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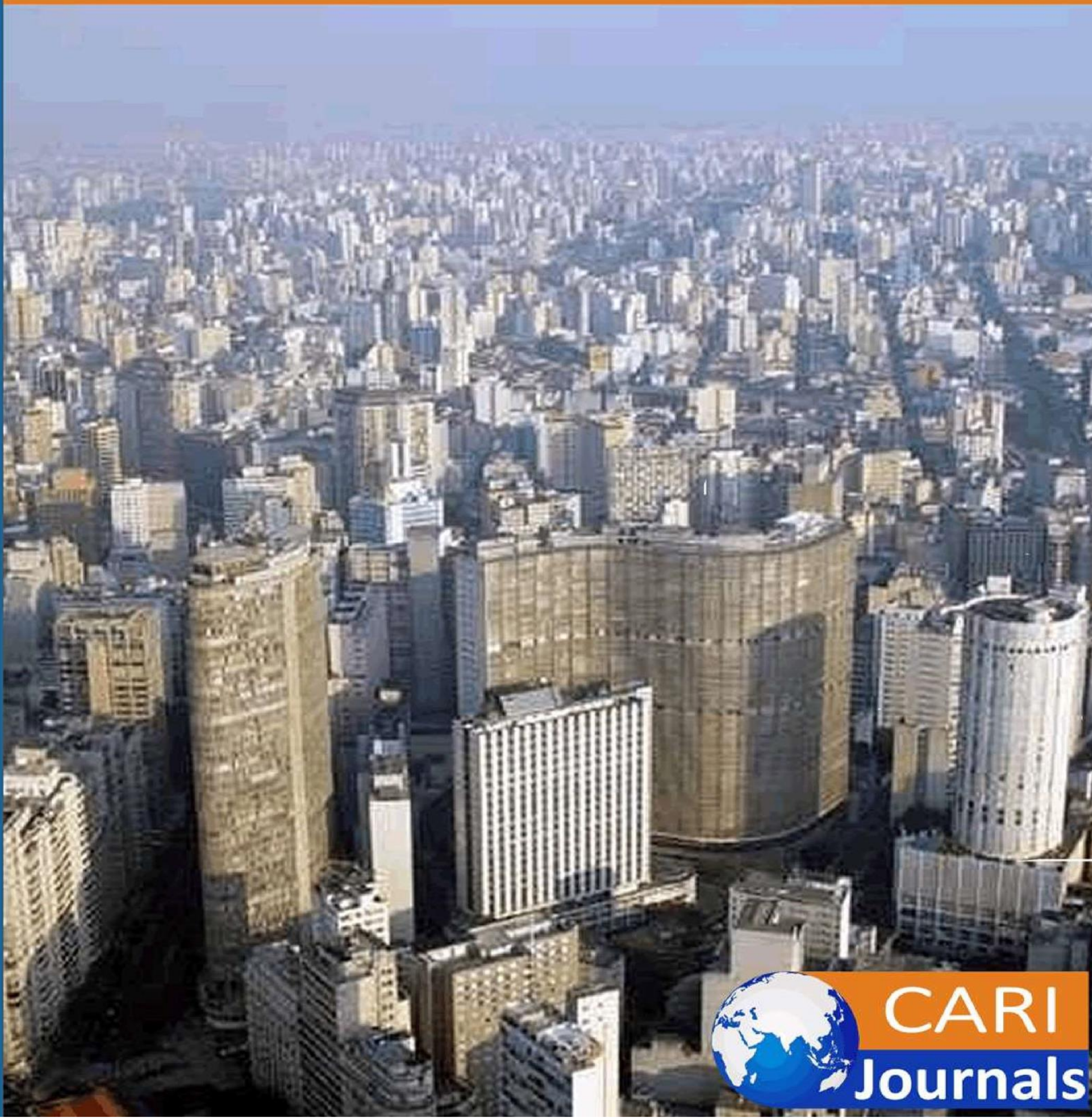

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The Internet of Things (IoT) in Farming: Smart Solutions for a Sustainable Future

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Abstract

The rapid integration of the Internet of Things (IoT) in agriculture is revolutionizing farming practices, offering smart, data-driven solutions to address global challenges like food insecurity, resource inefficiency, and environmental degradation. This paper explores the transformative role of IoT in precision agriculture, livestock management, and the development of agriculture hubs worldwide. Drawing on global case studies, the study highlights the tangible benefits of IoT, such as a 25% increase in crop yields, 30% reduction in water usage, and improved animal health and traceability. It emphasizes the synergy between IoT, AI, robotics, and blockchain in shaping future farming systems. Countries like India, the Netherlands, and Brazil are showcased as leaders in deploying IoT-enabled solutions for both smallholder and large-scale farming operations. While technological, infrastructural, and financial barriers remain especially in developing regions interventions by organizations like FAO and the World Bank are helping to bridge these gaps. The research underscores the need for increased investment in IoT-driven agriculture to ensure long-term sustainability, food security, and environmental stewardship. Thus, the paper concludes that IoT is not just an innovation but a necessity for the evolution of global agriculture in the face of growing population demands and climate change.

