PRECISION AGRICULTURE

INDUSTRY INSIGHT

JEME BOCCONI STUDENTI

MINERVA INVESTMENT MANAGEMENT SOCIETY

1. PM Summary

Precision agriculture (PA) is a modern farming approach utilizing technology to enhance farm management, optimize resource usage, and improve overall performance in both crop and livestock farming. We see this technology as having a deep impact on the agricultural industry as we know it today and note potential investment opportunities within the sector.

Key Tailwinds

- Technological Advancements: GNSS and EO technologies offer precise monitoring and data collection, aiding in resource management and sustainable farming practices.
- Regulatory Support: Favorable regulatory environments in various regions encourage the growth of the precision agriculture sector.
- Alignment with Sustainability Goals: PA aligns with sustainability and environmental, social, and governance (ESG) goals, attracting interest from investors.
- Investments Driving Growth: Ongoing investments are propelling innovation and growth within the precision agriculture industry.

Key Headwinds

- Connectivity Challenges: Insufficient internet access, especially in rural areas, impedes the widespread adoption of PA techniques.
- Infrastructure Limitations: Outdated infrastructure in many farms globally hinders the integration of advanced PA technologies.
- Adoption Barriers for Smallholders: High costs and lack of digital education among smallholders pose challenges in embracing PA techniques.
- Age of Farmers: Aged farming population exhibits risk aversion to new technologies, impacting the pace of adoption.

Investment Opportunities

- AI and Robotics: AI and robotics, being rapidly evolving segments, offer growth potential with various startups specializing in precision agriculture attracting substantial investments.
- Infrastructure Upgrades and Modernization: Investments in updating and modernizing aging infrastructure, sensors, and control systems present significant opportunities.
- Data Providers, GPS, and Satellites Operators: Investing in companies that provide essential data, GPS services, and satellite operations needed for precision agriculture can play a crucial role in improving the sector's efficiency and effectiveness.

2. Intro

Precision agriculture (PA) is a farming method that relies on using technology to better manage farms. It involves closely monitoring and responding to changes in the environment of a farm, like changes in weather or soil quality, in order to improve how crops and livestock are raised. PA can be used for both crops and animals and uses advanced tools to automate farming tasks, make better decisions, and improve overall farm performance.

The idea of precision agriculture started in the late 1980s with the goal of creating a system that helps farmers make smarter decisions about how to run their farms. This system aims to help farmers get the most out of their investments while also taking care of important resources.

One specific method within precision agriculture is the phytogeomorphological approach, which looks at how the shape of the land affects how crops grow and how water flows on the farm.

The use of GPS and other similar technologies has made precision agriculture more widespread. These tools allow farmers and researchers to know exactly where they are on a farm and create detailed maps showing how different things like crop yield, terrain, moisture levels, and more vary across the land. Special sensors on farming equipment collect data on things like plant health and transmit it wirelessly.

This data can be combined with satellite images to help manage resources like seeds and chemicals more efficiently.

Drones have also become a valuable tool in precision agriculture. These small flying machines equipped with cameras can take pictures of the fields. The images are stitched together to create detailed maps that show things like crop health and the shape of the land. This helps farmers make better decisions about how much water, fertilizer, and chemicals to use in different parts of the field.

Precision agriculture is always evolving as new technology and data analysis methods become available. It's not only helping farmers produce more food but also addressing global food challenges and taking steps to protect the environment as the world's population grows.

In this report, we will investigate the dynamics of the industry and potential headwinds/tailwinds for investments within this quickly-evolving sector (**Table 1**).

Table 1 – Tailwinds & Headwinds Summary Table

Tailwinds	Headwinds
GNSS offers competitive results and drives larger benefits vs costs for large farmers	Internet access is fundamental towards the usage of PA techniques. However, so far, rural connectivity lacks both the necessary speed and sufficient coverage for farmers
Regulatory environment is supportive towards the industry	Average farm sizes make adoption (especially for smallholders in Europe) harder to achieve
Investments are driving growth within the sector	Infrastructure is not technologically advanced enough for PA techniques for most farms around the world
Sector is aligned with sustainable farming and ESG goals, driving further future interest from investors	High farmers' age and lack of digital education can hinder the adoption of PA techniques

3. Private Investments

Private investments in the computer and software sector have exhibited a consistent upward trajectory, with an annualized growth of 6.2% in the period 2018-2023 (**Graph 1**). This robust investment landscape has played a pivotal role in fostering the precision agriculture industry's sustained prosperity.

