologies help closely monitor such changes and provide real-time access to the farmers, with which they can alter their farming activities. Farmers are increasingly adopting these modern technologies to increase their efficiency. The increasing need for optimization of dairy and poultry herds and the growing demand for livestock products are the primary drivers for the growth of precision livestock farming using agriculture drones and smart farming software.

Restraints

Commercial drones have been successfully integrated into civilian airspace, although they need authorization from the concerned regulatory bodies before use. As UAVs/drones operate remotely or autonomously, manufacturers must ensure that their drones operate within limits and do **not affect the environment**. They should also be able to demonstrate that their drones do not affect other manned aircraft as well as lives on the ground. UAV manufacturers need to ensure that the control systems of UAVs cannot be hacked easily to make them safe for civil and commercial applications. Thus, issues with the **safety and security of UAVs** may result in government agencies banning their use in civil and commercial applications, thereby hindering the growth of the global agriculture drone market.

Developing countries such as India, China, and Africa account for many fragmented farmlands. Most farmers in these countries need access to fundamental farming technologies, such as yield monitoring, guidance technology, and variable rate technology. The **fragmented nature of the farmland** in various countries makes it difficult to implement a standardized solution. Land fragmentation leads to an improper allocation of input and resources, which further leads to high costs. Implementing agricultural drone technologies in fragmented lands reduces its efficiency, money, and resources, as managing and collecting data from scattered lands is difficult. In addition, it also makes it difficult for farmers to attain economies of scale.

Agriculture drones involve managing and **integrating different software and hardware** that provides real-time access to farming activity using data. It involves different types of UAVs, sensors, flow controllers, monitors, etc., which use AI and robotics to collect and analyze data gathered. Digital farming requires **technical knowledge** and the **lack** of this among farmers impacts the adoption of innovative technologies. Drone operators must ensure the entire system can operate well without human error. Many commercial drone accidents happen due to poor operator control. Some farmers witness difficulties in understanding the process and its use.

The future impact of this restraining factor is expected to reduce, consider that major market players are coming forward to provide training, consultation, and guidance sessions to the farmers. Also, these devices and software are focusing on providing user-friendly solutions to increase their adoption.

Opportunities

The influence of **big data** on smart farming is anticipated to be significant, with its impact felt across the entire food supply chain. Advanced technologies like sensors and GPS/GNSS generate massive amounts of data, providing remarkable decision-making capabilities. With the increasing installation of smart devices, sensors, and agriculture drones on farms, agriculture practices are rapidly becoming data-driven and data-enabled. The use of big data is predicted to play a crucial role in transforming the agriculture industry. Furthermore, the **Internet of Things (IoT)** and cloud computing are anticipated to facilitate the utilization of big data and introduce more robots and AI in farming. While many industries use drones, the adoption rate of tools required to collect aerial data is high in the construction, agriculture, and mining industries.

For instance, agriculture experts and insurance companies use DroneDeploy's SkyClaim app to detect crop damage and determine loss estimates using computer vision and AI. DroneDeploy customers have analyzed over 100,000 acres and 75 crop types using its app. PrecisionHawk (US) uses agriculture drones and different sensors, such as multispectral, thermal, and LIDAR sensors, to collect raw crop data for analysis using its PrecisionAnalytics software. PrecisionAnalytics is a complete aerial mapping, modeling, and agronomy platform based on 10 years of agriculture analytics experience and millions of acres of crop data.

Agriculture drone usage is gaining momentum due to the ease of usage and application of software and devices to implement day-to-day activities. Unmanned aerial vehicles (UAVs) or drones capture highly accurate aerial images, providing precised data to farmers on their **smartphones** or devices. Thus, agriculture technology developers are introducing multiple **user-friendly mobile farming applications (apps)** that farmers can access via smartphones. Most smartphone apps are inexpensive and provide crucial information related to farming, such as weather and climate conditions. These apps effectively help farmers to make smart decisions. Smartphones can be integrated with several hardware devices such as sensors, high-resolution cameras, and GPS receivers for various activities such as sample collection, aerial imaging, and record-keeping (experts recommended). Due to its convenience usage and affordability, the demand for the same will surge in the global agriculture drone market.

The demand for **automation** in the livestock industry is increasing significantly to increase productivity, improve farm management, tackle the challenge of high labor costs, and address the need for real-time analysis and better decision-making. Automation has become necessary for modern-day operations, and the integration of AI and IoT in daily farming activity substantially impacts farm operations' efficiency and output. Artificial intelligence and visual monitoring penetrate the agriculture drone space to gain insights into crop nutrients, water levels, and **early disease detection**. The availability of several advanced sensors, collars, and RFID tags at optimum costs has led to the adoption of such devices among farmers to monitor animals in real time. Moreover, the availability of real-time information through drones and software leads to timely decisions, thereby reducing operations costs.

Challenges

Raw drone data undergoes processing based on context, relevance, and priority to make it useful for decision-making. In precision farming, significant data is generated through mapping, variable rate seeding, soil testing, yield monitoring, and historical crop rotation. To evaluate farm conditions accurately, proper **storage and management of data** are crucial. Smart farm management decisions and operational improvements can be achieved through effective data management. The management of data collected by drones is a major challenge faced by the users as it requires expertise and knowledge. Also, many adopters of precision farming technologies need to learn how to analyze their precision data. The

adoption rate of agriculture drones could be boosted by providing easy data management solutions to farmers. However, to utilize it better, efforts should also be made to standardize the data format of precision agriculture processes.

Smart agricultural devices, including agriculture drones, communicate through various interfaces, technologies, and protocols. The **lack of standardization** of these communication interfaces and protocols may result in the misrepresentation of data. The lack of standardized technologies complicates the integration of systems and hinders the plug-and-play capabilities among unrelated systems. For instance, most equipment manufacturers use their own interface protocols for communications; this affects the communication between the devices offered by different equipment manufacturers.

