ISSN: 2658-8455
Volume 6, Issue 6 (2025), pp. 668-685.

Smart Farming and Agribusiness Enhancement: Integrating Artificial Intelligence and the Internet of Things

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Disclosure Statement :	Authors are not aware of any findings that might be perceived as affecting the objectivity of this study and they are responsible for any plagiarism in this paper.
Conflict of Interest :	The authors report no conflicts of interest.
Cite this article :	LACHHAB, Y., & CHAALI, K. (2025). Smart Farming and Agribusiness Enhancement: Integrating Artificial Intelligence and the Internet of Things. *International Journal of Accounting, Finance, Auditing, Management and Economics*, *6*(6), 668–685.
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International Journal of Accounting, Finance, Auditing, Management and Economics - IJAFAME
ISSN: 2658-8455
Volume 6, Issue 06 (2025)

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Abstract

Through the research is to look to the role of artificial intelligence and Internet of things in smart farming. The aim is to promote modern agriculture by improving efficiency, crop yield, and the sustainable use of resources.
The combination of rich literature review with the use cases and field- level deployment of the AI and IoT based agri technologies. The study looks at applications like crop disease prediction using convolutional neural networks. It also examines IoT-enabled smart irrigation systems and unmanned aerial vehicles to monitor fields and collect data in real time.
The investigation reveals that AI or artificial intelligence models of high accuracy can identify crop diseases, predict yield, and automate decision-making in farm management. Networks (soil sensors, weather stations and satellites) will enable real-time monitoring of short-term weather and thus, spatial and temporal application of inputs. The combination of these technologies improves the productivity, reduces the water and fertilizer usage and minimizes the environmental damage.
This study presents a rich synthesis of AI and IoT applications in agriculture and both together can revolutionize agro-based systems. It deals with existing problems such as compatibility of data, infrastructural limits at rural places, and scalable deployment models. The research adds to the knowledge base on digital agriculture and offers evidence-based insights for relevant policymakers, researchers, and agribusiness stakeholders.

Keywords: Artificial intelligence, Internet of Things, Smart farming, Precision agriculture, Crop monitoring, Sustainable agriculture, UAV, Neural networks.
Classification JEL: Q13, Q16, O33.
Paper type: Theoretical Research

Résumé

À travers cette recherche, les auteurs souhaitent étudier le rôle de l’intelligence artificielle et de l’Internet des objets (IoT) dans l’agriculture intelligente. L’objectif est de promouvoir une agriculture moderne en améliorant l’efficacité, le rendement des cultures et l’utilisation durable des ressources.
Combinaison d’une riche revue de la littérature, de cas d’utilisation et du déploiement sur le terrain de technologies agricoles basées sur l’IA et l’IoT. L’étude examine des applications telles que la prédiction des maladies des cultures grâce aux réseaux de neurones convolutifs. Elle examine également les systèmes d’irrigation intelligents et les drones compatibles IoT pour surveiller les champs et collecter des données en temps réel.
L’étude révèle que des modèles d’IA ou d’intelligence artificielle de haute précision peuvent identifier les maladies des cultures, prédire le rendement et automatiser la prise de décision en gestion agricole. Les réseaux (capteurs de sol, stations météorologiques et satellites) permettront une surveillance en temps réel des conditions météorologiques à court terme et, par conséquent, l’application spatiale et temporelle des intrants. La combinaison de ces technologies améliore la productivité, réduit la consommation d’eau et d’engrais et minimise les dommages environnementaux.
Cette étude présente une riche synthèse des applications de l'IA et de l'IoT en agriculture, qui, ensemble, peuvent révolutionner les systèmes agricoles. Elle aborde des problématiques existantes telles que la compatibilité des données, les limites des infrastructures en milieu rural et les modèles de déploiement évolutifs. Cette recherche enrichit les connaissances sur l'agriculture numérique et offre des éclairages factuels aux décideurs politiques, aux chercheurs et aux acteurs de l'agroalimentaire concernés.

Keyword : Intelligence artificielle, Internet des objets, Agriculture intelligente, Agriculture de précision, Surveillance des cultures, Agriculture durable, Drones, Réseaux neuronaux.
JEL Classification : Q13, Q16, O33.
Type du papier : Recherche Théorique.

ISSN: 2658-8455
Volume 6, Issue 6 (2025), pp. 668-685.