Private investments in industrial equipment and machinery enjoyed a healthy 4% growth rate in 2021 (**Graph 2**). However, in the subsequent year, 2022, these investments took a substantial hit, plummeting by almost 6%. This decline can be primarily attributed to a confluence of factors, notably supply chain disruptions stemming from the conflict in Ukraine, which led to increased operating costs for manufacturers, as well as a heightened cost of debt.

2022 witnessed a notable downturn in the realm of venture capital, and agrifoodtech was no exception to this prevailing trend. Specifically, funding for agrifoodtech startups contracted to $29.6 billion in 2022, representing a significant 44% decline compared to the prior year. However, it is important to highlight that the agrifoodtech sector has displayed remarkable growth, surging from a valuation of $12.2 billion in 2017 to $53.2 billion by 2021.

Notably, within the agrifoodtech landscape, businesses specializing in farm robotics, mechanization, and other agricultural equipment managed to secure a $709 million in global investments during 2022.

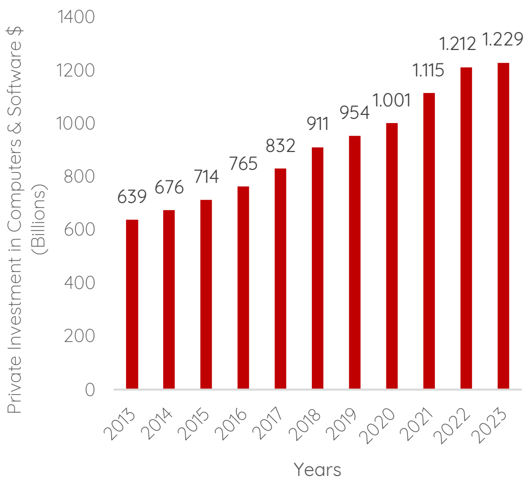
Large agribusinesses play a crucial role in driving forward the world of precision farming and the broader digital agriculture landscape. They do so in three key ways.

Firstly, these corporations heavily invest in research and internal technology development. For instance, earlier this year, a prominent investor in Deere & Co, a leading player in this sector, underscored the idea that "Precision agriculture is a good thing for everybody: for the environment, the farmer, the customer at the end of the supply chain, and also for Deere". In its 2022 financial report, the company stated net sales from production & precision agriculture increased by 33% from the previous year.

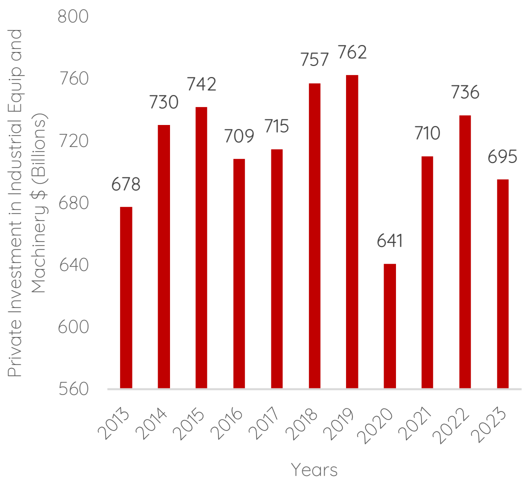
Secondly, these multinational agribusinesses actively contribute to the growth of successful digital agricultural solutions. They serve as strategic investors and advisors to solution providers and also nurture promising innovations. An example is THRIVE, an accelerator based in the United States, which receives support from major agribusinesses such as Corteva.

Lastly, these corporations play a crucial role in promoting robust agricultural markets. They use digital tools, whether developed internally or sourced externally, to increase their procurement from smallholder farmers. This positions agribusinesses as anchor institutions, providing farmers with reliable buyers and better prices than they might otherwise secure.