Precision farming is a smart farming technique that requires technical know-how, which is not easily accessible, making it difficult for farmers to adopt advanced precision farming technologies. This creates a **technological gap** and makes it difficult for farmers to understand the concepts and benefits of precision farming. Lack of technical knowledge is a major factor restraining the farming community in developing countries such as China, India, and Brazil, along with the majority of African countries. Governments and market players are taking initiatives to provide training and consultation to farmers to tackle this problem; however, many farmers still need to be made aware of the purview of these efforts. To overcome this restraint, many developing countries invest in educating and informing their farming populace about the benefits of precision farming tools and techniques, including agriculture drones.

When it comes to drones, the reliability of the whole system, which includes the vehicle itself, the ground station, and communication equipment, is crucial. Even though these aircraft do not have onboard pilots, **human error** during operation can lead to unfortunate situations. Compared to traditional airplanes, UAV systems rely much more heavily on computer technologies, autopilots, and radio transmissions. Therefore, it takes expertise, skill, and knowledge to operate and control drones properly. Unfortunately, the accident rate for drones is higher than that of manned aircraft. Approximately 30% of UAV accidents are caused by human errors, while 50% occur due to material failure. Designing better systems to control drones and training drone pilots to reduce accidents can reduce the number of accidents.

Small and fragmented land holdings in various geographies of the world have been a hindrance to the implementation of modern farming methods. Advanced technologies reap benefits when a large area is under cultivation by providing economies of scale. Small-scale farmers generally hold small parts of the land, and drone equipment or software requires higher investment, and the return on investment is usually huge on bigger farms, which account for more than 100 acres. These farms need more technical knowledge with the introduction of more specialized and expensive software systems. This issue is particularly widespread in developing countries as there is a lack of skill and technical awareness among farmers and the farmlands are fragmented. Farmers need to pay an additional cost for integrating software with the hardware devices and for further consultation to use these software solutions as they are complex to use, which is a major challenge in the market.

1.2 Technology Analysis

Technologies used in the agriculture drone field include sensors, communication networks, Artificial Intelligence (AI), robotics and other advanced machinery and often draw on the principles of the Internet of Things. Each of these brings something valuable to farming, from data collection to management and processing, as well as guidance and direction.

Artificial Intelligence

With the increasing digitization of agricultural production processes and distribution mechanisms in this context, it is important to identify key and emerging issues, including data fragmentation, cost implications, limited connectivity, data trust, and security. Every day, farms produce thousands of data points on temperature, soil, usage of water, and weather condition. With the help of **artificial intelligence and machine learning models**, this data is leveraged in real-time for

obtaining useful insights such as choosing the right time to sow seeds, determining crop choices, and hybrid seed choices to generate more yields. Many technological companies like PrecisionHawk and Trimble developed UAVs, which use computer vision and artificial intelligence to monitor and precisely spray on weeds. With the help of technologies such as big data, AI and machine learning, companies can **detect pest and disease infestations, estimate the tomato output and yield, and forecast prices**. They can guide the farmers and governments on future price patterns, demand level, type of crop to sow for maximum benefit, and pesticide usage.

IoT

IoT for agriculture drones improves farm, field, and cattle monitoring, risk management and planning. IoT-enabled agriculture allows farmers to monitor their products and conditions in real time. Additionally, IoT solutions in agriculture introduce automation, for example, demand-based irrigation, fertilizing and robot harvesting. These are some of the most popular types of precision farming systems:

- **Climate monitoring.** Weather stations equipped with farming stations help farmers track and predict weather conditions in a needed area. After having collected insights from the environment, connected devices send the data to cloud-based storage. From there, farm managers can use the information for climate mapping and crop selection.
- **Crop monitoring.** Crop management devices are a crucial component for using precision Ag technology efficiently. These devices are typically placed on the field — they will monitor water levels, crop health, and other relevant biochemical and physical properties. Using crop monitoring tools, a farmer can proactively manage anomalies, build prediction-based models and strategies, and prevent potentially harmful diseases.
- **Cattle monitoring.** Sensors are even more important for animal management than crop maintenance. For one thing, they can serve as location trackers so that a part of the livestock is not lost. Also, farm managers will get real-time insights on whether cows, pigs, and other farm animals are not sick or hungry. Connected collar tags are the most widespread form of devices for cattle monitoring. They cause no stress for the animal while providing farmers with real-time insights.
- **Greenhouse automation.** Delegating greenhouse management to an IoT platform for precision agriculture, many activities and processes in the greenhouse can be fully automated. Humidity, temperature and lighting control can be done automatically. Even soil or nutrient solution administration within the greenhouse can be managed without human supervision, due to precision agriculture systems.

Advanced Unmanned Aerial Vehicles

When equipped with advanced sensors, **drones** provide multispectral imaging, giving users greater detail about how a particular crop is faring. These cameras capture more information than a standard camera, including on the near-infrared band. Using light invisible to the unaided eye, these cameras can help farmers create more accurate drought maps and truly give crops the attention they need. Multispectral maps aren't the only kind of aerial imagery that's better when taken by a drone. Standard maps taken in red-green-blue (RGB) formats can show farmers how crop growth is progressing. For precision agriculture purposes, it pays to have drones take these photos rather than satellites. The much greater per-pixel resolution gives a more accurate, nuanced picture of crop status, allowing more highly customized precision farming strategies. Moreover, the use of drones in the precision application of chemicals such as pesticides is an important development for the future of agriculture. Using smaller amounts of these agents in places where they are most needed can support compliance with regulations calling for pesticide reduction.

