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RECENT TRENDS AND FUTURE DIRECTION OF AI-DRIVEN INNOVATIONS IN AGRICULTURE

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Abstract:

Artificial intelligence (AI) is the buzzword in today's setting. It has penetrated various industries, making impacts to the ways in which business is carried out. One of the areas of increasing adoption of AI is the agricultural sector, in which AI-enabled innovations have contributed to increased productivity and enhanced plantation outputs. In this context, understanding the trajectory of these innovations requires a systematic analysis of technological development, particularly through patent activity. Hence, this paper examines recent trends in AI-driven innovations in agriculture by analysing data retrieved from Lens.org. Data was collected, filtered, categorised and analysed, the report of which is presented in this paper. The study found a sharp increasing trend of AI-driven patents being filed and granted in recent years, beginning in 2022 onwards, involving major institutes from the information technology (IT) and electronics. The findings of this study offer a comprehensive view of how AI is driving innovation in agriculture, highlighting key technological domains, emerging trends, and strategic implications for stakeholders. These insights can inform future research, policy development, and investment strategies aimed at fostering sustainable and technologically advanced agricultural systems.

Keywords:

Artificial Intelligence, Innovation, Patent, Agriculture, Farming, Plantation

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Introduction

Artificial intelligence (AI) is becoming increasingly prevalent in farming, leading to significant changes in farming practices. As the world's population grows and natural resources become scarcer, the sector needs to quickly find ways to boost productivity, sustainability, and resilience. Traditional agricultural methods are increasingly insufficient to meet these evolving demands, prompting the adoption of advanced technologies such as AI. AI gives us powerful tools to solve these problems by making farming smarter, more efficient, and based on data.

AI has been used more and more in farming in the last few years. We utilize machine learning, robotics, and AI-powered sensors to monitor crop health, automate tasks such as planting and harvesting, and optimize resource utilization. Farmers are making better choices, wasting less, and getting more crops thanks to precision agriculture, predictive analytics, and real-time decision support systems. These new ideas enhance operational efficiency and contribute to environmental sustainability.

But using AI in farming is not without its problems. Access can be limited, especially for small-scale farmers, because of high costs, technical difficulties, and worries about data privacy. To make sure that innovation is responsible and open to everyone, we also need to deal with regulatory and ethical issues like data ownership and labor displacement. To make decisions about the future of AI-driven agricultural technologies and how to develop them, we need to know what they are like right now.

Accordingly, the objective of this paper is to examine the recent trends of AI-driven innovations by looking at patent data from Lens.org to find out what AI innovations are currently happening in agriculture and what they might look like in the future. The study looks at patents related to AI applications in farming by using the search term "artificial intelligence AND (plantation OR agriculture or farming)." The study looks at patent types, patent families, classification codes, and time-series trends to find the most important areas of new ideas and technological progress.

This study helps us understand how AI is changing the future of farming by giving us a better picture of the landscape of innovation. The results can help make strategic decisions, help make policies, and help decide which technologies to invest in that will help farming become more sustainable and efficient.

Conceptualizing Innovations in Agricultural Setting

More and more farmers and agencies in farming and plantation are using AI to improve production, sustainability, and the efficiency of their operations. AI technologies are used to improve many aspects of farming, from managing crops to allocating resources. Such technology helps them get more crops and less damage to the environment. There are several ways that AI can be used in agriculture, such as precision farming, predictive analytics, automation, and smart monitoring systems, as shown in **Figure 1**. All of these help change the way traditional farming is conducted.

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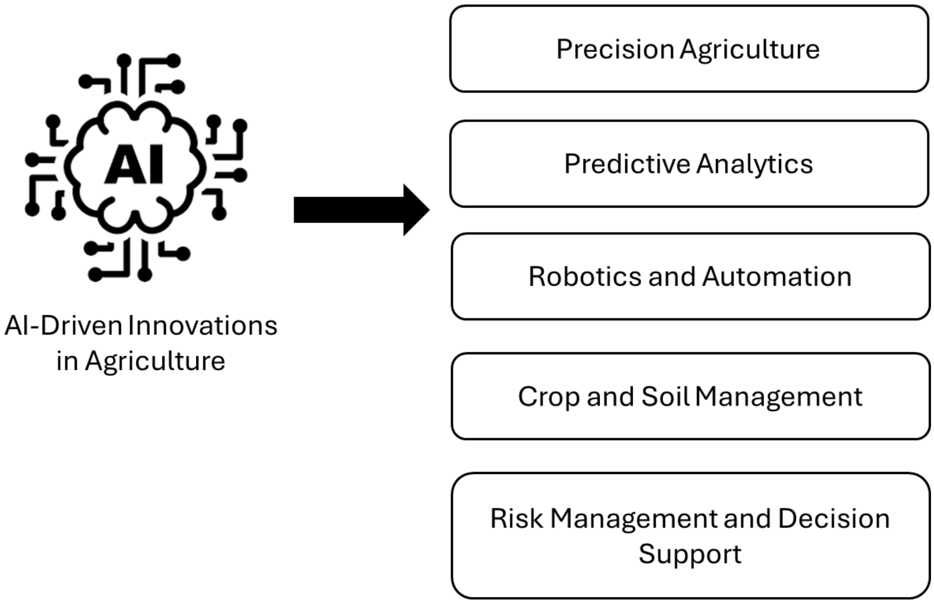

Figure 1: How AI Drives Innovations to Improve Agriculture

Precision Agriculture

AI-driven precision agriculture uses data analysis to improve methods like pest control, irrigation, and fertilization. This lets resources be used more efficiently and less wastefully by targeting the needs of each crop and field (Henrietta, 2024; Ritambara et al., 2024). Drones, internet of things (IoT) sensors, and satellite images give farmers real-time information about the health of their crops, the moisture in the soil, and the weather, which helps them make smart choices and use their resources more efficiently (Gupta, 2025; Berna et al., 2024).