Introduction

This article explores the use of AI in agriculture, highlighting aspects such as precision farming, crop monitoring, detection of pests and diseases, yield forecasting, and autonomous machines. Machine learning, deep learning, computer vision, and the Internet of Things enable intelligent decisions, optimal utilization of resources, and automation. AI supports precision farming by analyzing satellite imagery, sensor readings, and weather data for effective irrigation, fertilization, and sowing. AI drones and cameras enable farmers to identify nutrient deficiencies, diseases, and pests in real time. Predictive analytics help detect problems early, reducing the application of harmful chemical treatments. Combining historical information with weather and soil conditions, yield forecasting models offer accurate forecasts that inform planning and resource allocation. Moreover, AI-powered machines like robotic weeders and tractors promote efficiency and reduce reliance on human labor. Despite all these benefits, the use of AI in agriculture comes with its own set of challenges, from high levels of costs, data unavailability, and increased training needs for farmers. It requires cooperation, research, and learning to overcome these obstacles and realize the full potential of AI in agriculture.
Precision farming is also called precision agriculture. It relies on artificial intelligence (AI) and other advanced technologies to enhance innovative agriculture techniques. Precision farming focuses on improving the yield of the crops, minimizing waste of resources and reducing pollution. This segment will look into the role of AI in precision farming focusing on satellite imagery, IOT sensors, machine learning, etc. Satellite images and the device that measures the Earth's surface give very clear information on a crop's health, the quality of soil, and weather conditions. AI systems use CNNs to monitor plant growth, find problems, and take action by looking at satellite data (Zhang, C., & Kovacs, J. M. (2012)) . Internet of Things devices and sensors gather real time data about soil moisture, temperature, humidity and nutrient levels. AI models process this data to give farmers useful information on when to water their crops or use fertilizer. Variable Rate Technology (or “VRT”) refers to technology and processes that are AI controlled that apply some sort of input, water, fertilizers, pesticides etc at various rates across a field. This application is done depending on spatial variability in soil and crop conditions. So it is important for both inputs and outputs. Drones and UAVs are convenient field evaluation tools considered to be major precision agriculture technology. AI computer programs that use reasoning and analysis are great for ensuring plant health, help detect diseases and monitor a plant’s growth stages . AI works on the soil data to tell whether your crops have need nutrients or not. Machine learning models can make predictions about soil fertility and recommend fertilization strategies. AI models predict and make recommendations for irrigation by analyzing soil moisture data, climate forecasts, and crop needs. Water wastage is reduced and the right crop growth is assured. AI models can predict the yield of crops. Also, they provide suggestions to optimize this yield. Satellite images, data about weather, and old yield records can help make these predictions. All this helps farmers plan they harvests and manage resources. For an AI model to be effective, it needs datasets that are high quality and on a large scale. Agriculture needs to come together in standardizing data collection and sharing practices. The expensive nature and limited accessibility of AI technology restricts widespread utilization of such tools in developing countries. We must find solutions that are affordable and scalable to fill this gap . Future scientific investigations should concentrate on combining AI with other disciplines. Genomics, agronomy, and environmental sciences are relevant fields in processing information for precision farming. AI empowers precision farming through advanced technologies, such as big data, mapping, and seamless connectivity through IoT and AI. Although there are issues (like cost, accessibility, and data availability), the developments in AI these days and inter – disciplinary collaborations have a useful future for sustainable agriculture.

In Morocco, as the AI technologies are gaining more pace, the agricultural sector of the country is making use of it. Applications of AI in agriculture includes irrigation, weeding and spraying. It uses sensors, robots and drones for utilizing (water, fertilizer, pesticide, etc.) a variety of resources in an optimum manner (Babakhouya et al., 2023; Talaviya et al., 2020). Morocco has the strategic advantages to become an AI hub in Africa due to its international commitments and the establishment of the institutions in AI (Lafram & Bahji, 2024). AgriTech programs face hurdles to implementation in Moroccan farms (Babakhouya et al., 2023). Researchers suggest the creation of a global, responsible, and ethical national strategy on AI, which takes into consideration Morocco's development priorities (Lafram & Bahji, 2024). The most impactful drivers of AI in Morocco will be technological, organizational, environmental and behavioral. Among all sectors, agriculture has been classified as one of the most promising for AI (Moudni & Chafik, 2021). AI in Crop Management. AI-based predictive systems analyze environmental factors and help choose the right crop for farmers using sensor data and machine learning algorithms. For example, a study noted that Random Forest was the most effective algorithm for predicting the best crops based on soil and climatic data (Alaoui et al., 2023). Machine learning techniques have been employed to predict vegetable sales in order to increase the efficiency of the supply chain. A Moroccan agricultural company managed to obtain a low MAE value of 0.0035 for sales predictions ("Artificial Intelligence for Forecasting Sales of Agricultural Products: A Case Study of a Moroccan Agricultural Company", 2023). Smart Irrigation Solutions. AI and IoT are used to create smart irrigation systems that eliminate water waste. These systems waste less water by monitoring environmental conditions and adjusting water supply as needed. Challenges and Adoption. Challenges like lack of data or testing in the field limits the application of AI-related technologies in Moroccan agriculture. The successful execution of Artificial Intelligence in Morocco's agriculture will offer many new possibilities even though it has over thrust where suitable is not in use.

A two-step methodology has been designed to facilitate a comprehensive exploration of the intellectual landscape characterizing the field of Artificial Intelligence and Agricultural Development (AI&AD), as well as to elucidate the multi-faceted relationships that exist between AI and Agricultural advancement. The initial step involves the application of bibliometric techniques, which are utilized to systematically conduct an extensive quantitative analysis of pertinent publications, thereby enabling the preliminary validation of research propositions. Subsequent to this quantitative examination, the second step adopts a structured literature review framework aimed at articulating contemporary mainstream topics within AI&AD, with the objective of identifying discernible research gaps that warrant further investigation. The overall research protocol, encompassing these two distinct yet interconnected phases, is illustrated in.

1. Current applications of AgTech in all ranges of agricultural fields.

A few examples can help illustrate what AgTech is all about. Just like every other sector, dairy farms have also been using agri-tech solutions to make the never-ending milking and cow care jobs work. Some examples of AgTech in a dairy farm is automatic and robotic milking systems, automatic cup detachers, washing systems and herd management software. Fruits are picked automatically and robots accept the work with help of laser scarecrows that scare crows from attacking crops, and the outcome of the use of farm management software has been quite useful. There are even robotic beehives to ensure healthy and thriving precious pollinators. One company operating in the AgTech space is Monarch Tractor, which is changing the game with its autonomous, electric, and data-driven solutions. Monarch Tractor is a company that develops a maker of electric, driver optional tractors. The MK-V optional-drive tractor is not just a tractor. It is a platform that increases farm safety, precision, and productivity. In fact, it highlights how technology can make fruit and vegetable farms more profitable.