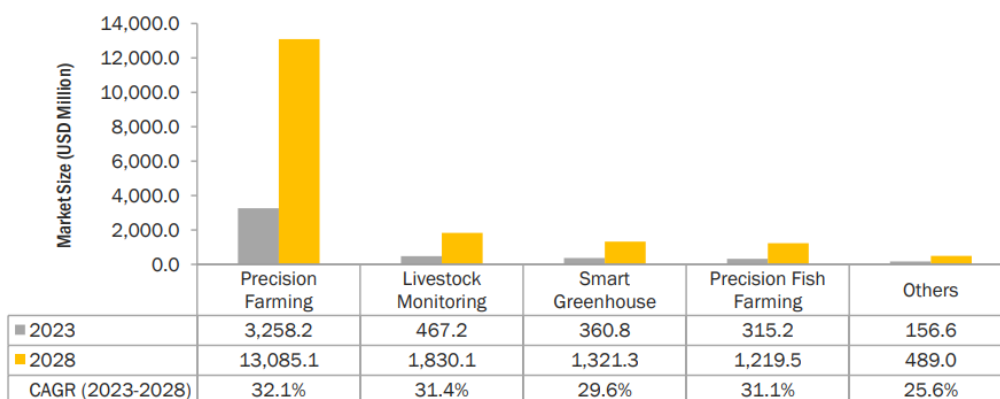
1.3 Market Segmentation by Application

The main applications for agriculture drones include **precision farming, livestock farming, smart greenhouse, precision fish farming and others** (horticulture and forestry) (Figure 3).

Drones allow farmers to collect real-time data, make informed decisions, and optimize resource allocation. **Precision farming** uses drones to monitor crop health and implement targeted interventions, while field mapping provides detailed maps for better land management. The market for precision farming was valued at USD 3,258.2 million in 2023 and is projected to reach USD 13,085.1 million by 2028; it is expected to grow at a CAGR of 32.1% from 2023 to 2028.

Livestock monitoring helps ensure the well-being of animals and precision **fish farming** optimizes fishpond conditions. The market for precision fish farming is expected to grow at the highest CAGR of 31.1% during the forecast period. These applications improve data collection, decision-making, resource efficiency, and sustainability. Integrating drones into agriculture has revolutionized traditional farming practices, empowering farmers to adopt data-driven approaches and leverage technology to achieve better agricultural outcomes.

Figure 3. Agriculture Drones, by Application¹, in the Period 2023 - 2028



1.3.1 Focus on: Precision Farming

Precision farming utilizes advanced technologies and tools to enhance agriculture, by analyzing data collected from fields and applying appropriate inputs to improve crop productivity. This approach enables farmers to manage variations in their fields, producing more crops using fewer resources and reducing costs. With the aid of precision devices, farmers can gather farm-related data and make informed decisions.

With advancements such as automation and GPS guidance that have already changed the farming industry, **drones** are now poised to modernize it once again. Drones can produce precise **maps** for soil analysis at the beginning of the crop cycle, which helps to direct seed planting patterns. After planting, this data helps determine **irrigation** and nitrogen-level management. Currently, the agricultural industry's largest obstacle is the low efficiency in crop monitoring resulting from the massive scale of industrial farming, exacerbated by increasingly unstable weather conditions that intensify risk and maintenance costs. Drones allow **real-time monitoring** at a far more accurate and cost-effective level than previously used satellite imagery. Drones equipped with hyperspectral, multispectral, or thermal sensors are able to identify areas that require changes in **irrigation**. Once crops start growing, these sensors calculate their vegetation index, an indicator of health, by measuring the crop's heat signature. By scanning crops with **visible and Infrared (IR) light**, drones can detect

¹ Other applications mainly include horticulture and forestry.

bacterial or fungal infections to plants, thereby helping to prevent the spread of the diseases. With multispectral images, one can detect diseases and/or sickness before it is observed manually.

The **latest Developments** of Agriculture Drones in Precision Farming are the following:

- **Sony** (Japan) has launched a new crop management solution consisting of a newly developed drone-mounted multispectral sensing unit and Fast Field Analyzer image analysis software.
- **Parrot** (France) introduced Parrot Bluegrass Fields. This end-to-end agriculture drone solution provides farmers, agronomists, and researchers with the insights they need for boosting the quality of their crops and maximizing yields.
- **Taranis** (Israel), a precision agriculture intelligence platform, announced the closing of a USD 20 million Series B financing round. With the potential to increase yields by 7.5%, Taranis uses deep-learning technology and agronomic understanding to offer unprecedented insights that create a more sustainable farming ecosystem.

The market segment for precision farming by sub-application is reported in Table 1.

Table 1. Precision Farming: Agriculture Drones Market, by Sub-Application, 2023–2028 (USD Million)

Sub-Application	2023	2024	2025	2026	2027	2028	CAGR (2023-2028)
Field Mapping	1,789.3	2,369.2	3,150.0	4,202.0	5,630.4	7,567.6	33.4%
Variable Rate Application	632.6	823.9	1,077.5	1,413.9	1,863.7	2,464.4	31.3%
Crop Scouting	353.0	452.5	582.3	751.4	973.6	1,264.9	29.1%
Crop Spraying	214.5	286.0	382.9	514.1	693.4	937.8	34.3%
Others	268.8	337.2	424.1	533.9	673.7	850.5	25.9%
Total	3,258.2	4,268.9	5,616.7	7,415.4	9,834.8	13,085.1	32.1%

Field Mapping

The utilization of drones in agriculture is being driven by two key factors: convenience and affordability. Farmers and agronomists have the option to either rent or purchase unmanned aerial vehicles (UAVs) in order to capture images of their crop fields. The process of "stitching" together the images taken from various angles into a unified map is carried out by a team of experts or trained farmers. A cloud-based software tool is then utilized to correct the images and blend them into a single perspective, which is referred to as "orthorectification." By entering GPS readings of a few ground control points on the unstitched photos, additional software is able to add real-world location data to create a "**geo-referenced**" map. This process is applicable for various tasks, including weed detection, plant counting, crop health monitoring, harvest season monitoring, crop spraying, and yield prediction.