Predictive Analytics

AI-powered predictive analytics solutions also help farmers foresee market trends, deal with the risks that come with pricing changes, and make supply chain logistics better. These technologies also help plan planting schedules better and prepare for problems like disease outbreaks (Singh et al., 2024; Gupta, 2025). Machine learning algorithms look at big amounts of data, like weather and soil conditions, to guess how much crops will yield and help with strategic decision-making (El Qarawy, 2023; Rattan et al., 2024).

Robotics and Automation

Also, using AI in robotics and automation has changed labor-intensive farming tasks like planting, harvesting, and checking crops' health. For this purpose, drones are used to oversee the plantation area, and record any necessary interventions needs by the farmers. This has lowered costs and made things more efficient by reducing the need for manual labor (Singh et al., 2024). AI systems also automate tasks like fertilizing and watering plants, which saves money on labor and resources (Ritambara et al., 2024). Such innovative solutions by combining robotics and automation has significantly improved the smart irrigation systems, as well as determining the correct formula for plantation solutions.

Crop and Soil Monitoring

Advanced AI technologies like hyperspectral imaging and 3D laser scanning give us detailed information about crop and soil conditions, which makes it easier to maintain their health

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(Chettri et al., 2024). AI systems can also look at soil data and suggest the best ways to add nutrients to the soil. This process makes the soil healthier and helps crops grow better (Chettri et al., 2024; Berna et al., 2024).

Risk Management and Decision Support
Finally, AI is very important for managing agricultural risks and helping farmers make decisions by looking at possible threats and giving them strategic advice that makes their farms more resilient and adaptable (El Qarawy, 2023). AI-powered decision support systems help farmers make smart choices, which keeps farming operations sustainable and adaptable to changing market and environmental situations (Singh et al., 2024).

As can be seen from the literature analysis, the approaches used in agriculture are aimed at improving the quality of life for the community (Mohd Karim et al., 2025). The stable and beneficial use of AI for society will ensure that agricultural projects bring advantages to various stakeholders. Therefore, a successful project hinges on meaningful engagement with the community, a comprehensive understanding of the local context, and a carefully designed and implemented development strategy (Mohd Karim & Sakdan, 2019). Striking a balance among these components ensures the project remains impactful, sustainable, and beneficial over the long term, especially in the agriculture sector.

Methodology
This study investigates recent trends in AI-driven innovations within the agricultural and plantation sectors by analyzing patent data retrieved from the Lens.org database. The methodology is structured into four key stages: data collection, keyword filtering, data categorization, and analytical procedures.

Step 1 - Data Collection
Patent data were sourced from Lens.org, a comprehensive open-access platform for patent and scholarly data. The search for patent documents was conducted using the keyword string: "artificial intelligence" AND (plantation OR agriculture OR farming). This query was applied to the full text of patent documents to ensure comprehensive coverage of relevant innovations. The search was limited to patents published within the last two decades to capture recent trends and developments.

Step 2 - Keyword Filtering and Inclusion Criteria
To ensure relevance, only patents explicitly referencing AI technologies in the context of agricultural or plantation applications were included. Duplicates and unrelated patents were excluded through manual screening and automated filtering based on title, abstract, and classification codes. Classification codes as significant in classifying the aims/purpose or the category of the patents as recognised internationally, such as physics, chemistry, social sciences, and there are also sub-classifications. The final dataset comprised patents that demonstrated a clear application of AI in agricultural contexts, such as crop monitoring, precision farming, automated machinery, and predictive analytics.

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Step 3 - Data Categorization
The selected patents were categorized based on the following dimensions:

- Patent Type: Differentiating between granted patents, patent applications, amended patents and others.
- Patent Family: Grouping related patents filed in multiple jurisdictions under a single innovation.
- Patent Classification: Using the International Patent Classification (IPC) and Cooperative Patent Classification (CPC) systems to identify technological domains and subdomains.
- Temporal Distribution: Organizing patents by publication year to analyze trends over time.

Step 4 - Analytical Procedures
Descriptive and inferential statistical analyses were conducted to identify patterns and trends in the dataset. Time series analysis was employed to examine the evolution of AI-driven agricultural patents over time. The distribution of patent types and classifications was analyzed to determine the dominant areas of innovation. Patent family analysis provided insights into the geographical and jurisdictional spread of key innovations, indicating the global interest and investment in AI-driven agricultural technologies.

This methodological framework enables a comprehensive understanding of how AI is shaping innovation in agriculture, offering insights into technological trajectories, research priorities, and emerging areas of interest.

Recent Trends of AI-Driven Innovations in Agriculture
A total of 18,690 patent documents were retrieved using the keyword string "artificial intelligence" AND (plantation OR agriculture OR farming) (Search conducted on 25 July 2025). From 2020 onwards, the trend has shown exponential growth of AI-driven innovations in agriculture, as can be seen in **Figure 2**. The highest number of patents were applied in the year 2024, with a total number of 2,330 patents, followed by 2023, with a total number of 2,171 patents, and 2022, with a total number of 2,080 patents. However, it is crucial to be noted that the patent data at the time the query was carried out was mid-year for 2025. As of 25th July 2025, there are 1,479 patents filed, and could grow more by the end of 2025.