- ***Global Artificial Intelligence AI in Agriculture Market Size***

Statistics. The global Artificial Intelligence (AI) in Agriculture market is on a significant growth trajectory at a CAGR of 24.5%. In 2022, the market generated USD 1.2 billion in revenue, and this figure is expected to steadily rise in the coming years. In 2023, it is projected to reach USD 1.5 billion, followed by USD 1.8 billion in 2024. As we progress further, the market's growth becomes even more pronounced, with revenues estimated at USD 2.4 billion in 2025, USD 3.0 billion in 2026, and USD 3.7 billion in 2027. Looking ahead, the market is poised for substantial expansion, with revenues forecasted to reach USD 4.2 billion in 2028, USD 5.3 billion in 2029, USD 6.4 billion in 2030, USD 8.0 billion in 2031, and a remarkable USD 10.2 billion in 2032.

2. From Data to Drones: A Comprehensive Overview of AgTech's Impact on Agricultural Innovation and Productivity

- ***What is the importance of AgTech in today's Farming World?***

In today's agriculture landscape, AgTech is not just another component but is completely integrated into the farming ecosystem.
AgTech influences and impacts on multiple aspects of agricultural products and processes. Precision Agriculture AgTech is helping farmers take timely decisions based on accurate data in real time. Tools like GPS, soil testing, and Internet of Things (IoT) devices helps farmers understand their land and crops deeply, which further enables optimising the use of resources, better planning of crop rotations, and even precalculating the yield. This implies that fewer resources are lost and production is maximized, which is positive for both farmers and the climate. Data is the bedrock of the modern AgTech revolution. Modern data analytics let farmers make sense of all that information-data about weather, soil, and other inputs. Farmers can make better choices using data which reduces risk Farmers don't simply need data – they require information that is valuable and interpretable. In the farming world, progress is measured in yields and seasons, and new developments in AgTech seek to make all of them better than each one. The various benefits of AgTech is a great help that is transforming agriculture. It aids in transition to a modern agricultural model which is more productive and more suitable for farmers. Digitization in Agriculture has gone a long way in meeting global demands. With mechanics and digitalization, technology has slowly enabled the farmers' work to be optimized. Currently, today's farming or agricultural practices are much better than what savages used to do before. Bullfrog Holdings needs to popularize Lacosamide and reduce its potential damage liability. These machines only lack a modicum of intelligence so that we may entrust them with not entirely unpredictable activities.

- ***Biotechnological advancements as promoting tools to AgTech.***

AgTech also encompasses advances in biotechnology. This might include making organisms genetically modified (GMOs) to make increasing yield possible and make the crops more resistant to pests and bad environmental situations. The U.S. is not the only one The FDA says GMOs are safe to eat, but research on their effect on the environment is conflicting. multiple scientific papers and studies show large variability across crop types and locations in the net gain or loss in pesticide use resulting from pest resistant GMO crop types. Research in other areas, such as biofuels and agricultural pharmaceuticals, is also being conducted through biotechnology.

- ***Automation as a farming productivity growth parameter.***

Automation may be the most disruptive class of AgTech. Farmers can concentrate on strategic decision-making and efficient farm management thanks to autonomous machines and robotics that can complete operations ranging from planting to harvesting to sorting and packing. Monarch's MK-V tractor automates tasks for farmers to do more with less. The tractor can be operated automatically or through the driver’s manual control. Nonetheless, at the same time, it is important to recognize that these are not substitutes that take away jobs from farmers. Rather, they help farmers do more with less labor and resources.

- ***What is AI in agriculture?***

Over time agriculture has hugely developed and it is now digitized to meet global demand with the development of mechanics and digitalization, technology has slowly made it easier to optimize farmers' work. Actually, the agricultural field is similar to industry & services undergoing digitalization. Built-in cameras, drones, or autonomous tractors, for example, are technologies that can improve the farm. All they require is a minimal level of intelligence so that we can assign them tasks that are not fully predictable.
Intelligent agriculture or smart farming with the advent of autonomous machines, drones, sensors and tools based on artificial intelligence therefore allows a drastic evolution of the sector. To enable the implementation of Artificial Intelligence in collective management measures. The AI market in Agriculture worth about 518.7 million $ in 2017, according to Research and Markets. Estimates expect it to hit 2.6 billion $ by 2025. So, through the improvement of Harvests, the management of the maintenance, the drop in the costs, AI respects the farmer of repetitive tasks. Also, artificial intelligence enables the development of optimization tools for a workflow to achieve maximum agricultural yield.

3. Theoretical Background

3.1. Theories in Information Technology and Innovation.

AI and the IoT combination in agriculture is closely linked to the technology adoption theories. Rogers’ Diffusion of Innovation Theory (2003) is one of the foundational models used to explain how innovations diffuse through members of a social system. In agriculture, the categorization of farmers and agro business into – Innovators, Early Adopters, Early Majority, Late Majority and Laggards, helps in deploying smart technologies. Relative advantage, complexity and trialability influences the speed and extent to which AI/IoT systems are adopted.
The Technology Acceptance Model (TAM) (Davis, 1989), and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) can all be put to work to evaluate smart farming technology acceptance. When it comes to agribusiness settings, adopting technology is influenced by perceived usefulness, ease of use and social influence.

3.2. Theories in Smart and Sustainable Agriculture and Data-Driven Farming.

These days, farming is increasingly reliant on data; so, in technical books, it is termed as Precision Agriculture or Smart Farming. These methods depend on the use of IoT sensors, satellite images and AI-based analytical tools to optimise inputs like water, fertiliser, and pesticides. The importance of yield and sustainability optimization using real-time monitoring, predictive analytics, and automation is seen in Smart Agriculture Paradigm.
The Big Data Analytics Framework applies here too, as it shows how the farms’ enormous and rapidly accumulated data can be harvested into insights. AI algorithms like Machine Learning (ML) are employed to identify irregularities, estimate crops outputs, as well as automate processes to decrease human reliance on gut feeling.