Weed detection: In farming, UAVs or drones play a crucial role in identifying pests such as weeds. UAV platforms such as Lancaster from PrecisionHawk (US) can identify weeds at crucial points in the growing season. The only way to spot weeds is to inspect them if they are present visually. Farmers have to decide on weed control during the early stages, just after seeding. If farmers can aerially determine exactly where the weeds are, they can apply pesticides in specific areas, saving both time and money. Weed detection is carried out by determining the height or profile of anomalies across plots. Crops are generally of uniform heights, so sudden dips or peaks in the profile potentially denote the presence of weeds. There are ~8,000 species of weeds, most of which are harmful to farms. Weeds reduce crop yield by competing for water, light, soil nutrients, and space. They also reduce crop quality by contaminating the commodity; interfering with the harvest; serving as hosts for crop diseases or providing shelter for insects to overwinter; and producing the toxic chemical substances in plants, animals, and human beings.

Plant counting: Drones can be used in agriculture to gather data related to factors such as the number and height of plants. Previously, a farmer had to walk through the entire field to gather any previously mentioned data, which could take hours to months to accomplish. When a drone flies over a field, not only does it take images of the field and problems in the field, thereby counting plants. Further, the user is provided with information on plant size by individual plant, row, plot, or field. It can also determine plant uniformity and yields at an early stage.

Crop health monitoring: The process of crop health monitoring can be extremely difficult for any agriculture expert, analyst, or farmer. Agriculture drones are now being used for aerial imaging, which helps in crop health management. The assessment of crop health and early detection of crop infestations is critical in ensuring good agricultural productivity. Critical issues, e.g., moisture deficiencies, insects, fungal, and weed infestations, must be detected early enough to avoid a major loss for farmers by providing them with an opportunity to tackle them. Agriculture drones help farmers identify areas within a field that are experiencing difficulties so that they can apply the correct type and amount of fertilizer, pesticide, herbicide, and so on. Using this approach, farmers can not only improve the productivity of their land but can also reduce farm input costs and minimize environmental impacts.

Harvest season monitoring: Despite being hindered by legal issues, some farmers are working with drones using readily available, affordable equipment. The harvest season begins when the growing season ends and crops are ready to be harvested. Agriculture drones play a key role in monitoring crops during pre-harvest, mid-harvest, and late-harvest seasons. The wine industry's harvest season is the busiest time of the year. It is the time when winemakers start picking the grapes and preparing them for the crushing process before pressing and fermentation. It is also the time when grapes lose their bright green color and start to develop a more mature color. The color, taste, sugar level, and acidity of grapes, and weather conditions are the factors considered by winemakers to determine the time to harvest as each factor plays an important role in the growing and harvesting process. For monitoring both acidity and sugar levels during the growing season, winemakers must test the pH and sugar content or Brix of their grapes throughout the vineyard to determine their ripeness. The acidity level and sugar content differ depending on the taste the winemaker tries to achieve. Using drones with payloads such as multispectral and thermal cameras can help farmers and agronomists monitor the crops throughout the harvest season with ease and lower cost than the satellite imaging technique.

Others: Other uses, such as yield prediction and crop irrigation, are expected to boost the use of drones in farming. Unlike manned aircraft, agriculture drones can map crop damage in 3D, making damage and yield estimates more accurate; they can map fields at a low cost. In conventional irrigation, the suitability of various irrigation methods, i.e., surface, sprinkler, or drip irrigation, depends mainly on factors such as natural conditions, type of crop, type of technology, previous experience with irrigation, required labor inputs, and costs and benefits. However, the use of drones in irrigation has resulted in significant savings in water usage.

Variable Rate Application

Variable rate applications (VRA) can be either map-based or sensor-based. Map-based VRA is pre-planned; these applications are based on VRA prescription maps that an agronomist or advisor prepares based on data sources. VRA pertains to any technology utilized in farming that empowers producers to adjust the amount of resources given to crops. VRA merges a control system with variable rates (VR) alongside application equipment to apply inputs at specific times and/or locations to achieve site-specific input application rates. A series of components, including agriculture drones, differential global positioning systems (DGPS) receivers, computers, VR software, and controllers, are combined to make VRA effective. By using a sitespecific approach, farmers can apply products solely where they are necessary in a field. Adjusting input applications can reduce input and labor expenses, increase productivity, and decrease the potential impact of overapplication on the environment.

Crop Scouting

Crop scouting is also referred to as mid-season crop health monitoring. The ability to inspect mid-season crops with normalized difference vegetative index (NDVI) or near-IR (NIR) sensors is one of the pathbreaking applications of agriculture drones. Integrating IR technology with UAVs or drones has helped the precision farming industry, enabling farmers to keep an eye on the entire farm without being physically present. These IR cameras can also be used to provide an array of information such as the presence of different species in their fields, moisture levels of the soil or grains, plant development stages, and plant health.

Crop Spraying

Good coverage and drift management are the two main factors considered by farmers while planning **spraying** operations. A fine mist spray may provide better coverage of the target area, but mist is also more prone to drift. Drift means a loss of efficacy, a waste of product, and perhaps most worrisome damage to non-target areas, including neighbors' crops, shelterbelts, and yard sites. A finer spray may be more efficacious than a coarse spray but finding a suitable day to apply a fine spray without significant drift can be difficult. For the expected crop yield, using a low-drift nozzle beforehand to get rid of weed competition is better than waiting longer for a relatively calm day to use a finer spray. Thus, spraying at the right time is more important than how it is done. The adoption of drones for crop spraying is an efficient practice to increase the yield of crops and reduce the wastage of fertilizers and pesticides.

Others

Other precision agriculture applications mainly include **weather tracking and forecasting, irrigation management, and inventory management**. Weather tracking is one of the important parameters in precision farming as it facilitates up-to-date information on prevailing climatic conditions, such as temperature, rain, wind speed and direction, and solar radiation. Irrigation management helps enhance the productivity of land and minimize water wastage, soil infertility, salinization, and crop water stress, among others. The application of advanced technologies in irrigation assists in improving yield, production, and profitability.