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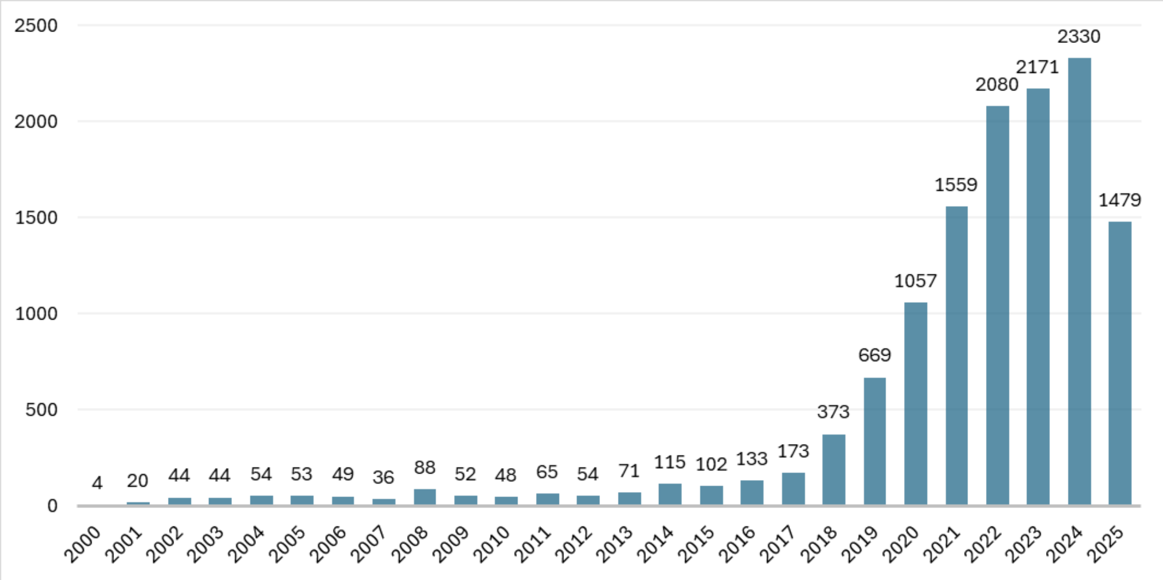

Figure 2: Patent Documents by Year

(Source: Lens.org)

Top Applicants and Owners of AI-Driven Patents in Agriculture

In terms of applicants for AI-driven patents, the entity with the highest number of patent applications is LG Electronics, with a total of 3,181 documents, followed by Qualcomm (352 documents), John Deere (354 documents), Strong Force IoT Portfolio (335 documents) and IBM (240 documents). The remaining of the top patent applications in this context are shown in **Figure 3**. As can be seen from the list of top applicants of AI-driven patents in agriculture, these are major companies in the area of information technology (IT), computing, IoT and electronics. This observation reflects the dominant role of IT and electronics industries in shaping agricultural AI applications.

International Journal of Innovation and Industrial Revolution
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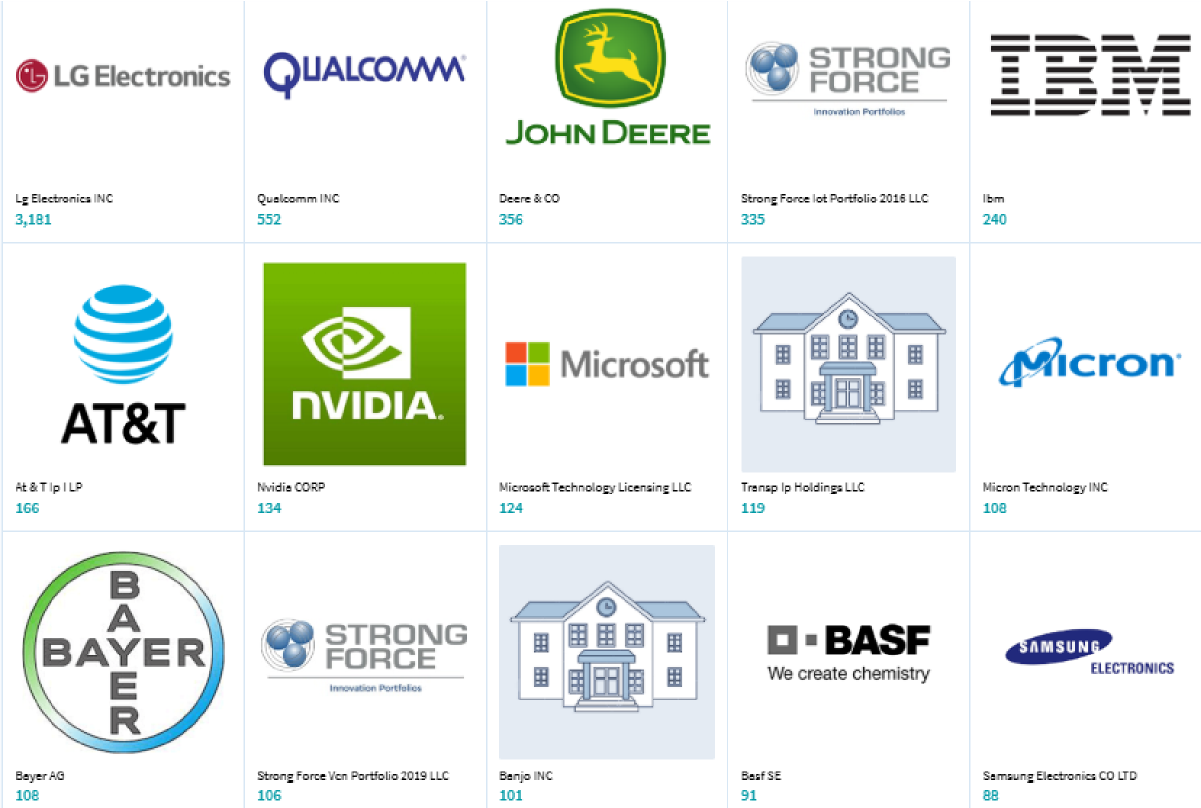