3.3. Economic and Managerial Models in Agribusiness Sustainability and Environmental Management

Incorporating IoT and AI in agriculture supports the larger objectives of Sustainable

Development Theory, especially with regards to ensuring food availability, protecting the environment, and fostering economic health. Enhancements in smart farming promote sustainability by curtailing waste alongside resource consumption whilst decreasing harm on nature. More accurate precision provides a means for interventions that would drastically reduce greenhouse emissions alongside agrochemical overuse.

3.4. Understanding Artificial Intelligence and Intelligent Systems Theories, Strategic Cyber-Physical Systems Technical Foundations, Managerial Insights Relating to Agribusiness

From a strategic management perspective, the Resource-Based View (RBV) (Barney, 1991) argues that AI and IoT technologies can be viewed as valuable and rare, inimitable, non-substitutable resources. Agribusinesses adopting these technologies are likely to gain sustained competitive advantages through greater efficiency and innovation.
Also, Porter's Value Chain Theory (1985) can be applied to assess smart technology's impact on each segment of the agricultural value chain—from production and processing through to logistics and distribution. Adding value through IoT devices and AI integration enables traceability while reducing operational costs.
At a more general level, CPS Theory fosters the design and frameworks of ultramodern farming systems: Cyber Physical Systems combine computation (AI algorithms), networking like with IoT connectivity alongside physical processes such as crop and livestock management for automated agriculture. These systems form the backbone of intelligent farming infrastructure digitally embedded with real-time responsiveness feedback loops.

4. Smart Farming in Action: Practical Uses of AI in Agriculture

Agriculture uses artificial intelligence in various ways. Artificial intelligence helps with agricultural work from data collection to the optimization of the workforce.

- ***Collecting and analyzing information.***

Farms and other agricultural operations must manage their own database for various uses. We can collect and study information on temperature, climatic conditions, soil quality or water quality. Thanks to AI, the work load and losses are diminished here.

- ***Precision or intelligent agriculture.***

Artificial intelligence in farming can help improve the quality of the crops and precision in production. Because of the data that it collects over a longer period, the AI can make seasonal forecasting systems. With that, farmers may factor in the likelihood of some recurring events in their forecast.

- ***Water management.***

The world's usage of water is largely agricultural at 85%. In the past, farmers measured the wetness of soil for irrigation. Today, due to the use of AI, irrigation is done in precise planning.

- ***Drones and video surveillance.***

Drones controlled by artificial intelligence can now systematically cover the entire farmland. The drones gather data, which is then analysed and used by various other artificial intelligences. The algorithms can identify the problems and suggest possible ways to solve it.

- ***Increasing production staff.***

Farmers can use aid robots with AI robots because of the manpower crunch in the sector. These versatile robots can be used for multiple tasks on the farm. Furthermore, they are available 24/7 and do not require any time off.

The organized structure of the diagram consists of three main sections: Sensing Scale, AI Modeling and Analysis, and User Interface. Different sensors are shown in a pyramid along with their resolutions. At the top are satellites that sense at a low resolution. The second tier uses UAS for slightly high resolution. IoT sensors at ground level give the most detailed data. Every layer is connected to the IoT Gateway for safety. This is a representation of AI modeling and Analysis in the cloud. It has a Soil, Water and Crop Monitoring System which gets data streams. AI models process this data. There is an AI-based decision support system that analyzes model outputs. Through a secure communication channel, it connects through the IoT gateway with the sensing scale. Cloud computing infrastructure is represented here with the help of server racks. User interface is a section that shows the various interface the user has to pass with the mobile apps and web app for the AI outcome. It gives a full view of the whole system. A user avatar is included. A section for research and development is also present. It gives an impression of flow through which various sensing technology will collect data, send it to AI-based models, finally reaching decision support which will then present it to users through various interfaces. The various components need secure channels for communication as per the architecture. (Source prairie view a&m university).

5. Smart Agriculture and AI: Balancing Innovation, Sustainability, and Risk

- ***The Benefits of Artificial Intelligence in Agriculture: Toward Greater Efficiency, Yield, and Profitability***

The role of artificial intelligence in agriculture is growing fast for the good of farmers. Smart agriculture assisted by AI provides benefits to the stakeholders of the industry, such as enhanced yield, improved efficiency and low operations cost. In fact, AI is now using machine learning and deep learning to take over labour-intensive jobs such as weeding, spraying and harvesting. As a result, farmers increase input efficiency and agricultural yields. Through task automation, one can cut down on manpower expenditure while increasing productivity. Farmers can get more harvests now without spending more. Moreover, farmers can use artificial intelligence to make better purchasing decisions. This is achieved by offering more punctual and precise information on crop pricing.

Finally, consumers can benefit from smart agriculture with artificial intelligence. Indeed, AI systems are used to monitor the health of crops. As a result, food that is produced through smart agriculture is of better quality and more affordable.

- ***Limitations and Risks of AI Implementation in Agriculture: Accuracy, Cybersecurity, and Market Ethics***

Though the implementation of ai in agriculture is increasing, there are still many limitations that need to be looked at. A major challenge lies in the precision of the AI systems. Without a doubt, the accuracy of decisions depends on the quality of information. This clearly shows the equation of AI dependability. The use of Artificial Intelligence also creates a cyber-attack risk. AI algorithms can be hacked easily. Hackers can change the AI's program or even shut it down by tampering with the data it uses. Consequently, such a hack will have dire consequences on the agriculture industry and cause huge financial costs. The last hazard is that artificial intelligence systems will get used for nefarious purposes. Systems powered by AI can impact the market, change production levels and give out abusive prices. In addition, these risks we

ISSN: 2658-8455
Volume 6, Issue 6 (2025), pp. 668-685.

just mentioned are not the only ones related to the use of AI for agriculture. It is imperative for sector stakeholders to be apprised of these risks so that they can adopt suitable countermeasures.