<u>Graph 1 – Private Investment in Computers & Software $ (Billions). Source: IBISWorld</u>



<u>Graph 2 – Private investment in Equipment and Machinery $ (Billions). Source: IBISWorld</u>

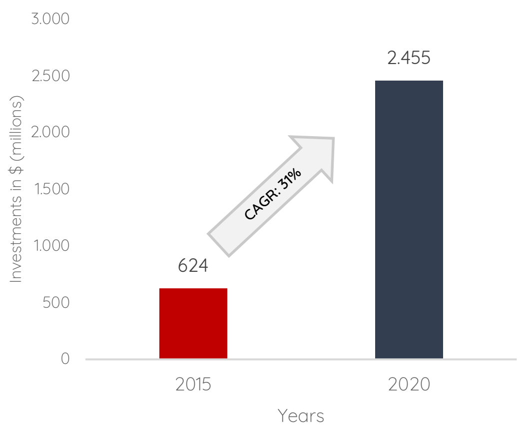


4. Public Investments

Increased government investment is strengthening agricultural producers' end market. Precision agriculture systems developers cater primarily to the prevailing farming industry in the United States. Governments are investing heavily in the research and development of these systems and subsidize many farms that cater to precision agriculture. As an example, a strong government leadership in data digitization has fostered the development of a robust digital ecosystem in emerging markets like Rwanda and India. The Common Agricultural Policy (CAP) in Europe for the years 2021-2027, with a substantial fund of €386.6 billion, promotes the integration of green farming practices.

Additionally, Horizon Europe, allocating €10 billion, focuses on research and innovation in the domains of food, farming, and rural development. Also, in the United States, significant financial backing is provided to encourage innovation and technology adoption in agriculture. The Farm Bill of 2018, with an allocation of $428 billion over 5 years, supports advancements in the field. Moreover, we also note a significant increase in investments from sovereign wealth funds in agritech, forestry, and renewable sectors (**Graph 3**).

Graph 3: Investments by sovereign wealth funds in agritech, forestry, and renewable sectors (2015-2020). Source: IFSWF



Regulation overview

In the global perspective, precision agriculture stands as a pivotal tool to enhance productivity while aligning with sustainability objectives. Governments worldwide demonstrate a keen interest in promoting smart farming by offering inducements like tax benefits, subsidies, and investments in research and development. Nonetheless, the nascent nature of AI-driven technologies requires regulatory adjustments to fully capitalize on the potential benefits of precision agriculture. Presented below are insights into incentives and challenges shaping the landscape of agtech across specific regions.

In Europe, a robust regulatory environment places significant emphasis on data protection. The General Data Protection Regulation (GDPR) ensures strong safeguards for farmers' data and interests. However, drone usage is subject to stringent regulations under the Basic Regulation (EU) 2018/1139, potentially hindering the development of precision agriculture.

Within the United States, data protection laws primarily revolve around "personal data," leaving agricultural data largely unregulated. Furthermore, commercial drone use is federally regulated, requiring operator certification and adherence to specific flight restrictions.

Across South America, Brazil takes the lead in precision agriculture, showcasing technological advancements and a well-developed regulatory framework. However, other South American countries lag in regulatory development compared to their EU and US counterparts. Throughout the Asia-Pacific region, several countries actively champion the adoption of agricultural technology. In India, initiatives such as subsidies and committees, including the National Committee on Precision Agriculture & Horticulture (NCPAH), underscore a strong commitment to tech adoption. In China, technology adoption is encouraged, though weak data protection regulations may pose a barrier to the widespread use of precision agriculture technologies. Meanwhile, Japan exhibits a robust commitment to precision agriculture, exemplified by the successful Smart Agriculture Demonstration Project operating in 217 districts and featuring advanced data protection measures. In South Korea, financial aid is extended to small farms to facilitate the acquisition of agricultural technology.

5. Infrastructure

Aging infrastructure provides opportunities for technology companies and service providers to offer upgrades and modernization solutions. This includes the replacement of outdated sensors, connectivity hardware, and control systems with more advanced and efficient alternatives. There is a growing prevalence of digital tools and sensors, including technologies like satellite remote sensing, UAV imaging systems, Internet of Things (IoT) sensors, and ground-based robotic systems. These tools are rapidly gaining popularity for gathering vast amounts of detailed data related to crops, livestock, the environment, and farm machinery, both in terms of time and location. With the advancements in big data analysis and artificial intelligence, this digital information can now be effectively utilized to oversee production, enhance efficiency, and promote sustainability in agriculture. As the global precision agriculture market is expected steady growth (13.5% CAGR) until 2027, the subsequent demand pull-forward for infrastructure follows suit.