Figure 3: Top Applicants of AI-Driven Patents in Agriculture
(Source: Lens.org)

Accordingly, literature have suggested that AI is reshaping business models in agriculture, especially in areas like vertical farming, where it plays a key role in boosting productivity, improving operational efficiency, and enhancing the quality of agricultural products—all while helping to reduce overall costs (Cavazza et al., 2023). Vertical farming, which involves growing crops in stacked layers often within controlled indoor environments, benefits significantly from AI technologies that manage lighting, temperature, humidity, and nutrient delivery with precision. These innovations allow for year-round production and better resource use, making the model more economically viable and environmentally sustainable.

Additionally, IT and electronics companies are central to driving these innovations. By developing advanced AI platforms and digital tools, they enable farmers to make smarter, data-driven decisions. Along the same vein, companies have created systems that support precision agriculture by collecting and analyzing data from fields to guide decisions on planting, irrigation, fertilization, and pest control (Jeyalakshmi et al., 2024). These platforms help farmers optimize field operations, reduce resource waste, and improve crop yields. The strategic use of AI in these tools also opens up new business opportunities, such as subscription-based services, data analytics consulting, and integrated farm management solutions.

Zooming in further the patents filed and granted, the time series for the top applicant LG Electronics is as shown in **Figure 4**, with the highest number of patent documents is 568 in the year 2022, while for QualComm in **Figure 5**, the highest number of patent documents is 187

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DOI 10.35631/IJIREV.722025

in the year 2023, and for John Deere in **Figure 6**, the highest number of patent documents is 107 in the year 2024.

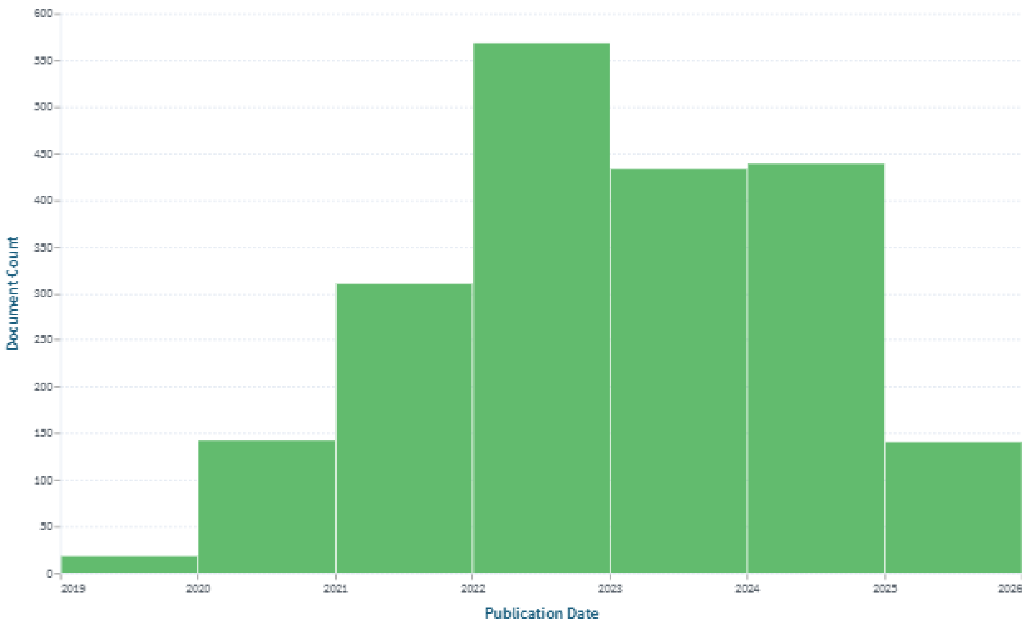

Figure 4: Patent Documents by LG Electronics

(Source: Lens.org)

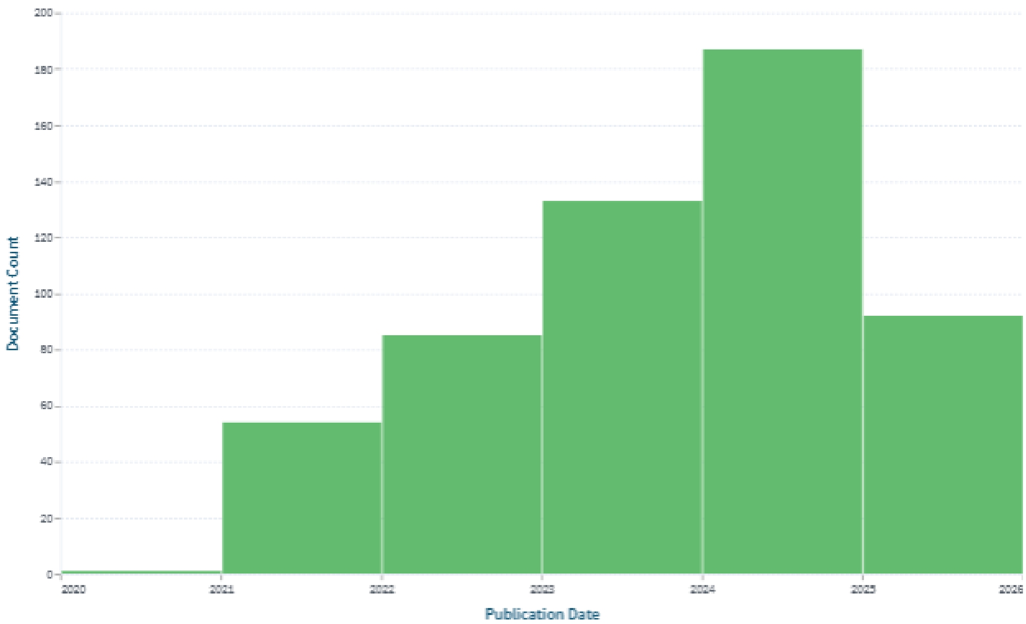

Figure 5: Patent Documents by QualComm

(Source: Lens.org)