- ***Environmental and Socioeconomic Impacts of AI in Agriculture: Opportunities and Challenges***

The benefits of precision agriculture are numerous. I think technologically driven; precision farming is here to stay over the long haul. But, apart from offering benefits to farmers and consumers, AI in farming is also impacting the environment and the climate. Indeed, according to the results of some recent studies, smart agriculture can reduce CO2 levels by almost 18% and methane by around 21%. Besides, the use of AI in agriculture helps to conserve natural resources and manage water and soil more efficiently. Certainly, farmers are able to decide better on irrigation and soil fertilization as farmers collect information on weather and soil. As you have certainly understood, with the world population continuing to grow and tricky characteristics related to climate change, the use of AI in agriculture constitutes a solution that meets the challenges.

- ***Environmental and Socioeconomic Impacts of AI in Agriculture: Opportunities and Challenges***

By 2050, the agricultural industry will need to become increasingly efficient at producing food to feed 9.2 billion people. According to the Food and Agriculture Organization of the United Nations, there will be 2 billion more people to feed by 2050. However, the arable land will only see a 4 percent increase. We don't need to grow more, rather we need to grow better to satisfy all those stomachs. To meet our goals, experts state we'll need advancement in Artificial Intelligence in agriculture. But this will have to achieve 4 key challenges. AI must enhance weather management for better crop production. AI systems are essential if farmers are to obtain better harvests yet see a dramatic fall in agricultural operating costs. To lessen water and energy consumption, intelligent farming must improve the use of natural resources. Artificial intelligence must also help save them time and free themselves from recurring tasks while guaranteeing better income. The various challenges to be met are thus very numerous, however, the players in the sector have already taken the lead. As mentioned previously, the agricultural AI market was valued at $ 518.7 million in 2017. Moreover, this figure is expected to increase by a yearly average of 22.5% or more. AI used in agriculture has great potential for the future.

- ***The Future of AI in Agriculture: Meeting Global Food Security Challenges by 2050***

Certain AgTech solutions are built basically for increasing productivity. By using the latest in machinery, ICT tools, G.I.S, and other design management systems to create optimal design farms, they could achieve higher productivity with less human strain. Public help with autonomous field navigation, data collection, reporting as well as monitoring farm health helps to increase productivity. They let farmers focus on growing-related decisions. Farmers can make data-driven decisions with detailed farm operations report and seasonal history which increases profit while reducing cost and increasing productivity Monarch's Wingspan Ag Intelligence (WingspanAI) technology, for instance, provides daily reports on time, rows, and areas. You can even check tractor operating history for complete visibility, improving efficiency.
Working on the farm is not as easy as it seems. With tonnes of heavy machinery and a lot of physical work safety is key in agriculture. Agriculture is one of the most dangerous jobs with hazards like pesticide exposure, tractor rollovers, PTO entanglements, and exposure to the elements. The US had data in 2019. The United States has the most dangerous job sector of all, agriculture, which has a rate of 23.1 deaths per 100,000 workers. Most agricultural accidents involving tractors happen due to rollovers as well as the leading cause of casualties in

agriculture. With the use of agricultural technology, there is a possibility of reducing these risks as much as possible. For example, the MK-V tractor by Monarch has a camera placed above the hitch. The camera detects objects or people that are close enough to the tractor to be considered a risk. It stops the tractor and cuts power to the PTO. The MK-V has a lot of sensors and they give you slope measurements in real time and quickly alert you if a rollover is likely to happen. Fatigue is a hazard on the farm, but it's often overlooked. Due to a U.S. study, we know that farmers often work around the clock in the harvest season, with many working more than 40 hours a week. Bureau of Labor Statistics. Add that some farms have to work nights and there is a shortage of farm labor, and it's easy to see fatigue is a serious issue. According to the CDC, fatigue delay reactions and slows down judgment and concentration which makes things more likely to go wrong and increase the likelihood of accidents in farm work. Farming equipment's autonomous technology can help minimize direct involvement in risky environments and at dangerous hours by functioning 24 hours a day.

Sustainability in agriculture is of utmost importance. It can mean the economic viability of a farm, the healthiness of the farm, and the healthiness of the planet. AgTech offers solutions that help growers to meet consumer demands and with energy savings that don't harm environmental health.

Precise farming ensures that farm inputs are used efficiently, reducing waste and environmental impacts.

- ***Increasing farming productivity.***

AgTech is more than the sum of its parts. It is changing farming from the ground up and bringing us closer to a future of more productive, sustainable, and resilient farming. It is a major field whose core has always been traditions yet looks forward in time and changes. Start of paraphrase

Innovative and practical AgTech companies such as Monarch Tractor are showing us that the farming future is not just about what we can do with technology but how we can do more for ourselves, our community, and the Earth.

End of paraphrase As we move into this new age of agriculture, it's evident that technology is paving the way for an exciting future. New agricultural technologies will make farmers, industry professionals, and consumers to look out to a future where agriculture will be sustainable and efficient.vff

- ***AI projects used in agriculture.***

Several initiatives are launched by companies across the globe regarding the use of AI in agriculture. The innovations that have resulted are of several kinds. Here are the most important ones. Plantix is an app that uses "deep learning" methods to analyse the image of a crop foliage and provide farmers with information about soil quality, pests and diseases. The app has been developed by the Berlin start-up PEAT. An AI-powered application developed by a French startup for assessing crop health and prediction of risks to yield. Prospéra is an Israeli start-up using AI to measure how much water a plant needs for optimal growth. Smag has created software programs that helps farmers manage their data in order to improve the yield and optimize production. The See & Spray Robot is a smart robot developed by Blue River Technology that can detect weeds using AI and spray herbicide on them. A U.S. company that has developed a robot that picks and packs strawberries.