The wireless network infrastructure designed for data transmission in agriculture is still underdeveloped with broadband connectivity being a major headwind. Replacing or upgrading aging infrastructure is capital-intensive. The initial investment is a major barrier especially for small-scale operators. According to the GSMA, the expense of constructing and sustaining network infrastructure in rural areas can be twice as high. This includes the first connectivity layer, the regional network infrastructure, responsible for wirelessly transmitting data from farms to the nearest primary connectivity point, and local sensor networks, including low-power, wide-area networks (LPWANs), designed for gathering sensor and machine data at the farm level. Older infrastructure may lack modern cybersecurity features, making it vulnerable to data breaches, which we view as a tailwind incentive to accelerate modern infrastructure adoption. Illustratively, in 2021, a ransomware assault compelled approximately 20% of the beef processing facilities in the United States to suspend their operations. An obstacle to overcome is the issue of interoperability. Numerous initial precision agricultural technologies were developed in isolation, with scant regard for compatibility—a trend that extends throughout the Internet of Things (IoT) domain. Consequently, valuable data remains siloed, and the extensive analytical prospects offered by standardization remain unrealized. Additionally, upgrading infrastructure can lead to downtime during the transition. This may disrupt farm operations and potentially impact productivity.

The infrastructure market for precision agriculture can be characterized as both consolidated and somewhat fragmented, depending on the specific segment or technology within the precision agriculture space. Some segments of the precision agriculture hardware and equipment market have seen consolidation. Larger agricultural machinery and technology companies have acquired smaller, specialized firms to broaden their product portfolios, notably Trimble, CNH Industrial, and John Deere, which has empowered consolidation through recent investment activity, characterized by CNH's acquisition of Blue River Technology or Deere's acquisitions of Bear Flag Robotics and AgriSync.

Fragmentation is more present considering recent developments with AI and robotics. In these emerging segments, the market can be fragmented, as numerous startups and specialized firms compete to establish themselves. The estimated value of the AI market in agriculture is currently $1.98 billion projected to grow to $4 billion in 2026 at a 26.4% CAGR. Startups specializing in precision agriculture have secured over $3 billion in funding across 250+ deals since 2021.

6. Overview on EO and GNSS Systems

The agriculture industry passed through several relevant technology innovations in the last 20 years. The most relevant are two: GNSS (Global Navigation Satellite Systems) and EO (Earth Observation). But to understand their relevance in the field, it is necessary to understand the key concerns of a farm, and how they can be addressed using the EO and GNSS technology (or the synergetic use of both), and more technically, what are GNSS and EO.

Radio Navigation Satellite Services (RNSS) is an infrastructure that allows users equipped with a compatible device to determine their position, velocity, and time by processing signals from satellites. The providers of RNSS signals are satellite positioning systems, including global and regional constellations and Satellite-Based Augmentation Systems, among which Global constellations (i.e., Global Navigation Satellite System (GNSS)): there are GPS (USA), GLONASS (Russian Federation), Galileo (EU), and BeiDou (PRC).

There are many types of applications for GNSS, from the mass market to professionals, and safety-critical applications, and critical infrastructures. Depending on user needs there are different key GNSS parameters needed to evaluate its performance (Availability, Accuracy, Continuity, Integrity, TTFF, Robustness to jamming and to spoofing).

EO Farming instead refers to Earth Observation Farming and encompasses all the methods through which data about Earth's physical, chemical, and biological systems are collected through remote sensing technologies, typically from instruments or sensors on satellites and aircrafts.

Lastly, as shown below (**Table 2**) it is pivotal for our analysis to understand where EO methods and GNSS come to be used in the agriculture industry. Four main areas have been identified: i. Environmental Monitoring, ii. Natural Resources Monitoring, iii. Operations Management, and iv. Weather services for agriculture.

Within these four spheres, we can appreciate how complimentary EO data & services and GNSS solutions are.

Table 2 – EO and GNSS Precision Farming Applications

Legend
- EO Application
- GNSS Application
- Synergetic Applications

Environmental Monitoring
- Carbon capture & content assessment
- Environmental impact monitoring

Weather services for agriculture
- Weather services for agriculture
- Weather forecasting for agriculture

Operations Management
- Asset monitoring
- Automatic steering
- CAP monitoring
- Farm machinery guidance
- Farm management systems
- Field definition
- Livestock wearables
- Pastureland management
- Precision irrigation
- Variable rate application

Natural Resources Monitoring
- Biomass monitoring
- Crop yield forecasting
- Soil condition monitoring
- Vegetation monitoring