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 7 Issue 22 (September 2025) PP. 457-471
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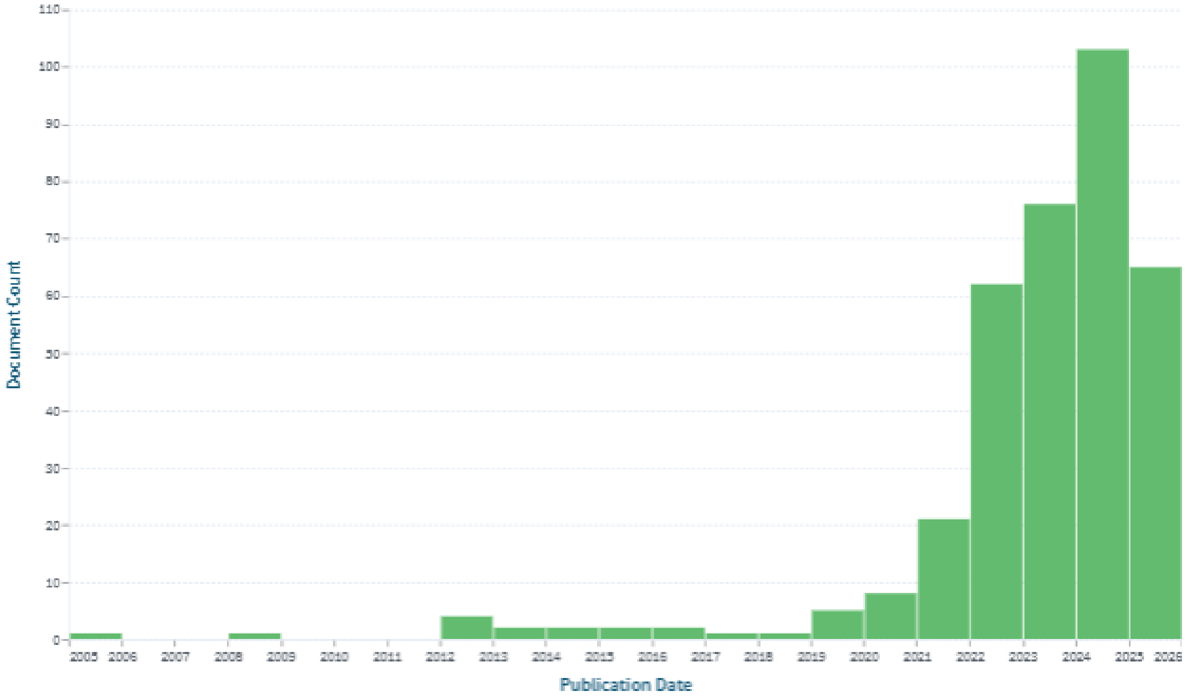

Figure 6: Patent Documents by John Deere

(Source: Lens.org)

Top inventors of AI-Driven Patents in Agriculture

Particularly for AI-Driven patents in agriculture, the top inventors on record from 2005 until July 2025 are as shown in **Figure 7** for both granted patents and applications. The data shows that the top patent applicants dominate the top inventors, being LG Electronics and Strong Force IoT. Top inventors from LG Electronics are Lee Yongdae (436), Kang Jiwon (395) and Jung Sunghoon (377). Meanwhile, top inventors from Strong Force IoT are Cella Charles Howard (426), McGuckin Jeffrey P (343) and Duffy Jr. Gerald William (337).

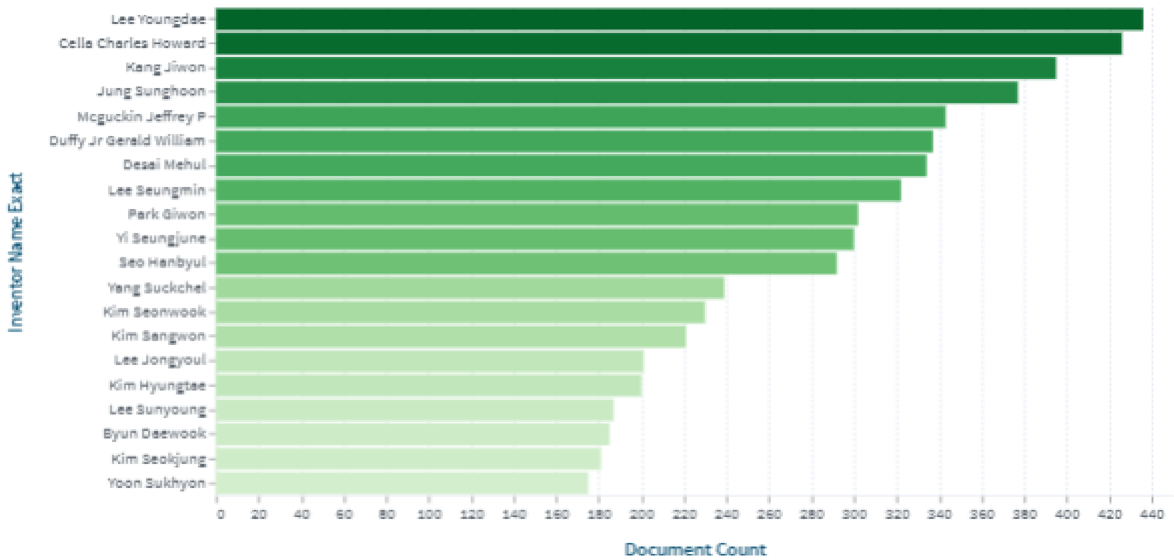

Figure 7: Top inventors of AI-Driven Patents in Agriculture

(Source: Lens.org)

International Journal of Innovation and Industrial Revolution
IJIREV
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Volume 7 Issue 22 (September 2025) PP. 457-471
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Patents by Jurisdiction
An analysis of AI-driven patents in agriculture broken down by jurisdiction is produced in **Figure 8**.