1.4 Market Segmentation by Component

The agriculture drone market comprises various components essential for these drones' successful operation and performance. These components include: **frames, controller systems, propulsion systems, camera systems, navigation systems, batteries, and other** crucial elements like wires, connectors, power systems, carry cases, sprayers, and sprinklers (Figure 4).

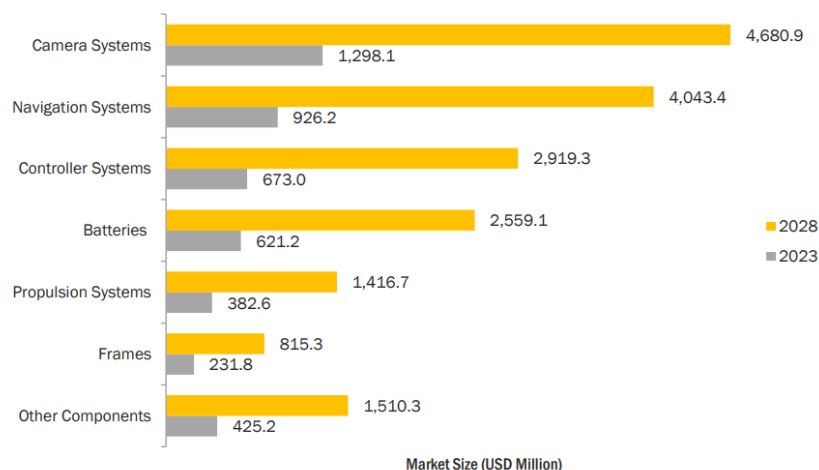
Agriculture drones are gaining popularity among farmers and agricultural stakeholders due to their numerous benefits. These advanced technologies, equipped with multispectral or thermal cameras, provide high-resolution aerial imaging, enabling farmers to monitor plant health, detect diseases or pests, and assess crop yields. The agriculture drone market for **camera systems** is projected to reach USD 17,945.0 million by 2028; it is expected to grow at a CAGR of 31.5% from 2023 to 2028. A camera system is a key component of agriculture drones as it influences the choice of a drone for a particular application. The ability to capture multiple images at multiple wavelengths makes multispectral cameras useful for detecting crops affected by diseases in the field.

The navigation and drone **controller systems** ensure precise positioning and autonomous flight capabilities, resulting in efficient and accurate data collection.

The agriculture drone market for **navigation systems** is expected to grow at the highest CAGR of 34.3% during the forecast period.

Reliable **batteries** and other essential components ensure extended flight times and operational efficiency. By utilizing these components, agriculture drones offer farmers reduced manual labor, faster data collection, increased coverage of large agricultural areas, and improved operational efficiency. As a result, farmers can save costs and achieve higher crop yields.

Figure 4. Agriculture Drones Market, by Component, in the Period 2023 - 2028



1.5 Market by Farm Produce

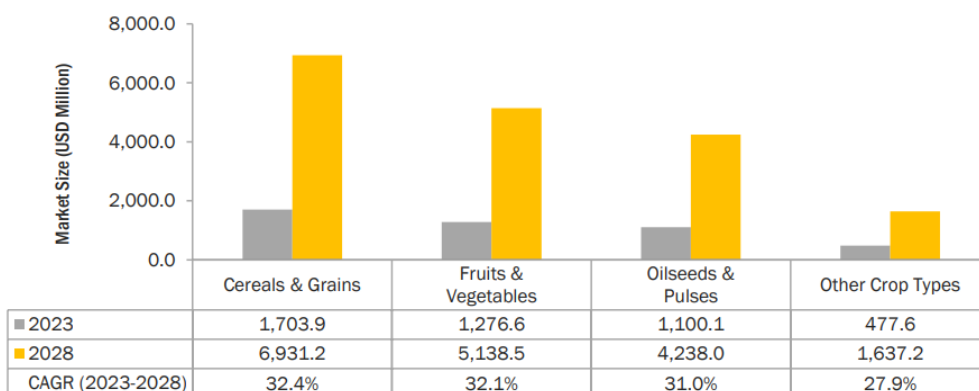
The market for agriculture drones, by **farm produce**, has been categorized into **Cereals & Grains, Oilseeds & Pulses, fruits & vegetables, and Other Crop types**, including turf & ornamentals, plantation crops, fiber crops, and silage & forage crops (Figure 5). Agriculture drones are revolutionizing the **cereal and grains market** by offering advanced monitoring and precision agriculture solutions. These drones enable farmers to assess crop health, detect diseases, pests, and nutrient deficiencies, and optimize irrigation and fertilization practices. With high-resolution imaging and data analysis capabilities, drones provide valuable insights into crop growth patterns, enabling timely interventions and informed decision-making. Drones also enable the collection of accurate data on crop yields and quality, aiding in crop management and planning for future seasons.

Oilseeds and pulses are essential crops in the agricultural industry, serving as sources of edible oils, protein-rich food products, and ingredients for various industrial applications. Agriculture drones with advanced imaging technologies, such as multispectral or hyperspectral cameras, can provide valuable insights into crop health, nutrient deficiencies, pest infestations, and weed growth. Farmers can make informed decisions regarding irrigation, fertilization, and pest control by analyzing the data collected by drones. This precision intervention helps optimize resource allocation, reducing waste and minimizing the environmental impact of farming practices. Using agriculture drones in oilseed and pulse cultivation enhances crop yield and quality while reducing production costs.

Drones are used to cultivate and monitor different **fruits and vegetables**, such as kiwis, strawberries, cauliflower, grapes, cranberries, and apples. Drones help in recording inventory of tree height and canopy volume, in the monitoring tree health and quality, managing water, nutrients, pests, and disease in-season, estimating fruit/nut production and yield and creating marketing tools (videos for promotion of the orchard, or sale of trees and fruit). **Berries**, such as strawberries, blueberries, raspberries, and blackberries, are witnessing a significant impact from the agriculture drones market. Drones are revolutionizing berry farming by enabling efficient plant health monitoring, disease detection, and precise application of fertilizers and pesticides. These aerial devices provide valuable data on crop yield, growth patterns, and irrigation needs, helping farmers optimize their operations and maximize harvests. The use of agriculture drones in the berry industry is on the rise, driven by the demand for improved productivity and sustainability.