7. Key Market Trends for EO and GNSS Systems

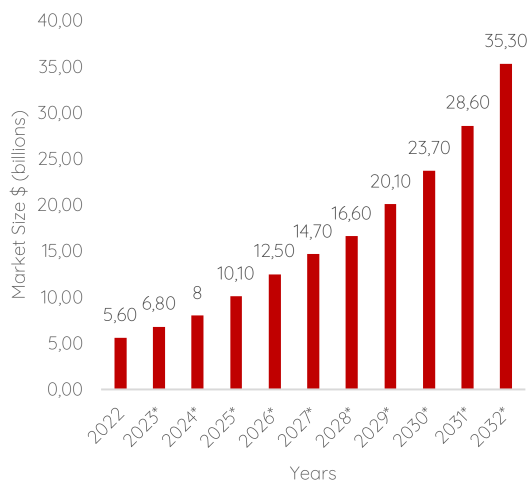
One of the defining trends in agribusiness is the growing emphasis on sustainable practices. The EU's Farm to Fork Strategy, an essential component of the Green Deal, underscores the importance of this shift, setting the pace for global adoption of sustainable agricultural methods. To realize the goals of sustainable soil management and biodiversity preservation, advanced solutions powered by GNSS and EO are indispensable.

Agtech startups have harnessed the potential of EO and GNSS to an unprecedented extent. Venture capitalists and corporate behemoths are pouring investments into these startups, acknowledging their potential to revolutionize sustainable food production. Intensified agricultural production, climate change, and deforestation is putting 20% of arable land under the threat of desertification. In this setting, alternatives are arising. Vertical Farming (that can be deployed in unlikely settings as cities and implies lower transportation costs) is one of them with a CAGR between 2022 and 2032 of 20.22%, and a forecasted market value in 2032 of $35.3 billion (**Graph 4**). A second interesting trend is the desert farming. The employment of GNSS-aided robots may become a common place for Vertical Farmer, and solutions such as nano liquid clay and root zone irrigation may open to new opportunities to farm in arid zones or desert areas.

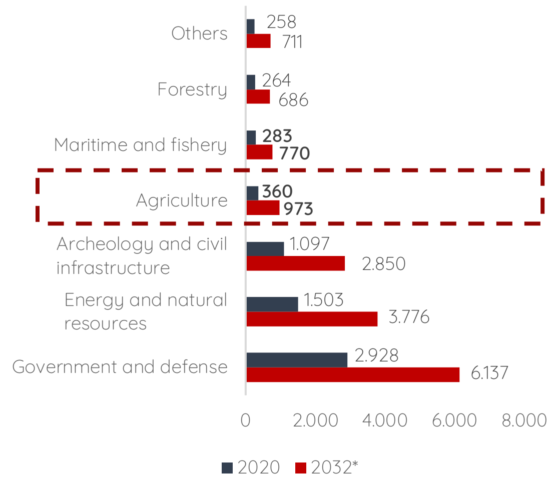
The agricultural commodity flow, historically laden with regulations and checks, is now witnessing a paradigm shift towards complete transparency. Blockchain, when combined with EO and GNSS, provides an immutable traceability chain that is instantly verifiable and wholly digital. Such advancements not only ensure the safety and quality of produce but also further policy objectives like promoting deforestation-free commodities and sustainable fisheries.

In tandem with their technological innovations, many agtech firms are also revisiting their business models. More companies now aim to offer foundational capabilities, such as EO-based analytics platforms for vegetation and soil monitoring, to other stakeholders in the value chain. This white-label approach signifies a more collaborative and integrated future for the agribusiness sector. As illustrated underneath (**Graph 5**), it is evident how the usage of global satellite EO market is expected to increase in many fields, and more precisely, how the agriculture industry is going to play a major role in this market evolution, with an increase of (170.2%), which is relatively the highest among the various industries.

<u>Graph 4 – Market Size projections Vertical Farming. Source: EUSPA, Statista</u>



<u>Graph 5 – Projected satellite earth observation market size worldwide, by end-user 2020-2032. Source: EUSPA, Statista</u>



8. GNSS Applications

The 4 main applications are: Variable Rate Applications (VRA), Automatic Steering, Farm Management System Service Revenues, and Commercial Augmentation Systems.