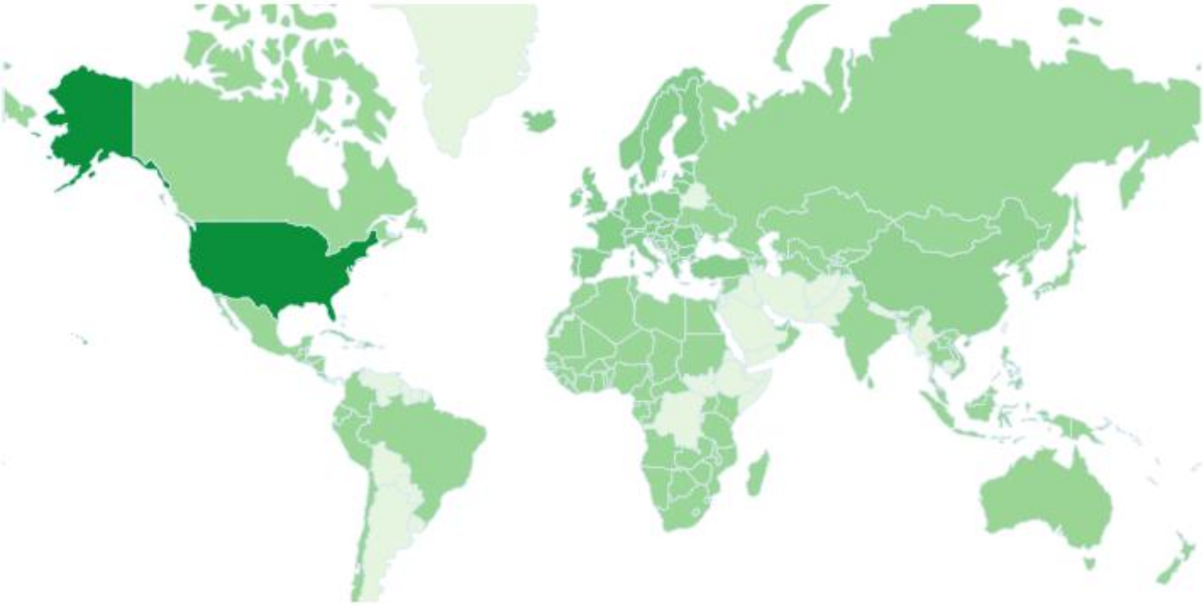

Figure 8: AI-Driven Patents in Agriculture by Jurisdiction
(Source: Lens.org)

Data shows that the highest number of AI-driven patents in agriculture to be in United States of America (12,940) followed by WIPO patents (3,504) and European patents (1,390). The following **Table 1** shows the breakdown of the patent documents by top seven jurisdictions.

Table 1: Patent Documents by Top 7 Jurisdictions

Jurisdiction	Number of patent documents
United States of America	12,940
WIPO	3,504
European Patents	1,390
China	605
Republic of Korea	59
Australia	22
United Kingdom	11

(Source: Lens.org)

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IJIREV
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Patents by Classification Codes

There are two primary types of classification codes, the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC). Both systems are used for categorizing patents, but they differ in their structure, detail, and application. The IPC is a long-established system managed by the World Intellectual Property Organization (WIPO), while the CPC is a more recent development, created as a collaborative effort between the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO). The CPC is designed to be more detailed and adaptable to new technologies, which makes it a more precise tool for patent classification and analysis. Nevertheless, both classifications are relevant to determine the classes in which the patents are filed and granted. Particularly for AI-driven patents in agriculture, they have been classified into IPC and CPC codes.

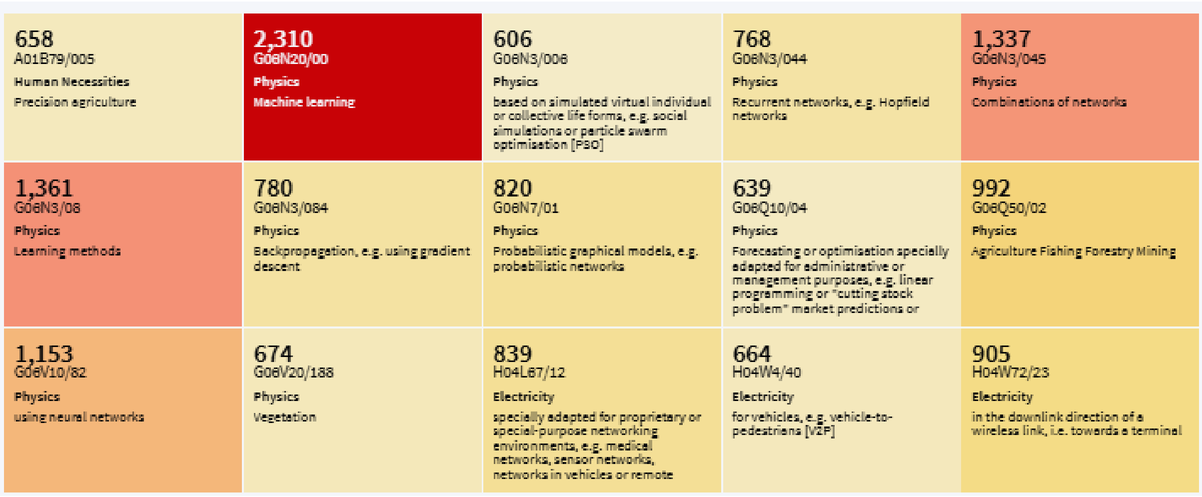

Figure 9: Top CPC Classification Codes for AI-Driven Patents in Agriculture
(Source: Lens.org)