Turf ornamentals, plantation crops, fiber crops, and silage and forage crops also benefit from the agricultural drone market. For turf ornamentals, drones aid in precise irrigation, disease detection, and maintenance of aesthetic appearance. In plantation crops, drones assist in monitoring tree health, optimizing fertilization, and detecting pest infestations. For fiber crops, drones help assess crop density, monitor weed growth, and identify areas for improvement. Silage and forage crops benefit from drone-based yield estimation, nutrient analysis, and timely harvest planning.

Figure 5. Agriculture Drones, by Farm Produce, in the Period 2023 - 2028



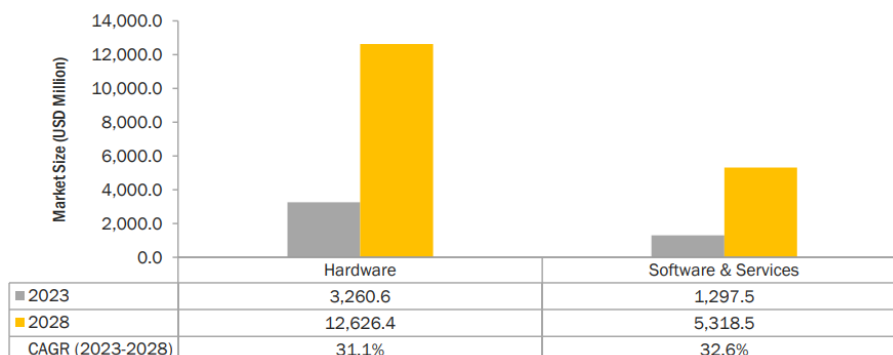
1.6 Market Segmentation by Offering

In terms of products and services, the drone industry can be divided into three segments: **hardware, software, and services** (Figure 6). The hardware segment includes the physical components of drones, such as drones, sensors, cameras, controllers, and batteries. The software segment comprises applications, platforms, and data analytics tools that enable data processing and analysis. Lastly, the services segment encompasses rental and leasing services, maintenance and repair, training and education programs, data processing services, and agricultural consulting.

Hardware segment is projected to reach USD 12,626.4 million by 2028; it is expected to grow at a CAGR of 31.1% from 2023 to 2028. Driven by the greater use of drones by farmers or agronomists, the hardware segment is likely to capture a major share of the agriculture drone market during the forecast period. In terms of hardware, 4 types of drones are commonly used in agriculture—miniature fixed-wing drones, quadcopters, multi-bladed small, unmanned helicopters, and hybrid drones.

The **software and services** in agriculture drones mainly include data management; imaging software; data analytics; and training, consulting, drone insurance, and drone law services, which have been grouped as others.

Figure 6. Agriculture Drones Market, by Offering, in the Period 2023 - 2028



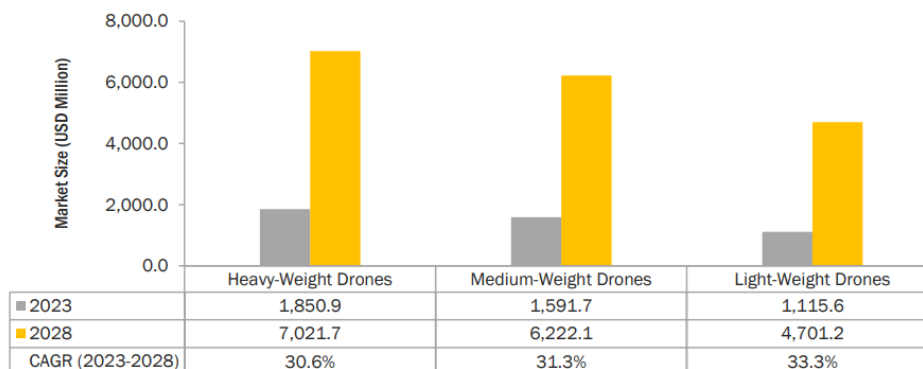
1.7 Market Segmentation by Payload Capacity

Payload capacity is a critical factor in the agriculture drone market as it determines the drone's capability to carry sensors and equipment for various agricultural activities. The market can be segmented into three categories based on payload capacity: **lightweight drones** (up to 2 kg), **medium-weight drones** (2 to 10 kg), and **heavy-weight drones** (above 10 kg - up to 25 kg) (Figure 7). **Lightweight drones** are agile and portable, primarily used for crop monitoring and aerial imaging. They are suitable for small-scale farming and precision agriculture. The market of Light-Weight Drones is expected to grow at the highest CAGR of 33.3% during the forecast period.

Medium-weight drones balance maneuverability and payload capacity, making them versatile tools for tasks like multispectral imaging, thermal mapping, and pesticide spraying. They cater to a wide range of farming operations. The market in Medium-Weight Drones was is projected to reach USD 6,222.1 million by 2028. As more farmers recognize the benefits of drone technology in optimizing farming practices and increasing yields, the demand for lightweight drones is expected to continue rising.

Heavy-weight drones possess a high payload capacity and are equipped with advanced sensors, enabling them to cover large areas, collect detailed data, and perform sophisticated analyses. They are commonly employed by large-scale commercial farms and agricultural service providers. The Heavy-Weight Drones segment accounted for 40.90% of the agriculture drones market in 2022. The market is projected to reach USD 7,021.7 million by 2028 and to grow at a CAGR of 30.6% from 2023 to 2028.