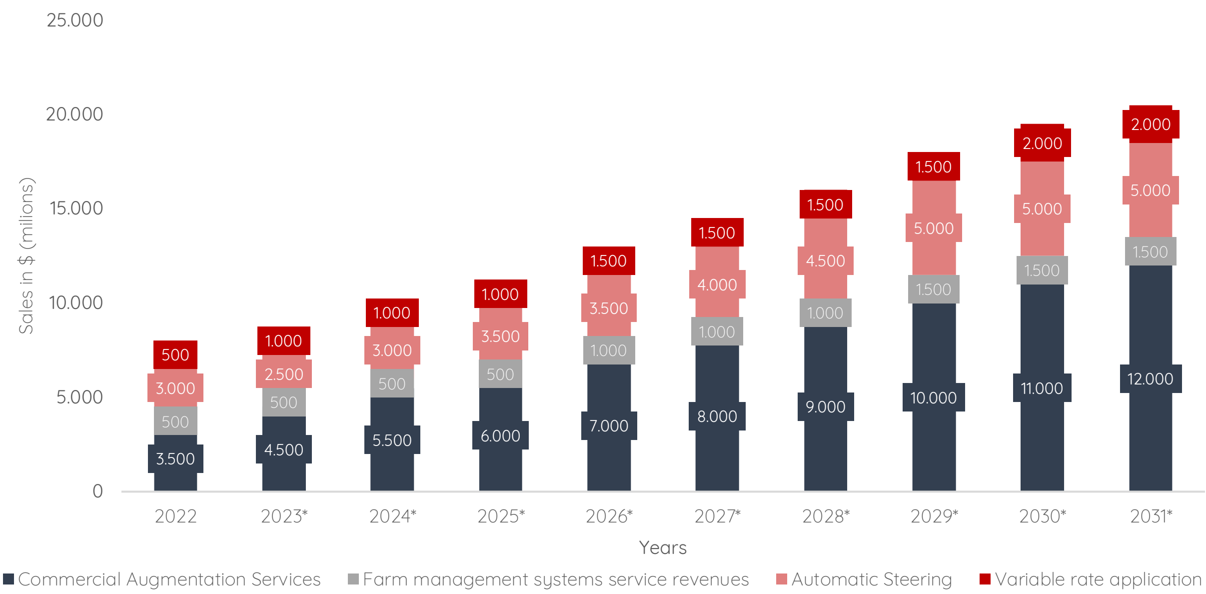
Variable Rate Applications (VRA) plays an essential role in optimizing resource allocation and improving crop yields. EO and GNSS technology integration empowers precise control over input variables, such as fertilizers and pesticides, thereby promoting efficiency and sustainable agricultural practices.

Similarly, Automatic Steering relies on GNSS for autonomous guidance of farming equipment. This technology minimizes overlaps and gaps during field operations, bolstering overall efficiency and sustainability in farming practices.

Farm Management System Service Revenues encompass various aspects of farm management, including asset monitoring, livestock wearables, pastureland management, precision irrigation, and more. These functionalities leverage EO and GNSS data to optimize resources and develop environmental sustainability.

Commercial Augmentation Systems significantly contribute to enhancing EO and GNSS accuracy by ensuring the effectiveness of applications such as environmental impact monitoring, precision irrigation, and weather forecasting, facilitating sustainable agricultural practices.
Analyzing the revenue trends for GNSS devices in agriculture across the four primary applications (**Graph 6**), Variable Rate Applications emerge as the frontrunner with the highest potential, showcasing a 16.65% CAGR. Closely trailing behind, both Commercial Augmentation Systems and Farm Management System Service Revenues demonstrate robust performance, with CAGRs of 14.67% and 12.98%, respectively. In contrast, Automatic Steering exhibits the lowest estimated growth, with a CAGR of 5.84%.

Graph 6 - Estimated revenue of global navigation satellite system (GNSS) devices in the agriculture sector worldwide from 2022 to 2031, by application (in million U.S. dollars). Source: EUSPA, Statista



9. Internet Access & Farm Size

The adoption of precision agriculture among farmers is still in its early stages and faces several limitations. In particular, we note the high costs associated with some of these solutions as well as the absence of digital infrastructure like Internet access as potential headwinds for precision agriculture technology adoption.

Internet Access

A study conducted by the United States Soybean Association found that nearly 60% of U.S. farmers and ranchers do not believe they have adequate internet connectivity to run their businesses. The study investigated fixed, satellite, cellular and hotspot connections and found that farmers do not agree that their internet access provides value for the cost either in their offices (65%) or in their fields (77%). And because their farms can't move, 78% do not have another viable option to change service providers. In the EU, broadband deployment differs among countries. A 2017 EU Commission study revealed that only 47% of rural areas had fast broadband. France and Sweden had higher penetration at 79% and 80%, while Hungary and Italy lagged behind at 25%. We note that both the US and the EU have recognized this issue. In the US, Congress appropriated $65 billion through the Infrastructure Investment and Jobs Act (IIJA) to close the digital divide and ensure universal access to reliable, high-speed, and affordable broadband across rural areas. In the EU, the European Commission approved the Connecting Europe Facility (CEF) programme, which will support investment in digital infrastructure networks. In particular, the funding programme would see EUR 2bn invested to develop connectivity across the EU, including in remote and rural areas.