Keywords, *Internet of Things (IoT)**,** Precision Farming**,** Smart Agriculture**,** Livestock Management**,** Sustainable Farming Practices*

Introduction

The Internet of Things (IoT) is transforming agriculture by providing advanced tools to solve key challenges in farming. With the global population expected to surpass 9.7 billion by 2050, food production needs to increase without harming the environment (Morchid et al., 2024). Traditional farming methods, which rely on manual work and high resource usage, are unable to meet these demands. IoT, through its data-driven approach, is recognized as a game-changer that increases efficiency, reduces waste, and improves productivity. IoT technologies, such as sensors, drones, and cloud systems, connect devices to collect and share real-time data across farms(Duguma & Bai, 2025). This allows farmers to monitor and manage important aspects like soil moisture, crop health, and weather conditions. For example, precision irrigation systems that use IoT deliver water exactly where it is needed, cutting down waste and conserving water. These technologies are not just theories that they have been proven effective in various agricultural projects around the world. The role of IoT goes beyond improving farm operations and it is also important for sustainability and global food security (Rajak et al., 2023). By making supply chains more transparent, IoT reduces food waste, which is a big problem contributing to environmental damage. IoT also helps track food origins, giving consumers' confidence in the quality and ethical production of their food. Many projects globally have shown IoT's ability to reshape agriculture, making it crucial for a sustainable future. This report discusses the use of IoT in farming, including its role in precision farming, livestock management, and global agriculture hubs. The findings show how IoT is helping to create a smarter and more sustainable farming industry.

Purpose

The purpose of this paper is to examine how the Internet of Things (IoT) is reshaping agriculture by improving productivity, sustainability, and resource management through smart farming technologies. It explores the application of IoT in various agricultural contexts and its potential to address food security and environmental challenges.

Methodology

This research employs a qualitative review methodology, synthesizing secondary data from peer-reviewed articles, institutional reports, and global case studies on IoT applications in agriculture. The study examines literature from diverse geographic contexts to assess the impact of IoT on precision farming, livestock management, and the development of agricultural hubs. Data were also sourced from authoritative organizations like the FAO (Rajak et al., 2023), USDA (Rajak et al., 2023), and academic analyses like Duguma & Bai (2025) and Marinello et al. (2023), who detailed smart farming implementations. Country-specific examples, such as India's PFDCs (NITI Aayog, 2024), Brazil's Agro IoT hubs (Lima et al., 2021), and the Netherlands' smart greenhouses (Sharma et al., 2023), were used to compare adoption strategies. This comparative approach enables a comprehensive understanding of IoT's effectiveness across farming systems. The analysis draws conclusions based on reported improvements in yield, resource efficiency, and animal health, alongside challenges in adoption. The methodology supports an in-depth exploration of IoT's transformative role in agriculture while identifying areas for further research and investment.

The Role of IoT in Modern Farming

The Internet of Things (IoT) has become a cornerstone of modern farming, addressing critical challenges in agriculture through advanced technology. By connecting devices and systems, IoT provides farmers with accurate, real-time data that significantly improves efficiency, productivity, and sustainability. Studies confirm that IoT is reshaping traditional farming methods and driving a new era of precision agriculture. One of the key roles of IoT in farming is its impact on resource management. Awan et al. (2019) has shown that agriculture accounts for approximately 70% of global freshwater use, much of which is wasted due to inefficient irrigation. IoT-based systems, such as soil moisture sensors, have proven effective in reducing water wastage. For instance, a study published by the International Water Management Institute demonstrated that smart irrigation systems could reduce water usage by up to 30% while still improving crop yields(Sharma et al., 2023). These systems monitor soil conditions in real-time and ensure water is delivered only when needed, conserving this essential resource.

IoT also enhances productivity through precision agriculture, which relies on data to optimize farming practices. According to Ramadevi et al. (2022), precision agriculture can increase crop yields by up to 25%. IoT tools such as drones and satellite imaging collect detailed data on soil health, crop conditions, and pest infestations. This data allows farmers to target specific areas of the field, applying fertilizers or pest control only where necessary. The result is healthier crops, lower costs, and minimized environmental impact. Automation is another critical contribution of IoT to farming. Smart machinery, equipped with GPS and IoT sensors, can perform tasks such as planting, harvesting, and even weeding with greater accuracy than traditional methods(Sharma, Sharma, Tselykh, Bozhenyuk, Choudhury, Alomar, et al., 2023). A case study from John Deere, a leader in agricultural technology, showed that IoT-enabled tractors reduced planting errors by 90%, ensuring consistent crop rows and better yield outcomes(Deere, 2022). Such advancements also help address labor shortages, which are a growing concern in many agricultural regions.