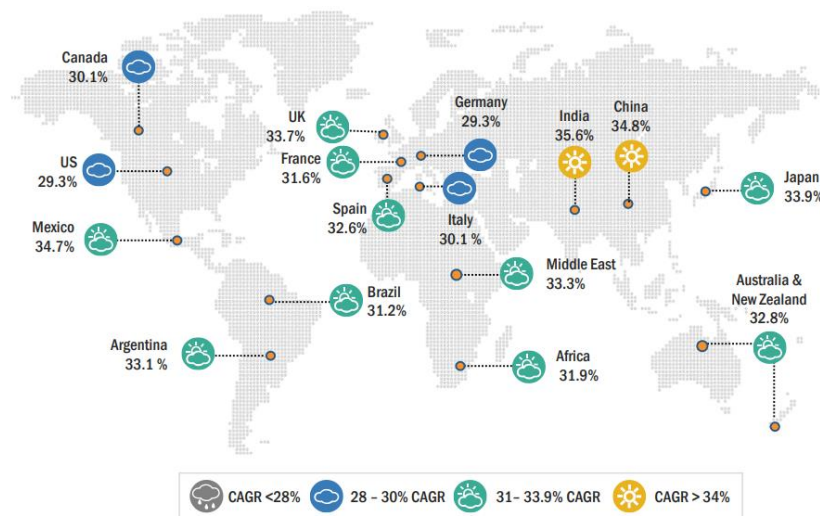
Figure 7. Agriculture Drones Market, by Payload Capacity, in the Period 2023 - 2028



1.8 Market Segmentation by Region

The agriculture drones market is widespread; it has been segmented into 4 major regions: **North America, Europe, Asia-Pacific (APAC), and RoW** (Figure 8). The market in **North America** is projected to reach USD 6,191.0 million by 2028; it is expected to grow at a CAGR of 29.7% from 2023 to 2028. The market in **APAC** is expected to grow at the highest CAGR of 34.2% during the forecast period.

Figure 8. Agriculture Drones Market: Geographic Snapshot



1.8.1 Focus on Europe

The agriculture market in **Europe** is highly professional and technologically advanced. This region includes countries that are among the strongest economies of the world and widespread industries such as automotive, electronics, and defense, which provide high capital investment capabilities to investors. Farmers in Europe are already using agriculture drones for applications such as yield monitoring, guidance and steering, variable rate application, crop scouting, and others. In a bid to revolutionize European agriculture, the European Commission's DG Agriculture and Rural Development, along with the EU Space Programme (DG DEFIS) and the EU ISA2 Programme (DG DIGIT), have introduced the FaST digital service platform. This platform aims to empower farmers by leveraging space data and digital technologies, including agriculture drones, for improved agricultural solutions. Known as FaST, this innovative platform combines IoT, machine learning, and both public and user-generated data to provide farmers with advanced tools for precision farming. The current version of FaST offers features such as overlaying farm data on GIS layers, utilizing imagery and real-time geo-tags, importing farmer data, and providing recommendations for fertilizer usage and management. Additionally, it offers climate updates to aid in informed decision-making.

The launch of 'Artificial Intelligence for Europe' in 2018 and '2030 Digital Compass: The European Way for the Digital Decade' in 2020 demonstrates Europe's recognition of the potential of IoT in agriculture. As a result, significant investments are being made in this sector. The European Innovation Partnership's Agricultural Productivity and Sustainability (EIP-AGRI) has also emphasized the need for digitization in agriculture, advocating for the adoption of correct strategies to maximize its benefits.

The introduction of the FaST digital service platform, along with Europe's growing focus on digitalization in agriculture, presents immense opportunities for the agriculture drones market. Agriculture drones are a key component of the digital technologies utilized in the platform, offering farmers the ability to collect real-time data, monitor crops, and optimize farming practices.

As European farmers witness the transformative impact of agriculture drones on their productivity and sustainability, the demand for these technologies is likely to surge. This, in turn, will drive the growth of the agriculture drones market in Europe, as more farmers seek affordable and accurate solutions to enhance their agricultural operations.

The **European agriculture drones market by country** and **by application** is reported in the following Tables.

Table 2. Europe: Agriculture Drones Market, by Country², 2023–2028 (USD Million)

Country	2023	2024	2025	2026	2027	2028	CAGR (2023–2028)
Germany	283.1	363.4	468.2	605.2	785.6	1,022.9	29.3%
UK	290.0	384.9	512.9	685.4	919.9	1,238.2	33.7%
France	286.6	374.1	490.5	645.3	852.8	1,130.5	31.6%
Italy	158.8	205.1	265.8	345.8	451.8	592.2	30.1%
Spain	203.7	268.0	354.1	469.3	624.8	834.4	32.6%
Rest of Europe	158.8	203.3	261.1	336.5	435.5	565.3	28.9%
Total	1,381.1	1,798.8	2,352.6	3,087.5	4,070.5	5,383.5	31.3%

Table 3. Europe: Agriculture Drones Market, by Application, 2023–2028 (USD Million)

Application	2023	2024	2025	2026	2027	2028	CAGR (2023–2028)
Precision Farming	927.8	1,215.0	1,597.6	2,107.9	2,793.8	3,714.6	32.0%
Livestock Monitoring	174.6	226.8	296.0	387.7	509.9	672.9	31.0%
Precision Fish Farming	90.2	115.5	148.6	191.8	248.5	323.0	29.1%
Smart Greenhouse	144.9	186.9	242.2	314.8	411.0	538.3	30.0%
Others	43.7	54.5	68.2	85.4	107.2	134.6	25.2%
Total	1,381.1	1,798.8	2,352.6	3,087.5	4,070.5	5,383.5	31.3%

1.9 Competitive Landscape

Key players in this market include: DJI (China), Precisionhawk (US), Trimble inc. (US), Parrot Drone Sas (France), BAYER AG (Germany), Yamaha Motor Co., Ltd.(Japan), Ageagle Aerial Systems Inc. (US), Dronedeply (US), Autel Robotics (US), Sentera (US), Optim Corp. (Japan), Microdrones (Germany), Aerialtronics (US), Delair (France), Xag CO., Ltd. (China), Skydio, Inc. (US), Agrodron AI (Brazil), Aries Solutions Pvt Ltd (India), Wingtra (Switzerland), Lockheed Martin Corp. (US), Gamaya (Switzerland), Atmos UAV (Netherlands), Skyx (Canada), Slantrange, Inc.(US) and Nileworks (Japan).