While those initiatives act as a potential mitigator, we still see the lack of connectivity across rural areas as a headwind for precision agriculture. Further investment and progress within this area would make our view change.

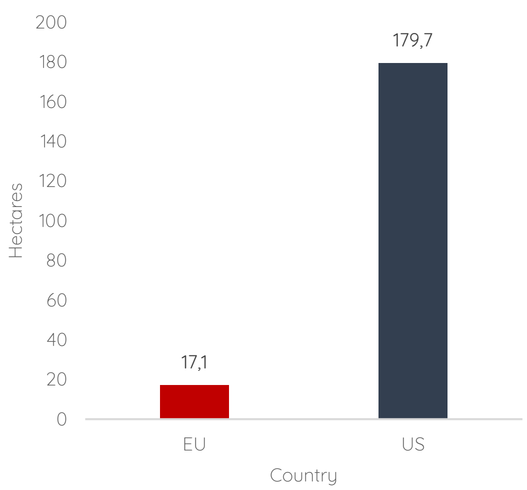
Farm Size

One of the major concerns around the adoption of precision agriculture methods is the cost. Smaller farms, with less capital available for investment, will find it harder to come up with the capital necessary for investment in infrastructure and drones. For example, a complete drone solution (including the analytics software, training modules and charging equipment) could amount to $5,000, which is unaffordable for most smaller farmers in low- and lower middle-income countries.

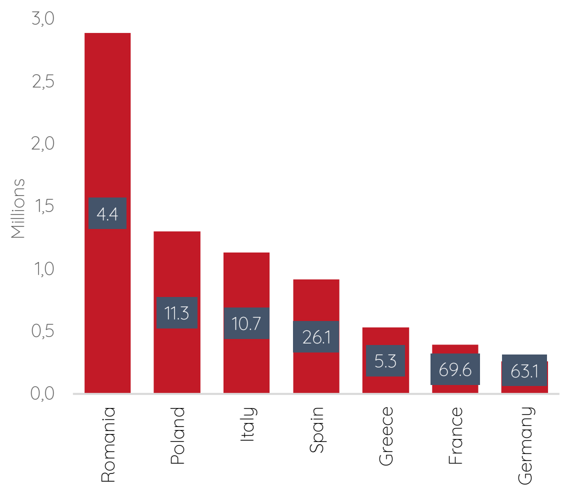
The high initial investment cost of drones makes them an expensive technology to use.

Looking at the US and the EU (which might adopt precision agriculture techniques faster due to their high development, education, income, and technological advancement), we note that this issue could affect the latter more than the former.

Graph 7: EU vs US average farm size (hectares). Source: Eurostat



Graph 8: Number of farms in the EU (millions) and average farm size (blue, in hectares). Source: Eurostat



In particular, we find that the US boasts 10x (**Graph 7**) more land per farm than the EU, on average. This is largely caused by the larger number of smallholder farms within Europe, especially in emerging economies, but also in some developed ones (Greece, Italy). For example, three countries within the EU: Romania, Greece, and Poland hold half the number of farms within the whole Union, while having an average farm size of 4.4 ha (Romania), 5.3 ha (Greece), and 11.3 ha (Poland) (**Graph 8**).

We also note a correlation between farm size and GDP per capita, at the latter's lower figures (**Graph 9**), indicating that smaller farms tend to be clustered in relatively less rich countries, acting as a double headwind to the adoption of PA techniques due to both their unaffordability for those farmers and lack of economies of scale achieved.

Nevertheless, we note that in some developing countries, drones are being made available for smallholder farmers at affordable prices through business models that support their use (e.g., drone-as-a- service). Additionally, the drone industry has fine-tuned some of its offerings (by reducing complexity) for smallholder farmers based on affordability and necessary features for smaller farms. For example, for some farms in Asia, a drone from a leading manufacturer could cost as little as $400. Further developments within this direction could accelerate adoption of PA techniques even within smaller farms in the EU and across the globe, driving growth for companies involved in developing associated products.