As shown in **Figure 9**, the top five CPC classification codes for AI-driven patents in agriculture are G06N20/00 Machine Learning (2,310), G06N3/08 Learning Methods (1,361), G06N3/045 Combination of Networks (1,337), G06V10/82 Using Neural Networks (1,153) and G06Q50/02 Agriculture Fishing Forestry Mining (992).

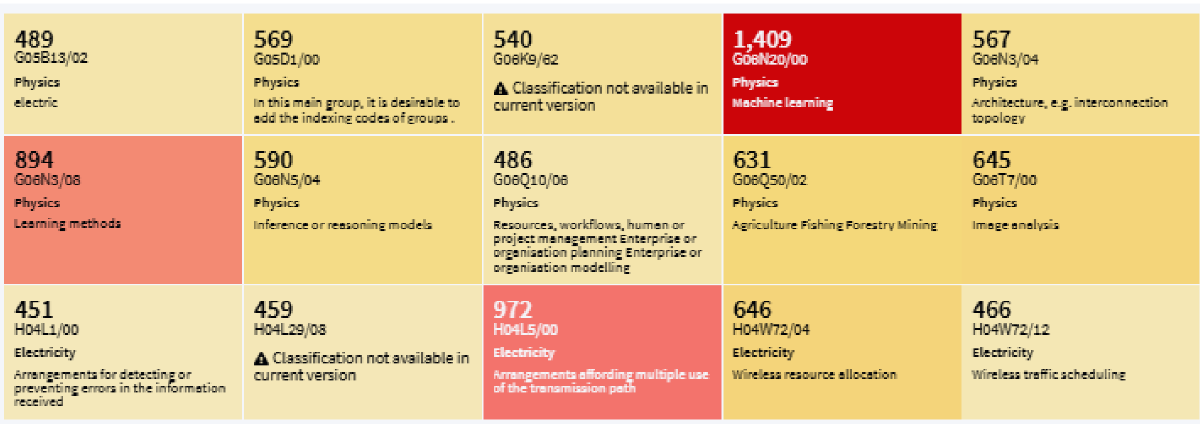

Figure 10: Top IPC Classification Codes for AI-Driven Patents in Agriculture
(Source: Lens.org)

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IJIREV
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On the other hand, as shown in **Figure 10**, the top five IPC classification codes for AI-driven patents in agriculture are G06N20/00 Machine Learning (1,409), H04L5/00 Arrangements affording multiple use of the transmission path (972), G06N3/08 Learning methods (894), H04W72/04 Wireless resource allocation (646) and G06T7/00 Image analysis (645).

Future Direction of AI-Driven Innovations in Agriculture

Based on the above discussion of recent trends of AI-driven innovation in agriculture, AI is evidently becoming a major force, and its role is expected to grow even more in the future. As AI continues to be used in different agricultural processes, it's helping make agriculture more productive, efficient, and sustainable. This role is especially important as the world faces challenges like a growing population and limited natural resources. In the coming years, patents related to AI in agriculture are likely to focus on areas such as precision farming, automation, and smart decision-making. These innovations are backed by ongoing research and technological progress in the field.

The first key area in AI innovation is precision agriculture. AI is being used to improve farming techniques through precision agriculture. This means using data to make better decisions about things like pest control, fertilizing, and watering crops. It was reported by iMARC Research (2025) that the global precision agriculture market size was valued at USD 9.3 Billion in 2024, and it is expected to reach USD 21.5 Billion by 2033, exhibiting a growth rate (CAGR) of 9.66% from 2025 to 2033 as shown in **Figure 11**.