The global snapshot of key participants in the agriculture drones market is reported in Figure 9.

² The rest of Europe primarily includes the Netherlands, Switzerland, Belgium, Poland, Denmark, Norway and Austria

Figure 9. Agriculture Drones: Global Snapshot of Key Participants³, 2022



European players are further described in Table 4.

Table 4. European Players in the Agriculture Drones Market

Company	Country	Description	Website
Aerialtronics	The Netherlands	Prominent player in the agriculture drone market, offering innovative solutions for precision farming and agricultural operations. Aerialtronics' drones are specifically designed to cater to the unique needs of the agriculture industry, providing farmers with advanced aerial imaging, data analytics, and crop monitoring capabilities	https://www.aerialtronics.com/en
Atmos UAV	The Netherlands	Atmos UAV is a high-tech company that designs and manufactures reliable aerial observation and data gathering solutions for professional users. The company specializes in land surveying, mining, precision agriculture, forestry, and other mapping-related applications	https://www.atmosuav.com/
Bayer AG	Germany	Bayer AG operates as a part of the Bayer Group and functions as a crop science company in seeds, crop protection, and non-agricultural pest control. It is a research-based agrochemicals and biotechnology company focused on the areas of crop protection, non-agricultural pest control, seeds, and plant biotechnology	https://www.bayer.com/en/agriculture/digital-farming-systems
Delair	France	Provides aerial-imagery-based data to help industries make informed decisions. The company is in the production and distribution of long-range and civilian drone solutions, and image processing techniques	https://delair.aero/

³ Note: this is not the extensive list of companies

Company	Country	Description	Website
Gamaya	Switzerland	Gamaya provides agricultural solutions to increase the efficiency and sustainability of the agriculture business by deploying the most advanced mapping and diagnostics solutions. The company offers patented hyperspectral imaging cameras integrated with machine learning, which provides intelligence-based insights about the crops	https://gamaya.com/en_us/
Microdrones	Germany	Provider of complete UAV solutions for drone surveying, mapping , construction, mining, inspection, precision agriculture, and other commercial drone applications. The products and solutions offered by the company are being used for precision farming to help grow and cultivate new varieties of crops more quickly	https://www.microdrones.com/en/
Parrot Drone SAS	France	Parrot's key strength lies in its strategic approach to the commercial drone market. By identifying professionals' requirements and seeking innovative start-ups, Parrot has built a strong ecosystem of products, including software, sensors, and services. Their focus on verticalization, targeting priority markets like mapping, precision farming, and inspection and surveillance, positions them as a reliable and comprehensive solution provider	https://www.parrot.com/en
Wingtra	Switzerland	Leading VTOL drone producer, specializing in the development and manufacturing of innovative unmanned aerial vehicles. Their flagship product, the WingtraOne drone, equipped with state-of-the-art sensors, offers survey-grade aerial data collection. This technology has found wide applications in agriculture, enabling precise mapping, monitoring, and data capture	https://wingtra.com/

2 Conclusions

Agriculture drones are used in precision agriculture to efficiently distribute weed control or fertilizers and optimize field management. The results include reduced operation costs, improved crop quality, and increased yield rate. Agriculture drones has the potential to make agriculture more productive and more consistent and to use time and resources more efficiently. This brings critical advantages for farmers and wider social benefits around the world. It also enables organizations to share information across traditional industry boundaries to open up new, disruptive opportunities.

Agricultural drones find extensive usage in various aspects of **farming**, foremost among them being crop monitoring. Equipped with high-resolution cameras and multispectral sensors, these drones capture detailed images of the fields, enabling farmers to assess crop health, identify diseases or pests, and pinpoint nutrient deficiencies. Farmers can make informed decisions regarding irrigation, fertilization, and pest control through careful analysis of this data, resulting in targeted interventions and optimized resource allocation.

Precision spraying is another pivotal application of agricultural drones. Drones with specialized sprayers can accurately apply pesticides, herbicides, and fertilizers to specific field areas. This precise spraying technique reduces chemical usage, minimizes environmental impact, and efficiently utilizes resources. Moreover, agricultural drones can access challenging terrains or areas with uneven **topography**, enabling consistent coverage and minimizing the risk of crop damage associated with heavy machinery.

The **advantages** of agricultural drones are manifold. Firstly, they save considerable time and effort for farmers. Drones can rapidly cover large areas, allowing farmers to monitor and analyze their crops in a fraction of the time required by traditional methods. Secondly, agricultural drones offer cost savings by optimizing resource utilization. Farmers can reduce unnecessary applications of fertilizers and chemicals by accurately identifying areas requiring intervention, leading to significant cost reductions. Furthermore, agricultural drones play a vital role in promoting sustainability in agriculture. Through the targeted application of inputs, they minimize environmental pollution and decrease the ecological footprint of farming operations. Additionally, the data collected by drones empower farmers to adopt precision agriculture practices, resulting in improved yields, reduced water usage, and minimized soil erosion.

Drones are increasingly being employed in **outdoor farming** due to their numerous advantages and capabilities. These unmanned aerial vehicles offer a wide range of applications and benefits that make them well-suited for outdoor agricultural operations. One of the primary reasons for the dominance of the outdoor segment is the vastness and complexity of outdoor farming environments. Outdoor farms often cover extensive areas, making it challenging for farmers to monitor and manage crops effectively. Agriculture drones provide a practical solution by offering aerial surveillance and data collection capabilities.

3 Sources

MarketsandMarkets Knowledge Store - Multisectoral database that collects market research reports in various technological fields and designed to process some information interactively. More than 1,200 market reports are published each year (<https://www.mnmks.com/>).

The information presented are contained in the report "*Agriculture Drones Market – Global Forecast to 2028*", published in June 2023.

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