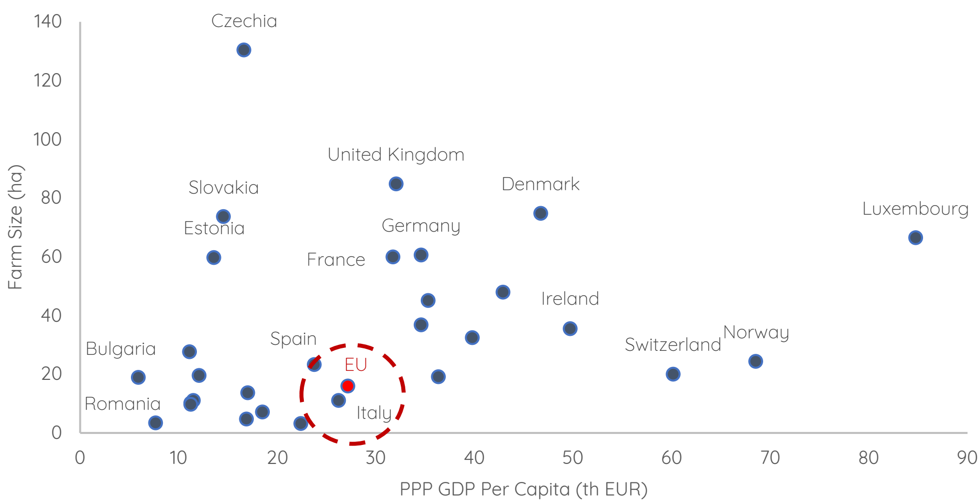
10. Farmers' Age & Education

Education and age play a pivotal role in influencing the adoption of new technologies among individuals. We view these factors as major headwinds to the precision agriculture industry. Older farmers exhibit higher levels of risk aversion regarding new technologies. The average age of all producers is over 57.5 in the United States as of 2017, up 1.2 years from 2012 according to the National Agriculture Census. The majority of European farmers are aged 55 years and above, with only a small fraction, approximately 6.9%, being younger than 35 years. Furthermore, nearly one-third of all farmers are older than the typical retirement age of 65 years. Agriculture has a lower proportion of young individuals compared to other economic sectors in Europe, and the number of young people involved in farming is declining at a faster rate than the older farming population.

Moreover, farmers with higher education levels are generally more receptive to new innovations, making the technology adoption process smoother. This trend has been observed in various contexts, such as forward pricing methods, microcomputer adoption in agriculture, internet usage, and reduced tillage practices, among others.

Unfortunately, in the US, only 38% of farmers hold a bachelor's degree. Similarly, in Europe, in the agricultural sector, educational levels of the workforce are much lower than national averages.

Graph 9 – Firm Size vs Countries' GDP per capita. Source: Eurostat



11. Sources

JEME Intelligence (2023).

Minerva IMS Intelligence (2023).

Bokusheva, R. and S. Kimura (2016), *Cross-Country Comparison of Farm Size Distribution*, OECD Food.

United Nations Development Programme (2021), *Precision Agriculture for Smallholder Farmers*.

USDA, National Agricultural Statistics Service (2017), *Farm Profits and Adoption of Precision Agriculture*.

USDA, National Agricultural Statistics Service (2022), *Farms and land in farms 2021 summary*.

USDA, National Agricultural Statistics Service (2023), *Farm Bill Spending*.

USDA, National Agricultural Statistics Service (2019), *Agriculture Improvement Act of 2018: Highlights and Implications - Research, Extension, and Related Matters*.

BCG Global (2021), *The Digital Agriculture Revolution will take more than innovating,*

Agfunder (2023), *Agfunder Global AgriFoodTech Investment Report 2023*.

New Model Adviser (2023), *Deere bets the farm on $150bn 'Precision Agriculture' opportunity*.

IBISWorld Industry Reports (2023), *Precision Agriculture Systems & Services in the US.*

IFSWF (2021), *Climate opportunities*.

European Commission (2023), *The Common Agricultural Policy (CAP) 2023-2027.*

European Commission (2021), *Connectivity: key to revitalizing rural areas*.

Our world in data (2023).

Eurostat (2023).

MDPI (2023), *Precision Livestock Farming Research: A global scientometric review*.

Statista (2021), *Precision farming and agricultural digitalization in England*.

EU Agency for the Space Programme (2022), *GNSS Market Report*.

United Soybean Board (2019), *Rural Broadband and the American farmer*.


MINERVA
INVESTMENT MANAGEMENT SOCIETY