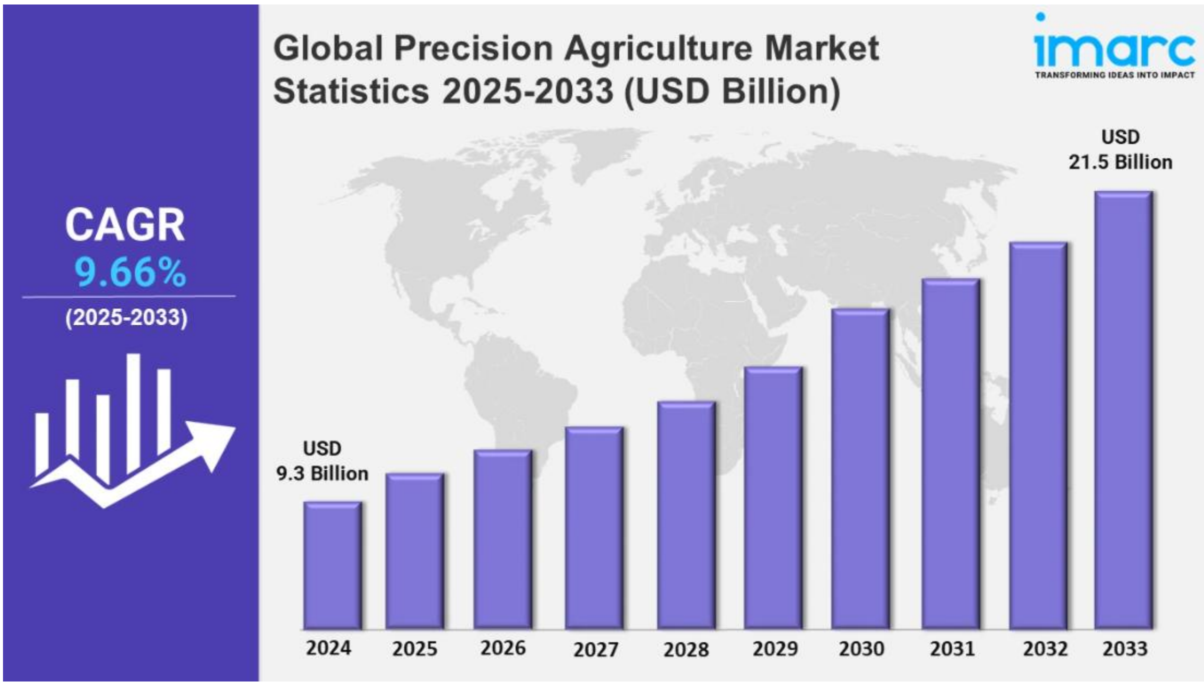

Figure 11. Global Precision Agriculture Market Statistics 2025-2033 (Shown in USD Billion)

(Source: iMARC Research, 2025)

AI-powered sensors can collect information about crop health, soil moisture, and weather, and then give specific advice for each field (Henrietta, 2024). Because this approach helps farmers use resources more efficiently and grow more food, it's expected to be a major focus for future patents.

International Journal of Innovation and Industrial Revolution
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IJIREV
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Another big area of interest is using AI to automate farming tasks. Robots and machines powered by AI can plant seeds, harvest crops, and check on plant health. This helps reduce the need for manual labor and makes farming more efficient (Mim et al., 2025; Sasikala & Sharma, 2022). Future patents will likely focus on making these technologies even better and more affordable for farmers.

Combining AI with the IoT is also changing how farming works. This combination allows farmers to get real-time data and make quick decisions (Mim et al., 2025). For example, smart farming systems can monitor crops and adjust watering or fertilizing automatically. Patents in this area will probably focus on improving how these systems connect and process data.

In terms of sustainability and resource management, AI is also helping farmers be more environmentally friendly. New technologies are being developed to use resources like water and nutrients more wisely and reduce pollution (George et al., 2024). Patents will likely cover tools and systems that support sustainable farming, such as AI solutions for managing water use and soil health.

For smallholder farmers, AI helps by offering affordable mobile tools for pest alerts, weather forecasts, and market prices, enabling better decisions with limited resources. Unlike large farms with advanced machinery, smallholders gain access to precision farming without heavy investment, improving yields, reducing waste, and enhancing sustainability in low-resource settings (Pena & Granados, 2024). Particularly for developing regions, AI helps overcome limited access to agricultural expertise, infrastructure, and capital. Mobile-based AI tools deliver localized advice on planting, pest control, and weather forecasts in native languages. AI-driven platforms connect farmers to markets and financial services, while low-cost sensors and drones enable precision farming without expensive machinery (Ahmad, et.al, 2024).

Nevertheless, the implementation of AI does not go without challenges, primarily in terms of technological and economic barriers. Even though AI has a lot of potential, there are still some challenges. High costs, complex technology, and concerns about data privacy can slow down how quickly these tools are adopted and patented (Mohamad & Mohd. Karim, 2025; Mim et al., 2025; Assimakopoulos et al., 2024). These issues are especially tough for smaller farms or those in developing regions.

From the regulatory and ethical perspective, there are also important legal and ethical questions to think about. For example, how will AI affect jobs in farming? Who owns the data collected by AI systems? These concerns need to be addressed to make sure AI is used responsibly (Mim et al., 2025; George et al., 2024).

In summary, the future of AI in agriculture looks bright, with many exciting innovations on the horizon. But to make the most of these opportunities, it is important for technology developers, governments, and farmers to work together. By tackling the challenges and making sure AI is used in a fair and sustainable way, we can help create a better future for farming and agriculture.

Conclusion

The study sought to analyse the recent trends of AI-driven innovations in agriculture, with the aim to appreciate the trends by jurisdiction, scope, purpose, time series and other related aspects of patents sourced from Lens.org. The ultimate aim of the analysis is to project future directions

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of agricultural innovations driven by AI. The study found interesting revelations such as a sharp increase in the patents filed and granted from the year 2022 onwards, and the trend only shows that more and more innovations driven by AI would make its was to the agricultural sector, thus improving the ways in which farmers and organisations would do their business.

Alas, from the other end of the discussion, some notable legal and ethical challenges are foreseen, given that the very nature of technology is like a double-edged sword. At one end it proposes interesting solutions to real-world problems, while at the other end it poses risks and challenges to the users, and other related parties involved in the ecosystem of the AI-driven innovations in agricultural setting.

Accordingly, future research could be directed towards exploring how AI adoption affects small-scale and rural farmers, particularly in terms of economic viability, access to technology, and long-term sustainability. Understanding these impacts can help tailor solutions that are inclusive and scalable. Such study can also explore the socioeconomic and cultural impacts of AI adoption in traditional farming communities. Apart from that, another important area for future study is the development of regulatory and ethical frameworks that guide the use of AI in agriculture. Research should focus on data governance, labor implications, and standards for transparency and accountability in AI systems so that the rights of the users, general public and the entire community in the agricultural sector would be protected.

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