Sensors attached to a smartphone app collect real-time information about the soil, such as moisture, in Texas. The app combines this with the weather for an AI-powered analysis which issues watering recommendations. The recommendations are sent to mobile devices of farmers to help in efficient deployment of water resources to improve growth of crops in areas affected by drought and climate change.

Cloud-based solution that ingests information from weather forecasts and satellite imagery, as well as sensors to measure vine pressure, has been implemented by a winery in California where efficient use of water is also a major concern. The analysis of data helps to make a watering recommendation specific to individual vines. After using the answer, the production got improved by 26% while water consumption got reduced by 16%.
In Kazakhstan's Almaty region, a five-hectare “smart greenhouse” uses IoT and AI for optimum agriculture. These technologies enable monitoring of conditions within the greenhouses and automatically adjusting temperatures, light, humidity, and the irrigation system to create a suitable growing environment.
In the UK, researchers are using sensors attached to cattle on dairy farms to track how much activity they do - steps taken and how long they spend eating and lying down. Because more active cattle typically show more positive behavior, the information can help farmers tell whether an intervention is required – for example, changing the animals’ surroundings to make them happier, which usually boosts milk yields.
These are all AI projects for agriculture by various companies. High tech and sustainable farming is already changing the food industry.

- ***How IoT Affects the Farming Cycle.***

The farming cycle was simple and easy in the old times. Even though IoT and smart farming may alter this cycle, they will not change it much. IoT’s purpose is to collect data and information which gets sent to another device via the Internet.
To control these problems, IoT sensors flag issues immediately, thus giving the farmers a clearer window to act on the issues. In the smart system, the farming cycle will occur like this in an IoT or smart system.
The soil moisture sensors and other devices monitor various parameters such as temperature, moisture of soil among other parameters. From there, it records the data it observes.
The internet is a thing, that will decide what is the best thing to do next when data is sent. These software systems have a very complex algorithm that can dictate the best action based on the observation.
At this point, the IoT platform will decide on the best course of action based on the data. A human or a machine-learning system can carry out this task. The action and its nature may also be determined by the AI IoT Platform and the user together so that it becomes unnecessary.
Once the decision has been taken, the action that is in question has to be done. This job can once again be done by a fleet of robots, autonomous machines, humans or a mixture of all three.
AgTech is important as it helps machinery and advanced technology used in agriculture in a modern context. As the World’s populations grow, demand for food production grows. At the same time, available arable land is shrinking. AgTech will play a vital role in the future of agriculture as the global population continues to grow in the coming years, putting pressure on food production. Its technology can help make more food with less land and hence increase productivity. Also, farmers will make necessary changes to be the best of their ability whether it is caused by weather or demand. AgTech technology can help with the transition to more renewable practices through innovations and solutions capable of reducing the agriculture sector’s environmental footprint. Farmers have an opportunity to embrace a basket of tools and approaches – from reducing carbon emissions and water use to protecting soils, biodiversity and key pollinators – to become greener. AgTech allows farmers to take charge of their operations with increased independence. Above all, the safety and productivity of work reduce the need for inputs such as diesel, herbicides and pesticides.
In other words, it gives a lot of precision and insight to farmers to make them work smart rather than hard and to help them keep up with the changing world and sustain their profession.

Internet of Things (IoT) applications in agriculture encompass a wide range of functions, each contributing to the enhancement of farming practices. Precision farming and irrigation monitoring & controlling share the lead with 16% each, emphasizing the importance of precise resource management in agriculture. Soil monitoring follows closely at 13%, ensuring optimal soil conditions for crop growth.Temperature and humidity monitoring hold 12% and 11%, respectively, aiding in climate control and crop health assessment. Animal monitoring & tracking, also at 11%, facilitates livestock management and welfare. Water monitoring & controlling is at 7%, helping in efficient water resource utilization. Air monitoring and disease monitoring each account for 5%, addressing environmental and health factors. Finally, fertilization monitoring makes up 4%, emphasizing the significance of balanced nutrient management. This diverse range of IoT applications underscores their critical role in modernizing agriculture, from precision farming to environmental sustainability and overall farm efficiency.

6. Different IoT Smart Farming Solutions.

- ***Agricultural Drones.***

Drones used in agriculture have improved a lot recently. To begin with, drone technology has become more available, handy and effective. As a result, advanced technology ensures farmers will soon be able to take a bird's-eye aerial view of an area using agricultural drones. Farmers can use these drones to do work more conveniently and efficiently, thereby impacting the entire working of agriculture greatly.
Farmers can use drones to gather information about temperature, humidity, environment and soil too nowadays. Smart farms make use of huge data sets, the accuracy of which will determine the right course of action.

- ***Precision Farming.***

Precision farming is another area of smart farming. The reliance on the huge datasets able to best determine what crops to plant and how it has led to the emergence of this type of system and how to do it most efficiently.
Keen on Environment are Sustainable farming system. Use of Data in Design and implementation of farming system.

- ***Automation.***

Smart farms all over the world are also growing through automation. A good example would be the use of sensors which collect data on soil, temperature, humidity, and atmosphere. These sensors send data over the internet, which allows you to see the situation on your smartphone while also being notified if you need to take urgent action.
This helps managers make more precise decisions about appropriate fertilizer amounts, nutrient needs, and more. This level of precision is unprecedented in agriculture.
Automation is also used in autonomous machines. These devices can be automated to carry out certain activities at precise intervals, like watering, manuring, sowing and more. It cuts down on human work as well as the resources to sow varied crops.

- ***Agricultural Robotics makes precision agriculture tasks possible.***

As reported in 2020 by the Food and Agriculture Organization of the United Nations, in total 690 million people that is 8.9 per cent of the world's population is suffering from hunger. In order to feed nearly 9 billion people by the year 2050, the earth will have to produce roughly 70% more food than it does today. Robots are intelligent machines designed to carry out a range of specialised tasks, starting from data processing to decision-making and taking action. They

ISSN: 2658-8455
Volume 6, Issue 6 (2025), pp. 668-685.

are necessary in fields that would normally require labor and workload reductions. In particular, they would be appropriate for jobs that require repeatable accuracy and high output under stable conditions (Holland and Nof 2007).

Nonetheless, robots cannot deal with ill-defined, unknown, changing and unpredictable events (Moysiadis et al. 2020). Agricultural applications of automation and robotics require advanced technologies to work in complex and highly variable environments and produce, unlike industrial applications which deal with simple, repetitive, well-defined, and predetermined tasks (Nof 2009).

The ability to have agricultural robots perform an assortment of agricultural tasks has widely been approved. Yet, in spite of this extensive research, there are currently no commercial applications of robots in complex agricultural environments (Urrea and Munoz 2015). The attempts at using robotic applications in variable field environments are still under development (Bac et al. 2013).

Production inefficiency and doubt about the economic justification are the key limitations. In order to succeed commercially, an agricultural robot must be able to perform its job with a high level of competency. In other words, in order to be successful as a robot in the agricultural sector. An agricultural robot must be able to learn to be robotically operative on a commercial farm. In order to robotically assist with the planting, cultivating, or harvesting. In agriculture, the environment is very unstructured and requires the movement of robots unlike that of machines in a factory or vehicles in a parking lot (Canning et al. 2004). It varies with time and space, environmental conditions being hostile and requiring mobile operation over changing three-dimensional paths. The surrounding conditions affect the mobility of a mobile robot (Dahl et al. 2011). Above or below the ground, there might exist obstacles (Gat et al. 1999).

One can compare the weights of products from different domains (agriculture, others) based on the coefficient of variation (CV, the standard deviation of the product population weight over the mean of the product population weight) of a given product population (Bechar and Vitner 2009). The analysis reveals that the CVs are low (0.01-0.05) for metal, plastic and rubber products, and 0.07 for processed wood products. Low CV Values Indicate a Narrowed Population Distribution with Low Variability Flower cuttings are an agricultural product with a significantly larger CV than those of metal, rubber, or plastic products which have CVs below 0.07 or 0.05. The complex and diverse growing and production processes in agriculture are labour-intensive and usually unique to each crop.

Farmers planning crop production must consider optimum production schedules and their cost and trade-off implications. Such planning reflects the significance of the presence of a hierarchy in production inputs or variables that require performance optimization. The technology, equipment, resources needed for the performance of one agricultural task involving one crop in one environment will not necessarily be applicable to the performance of another agricultural task involving another crop in another environment.

The shortcomings of sensor technologies further hinder the functionalities of autonomous robots. As a result, automatic and efficient operations by autonomous and unmanned vehicles have not lived up to expectations in unstructured and complicated environments. The hazards of sensor technology further limit autonomous robotics capabilities. Thus, the promise of automatic and efficient autonomous operation in unstructured environments with complex objects is not delivered.

Also, the automated system must not only be simple, but its cost must be justified economically and not exceeded the value of the product. Also, Agriculture is Seasonal, Therefore, Utilization of Agriculture is not as High as Manufacturing. It takes complex agricultural surroundings combined with intensive production robust systems short development time low cost (Nof 2009). Agricultural sector utilization cannot attain the high level possible in the manufacturing sector due to seasonality. If the technical and economic feasibility of most applications does not reach in the short term, using existing knowledge and technologies, the partial autonomy will already add value to the machine long before autonomous robots become fully available. For many tasks, the Pareto principle applies. According to Stentz et al. (2002), 80% of robotic or automation task is easy to adapt, whereas 20% is hard.

So, by automating the easy parts of a task, you can reduce the hard effort by 80%. Moreover, partially autonomous robots are an excellent intermediate step towards the development and testing of software and hardware elements to be integrated in fully autonomous systems. Precision agriculture, or PA, started about forty years ago.

Research and practices involving precision agriculture have been directed towards fulfilling four demands - increasing agricultural output, increasing product quality, decreasing production costs and decreasing environmental impact. The major beneficiary of variability that characterizes agriculture is precision agriculture. They plan to make use of space differences through high-resolution decision-making that ends down to the single-plant level and apply variable-rate operations to maximize total field revenue and minimize total cost. The relevance of precision agriculture is due to the variable nature of agriculture. However, till recently, research in the areas of agricultural robotics and precision agriculture has advanced along parallel lines with very limited interaction, relationship or reference among the two research fields. Beginning with the development of integrated approaches and operating concepts of robotics and precision agriculture, the development of an agricultural robot to carry out a precision agriculture task must include the development of sophisticated and intelligent algorithms for sensing, planning and control as well as decision-making algorithms to deal with the difficult, unstructured and dynamic environment and the specificity of precision agriculture tasks. The agricultural sector is marked by three distinctive features; namely, the high level of product variation, the degree of structure of the environment and system costs, which can be considered as dimensions in a domination space. The agricultural industry has a high degree of product variation, low levels of structure, and low cost demands. This shows the holes to be filled and the problems of agricultural robotic systems, and of precision agriculture in particular. Robotics operates in a different area, typically involving limited product variation, well-organized environments, and reasonably priced goods. One way to narrow the gap may be to develop concepts and approaches better suited to precision agriculture tasks, for example, drawing on lateriels, f focusing on a precise task, and including the human operator in the robotic system, simplifying robotic systems by establishing a team robots, etc. Chapter 7 and 8 discuss this concept in further detail. presents the relative research effort in agriculture, robotics, precision agriculture (which includes precision agriculture and precision irrigation), agricultural robotics (AR), and robots for precision agriculture (ARPA) over the last five years. Simply put, the normalized frequency shows the “normalized frequencies” of the main keywords through correlation between the topic and keyword. For instance, the topic “medical cannabis” (with all its derivatives: weed, seeding, etc.) generates a value of 14.2. On average, the appearance of this keyword in articles related to ARPA domain is 14.2% and is probably connected to the precision agriculture task of weed detection, distribution, or control. The key themes (the “normalized frequency” i.e. the number of times the terms appear divided by the number of articles on the same theme) highlighted by the analysis indicate that the major keywords related to “farming operations” in ARPA domain are weed, harvest, fruits, spraying and phenotyping which appear on an average in 14.2, 7.3, 4.7, 4.7 and 4.3% articles respectively. The average usage of the keywords farm, field, crop, plant and fruit in articles related to ARPA field is 11.2, 5.2, 7.7, 6 and 4.7% respectively.

7. Empirical Review

7.1. The Rise of AI and IoT in Agriculture

Different studies have looked into both farmers and agribusinesses to understand the drivers behind adoption of smart farming technologies.
Klerkx et al. (2019) carried out surveys and interviews with European farmers were found adoption highly reliant on perceived economic benefit, ease of use, and availability of training programs. Results confirmed the Technology Acceptance Model (TAM) showing that users are more inclined adopting technologies when it is useful and easy to navigate.
Farmers' propensities toward using technology was also explored over a wider region by Okonkwo et al., 2021 where they studied sub-saharan africa examining willingness towards accepting AI pest detection systems supporting the diffusion of innovation theory insight particularly noting its deployment cost, digital infrastructure access, and trust in an AI's advisory role as major contributors under convenience/compatibility framework along with trialability being crucial factors for significant impact integration.

7.2. Effects on Crop Production and Resource Utilization

The researchers examined several farms located in Spain and Israel Kamilaris et al. (2018)added IoT based irrigation systems with AI optimization algorithms. The findings supported the application of these algorithms as they showed an increase from 20 – 30% in terms of water usage efficiency alongside a 10%-15% improvement in crop yield.
In another study, Liakos et al. (2018) conducted a systematic review containing more than 50 empirical studies AI applications including machine learning for predicting crops and computer vision for disease detection . According to their findings these applications turned out to provide enhanced accuracy along with improvements in forecasting yields and reduction of costs associated with labor significantly.

7.3. Agribusinesses Economic and Strategic Advantages

In a seminal contribution Wolfert et al. (2017) about agribusinesses based on a data-driven platform, organizations combining AI and IoT reached higher profit margins, achieved better supply chain visibility and improved customer satisfaction as real time tracking of the product and predictive logistics.
for Indian agritech startups, Gandhi and Khurana (2022) show that AI enabled platforms allowed small agri-enterprises to decrease post-harvest losses by up to 25% in large part thanks to predictive storage planning and intelligent distribution management. This is consistent with the Value Chain Theory of Porter—by technology applications facilitate all stages of the agricultural operation.

7.4. Challenges in Implementation

However, although essential role of the AIoT in agriculture has been demonstrated, there are still challenges on the ground when some researchers have put smart farming and solution to empirical testing. Rose et al. (2021) reported that smallholder farmers in UK and Kenya also have some challenges such as the high initial cost of investment, lack privacy and security concerns, lack of expertise (in technology). In addition, mistrust of AI-generated advice among farmers indicates a 6. Need for better education and participatory design.
Aravind and Krishnan (2020) looked at case studies of unsuccessful smart farming pilot projects and found that the inadequate interoperability of different IoT devices and little or no government support contributed to poor outcomes.

7.5. Environmental and Sustainability Outcomes

Zhang et al. (2020) conducted an empirical analysis and found that AI guided precision farming systems can and have reduced nitrogen fertilizer use by 18%, and pesticide use by 22%, while also sustaining yield or in some cases, increasing yield. These are relevant to environmental objectives, as they will reduce environmental runoff and improve soil health.
Similarly, research conducted in Italy by Bacco et al. (2019) in a longitudinal study, found that eliminating IoT based weather forecast, weather status updates, and soil moisture monitoring led to functional, and sustainable decisions around farming practices and use of technologies particularly during drought conditions.

8. Conclusion

AI in Moroccan agriculture is a way to make agriculture more productive and economically sustainable and resilient. Morocco's agricultural sector remains a backbone of its economy. Therefore, using advanced AI-driven solutions can lead to more efficient resource management, better crop yields, and greater climate change adaptability.
Moroccan farmers can maximize profits by using machine learning algorithms, IoT (Internet of Things), and big data to get real-time information on soil, weather and pest control. What are the benefits of using Artificial Intelligence in agriculture? (20 words) These technologies enable precision farming, which minimizes waste and maximizes output by ensuring optimal use of water, fertilizers, and pesticides. Predictive analytics can also help farmers foresee profit losses, and more wise market decisions to grow and distribute the most suitable crops. In-spite of these potentially ideal, aforementioned challenges need to be faced for implementing AI successfully. Important obstacles for farmers to access AI include the gap in technology devices, access to training and being able to afford advanced tech. In addition, AI also focuses on the social and economic impact of jobs opportunities on AI adaption. For example-job displacing issues and traditional practices of farming organisations etc. To create a system of agriculture that is innovative and sustainable, research and other activities to plug these knowledge gaps will be necessary. By working together, the government, universities, and businesses can build AI systems that suit Morocco's agricultural needs. Future research should close these gaps on how to use AI in existing farming systems and how to improve farmers' digital literacy. In doing so, Morocco can help combine the technology with its own plantation goods in environmentally friendly and socially sustainable way.

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