The ability of IoT to monitor environmental conditions is vital for farming, given the unpredictability of weather and climate. IoT weather stations provide farmers with real-time updates on temperature, humidity, and rainfall (Awan et al., 2019). This data helps farmers make informed decisions, such as adjusting planting schedules or protecting crops from extreme weather. IoT also plays a key role in improving food quality and safety. Traceability systems, enabled by IoT, allow farmers and producers to track the journey of agricultural products from the farm to the consumer. According to Zerihun et al. (2022), IoT-based traceability systems have reduced food spoilage during transportation by 20%. Sensors monitor conditions such as temperature and humidity, ensuring that produce remains fresh and meets safety standards. Sustainability is a central focus of IoT in farming by optimizing the use of resources such as water, energy, and fertilizers, IoT reduces the environmental footprint of agriculture. Raj et al. (2021) *Nature*

Sustainability highlighted that smart farming practices could reduce greenhouse gas emissions by 15%. These practices also promote soil health, ensuring long-term agricultural productivity.

Evidence from various countries highlights the success of IoT in modern farming. In the Netherlands, IoT technology is widely adopted in greenhouse farming, where sensors control temperature, light, and humidity(Sharma, Sharma, Tselykh, Bozhenyuk, Choudhury, Abdu Alomar, et al., 2023). This approach has resulted in increased yields while reducing energy consumption. In Australia, IoT-enabled systems have helped livestock farmers monitor animal health and prevent diseases, contributing to more efficient and sustainable livestock management (Shahab, Iqbal, Sohaib, Ullah Khan, et al., 2024). Thus, the role of IoT in modern farming is transformative by enabling precision agriculture, improving resource management, automating tasks, and enhancing sustainability, IoT addresses the shortcomings of traditional farming practices. Its proven effectiveness across different regions and farming systems underscores its potential to revolutionize agriculture and ensure a secure, sustainable food supply for the future.

Adoption of Agriculture Hubs by Countries Worldwide

The adoption of agriculture hubs, enhanced by IoT technology, has gained momentum globally as countries prioritize efficient and sustainable farming systems. Agriculture hubs refer to centralized networks where IoT solutions are implemented to support farmers in accessing real-time data, modern tools, and shared resources. These hubs have become key drivers in transforming agriculture, especially in regions facing resource constraints or climate challenges. In India, agriculture hubs equipped with IoT technology have shown remarkable results in improving farm productivity (Shahab et al., 2024). Government-backed initiatives such as the Precision Farming Development Centres (PFDCs) focus on integrating IoT devices to support small and medium-sized farmers. IoT-enabled weather monitoring systems and soil sensors within these hubs allow farmers to make informed decisions about irrigation and planting schedules. India's National Institution for Transforming India (NITI Aayog) states that farms connected to these hubs have witnessed a 20–25% increase in crop yields due to better resource management (NITI Aayog, 2024).

The Netherlands has emerged as a global leader in smart farming, with its agriculture hubs recognized for their advanced use of IoT (Klerkx et al., 2019). Greenhouses in the Netherlands are equipped with IoT systems that control temperature, humidity, and lighting automatically. The World Bank reported that these hubs reduced energy usage in Dutch greenhouses by 30% while increasing crop yields significantly (Rehman et al., 2024). These hubs have also facilitated collaboration between farmers, researchers, and technology providers, leading to continuous innovation and improvement in agricultural practices.

In Africa, agriculture hubs are being used to support smallholder farmers who account for 70% of the region's food production (Choruma et al., 2024). Kenya, for example, has introduced IoT-based agriculture hubs to tackle water scarcity and low productivity in arid areas. Through these hubs, farmers can access irrigation systems powered by IoT sensors, which optimize water distribution. According to Choruma et al. (2024) the African Development Bank highlight that such hubs have improved water use efficiency by up to 40%, helping farmers grow crops even in drought-prone regions.

China has embraced agriculture hubs to modernize its farming sector and address the challenges of feeding its large population. The Chinese government has invested heavily in IoT-powered farming hubs, particularly in areas specializing in rice and wheat cultivation (O'Shaughnessy et al., 2021). These hubs provide IoT tools that track soil quality, pest activity, and crop growth. A study published by the Chinese Academy of Agricultural Sciences reported that IoT adoption in these hubs has increased rice yields by 15% and reduced pesticide use by 20%, contributing to both productivity and environmental sustainability (O'Shaughnessy et al., 2021).

In the United States, agriculture hubs are being established to promote precision farming and improve supply chain traceability (Naik & Suresh, 2018). IoT devices within these hubs monitor the production process, ensuring that high-quality produce reaches consumers. In California, a hub focusing on fruit and vegetable farming has implemented IoT systems to track temperature and humidity during transportation. According to the U.S. Department of Agriculture (USDA), this initiative has reduced post-harvest losses by 25%, benefiting both farmers and consumers (Naik & Suresh, 2018).

Agriculture hubs are also playing a significant role in Latin America, where countries such as Brazil are leveraging IoT for large-scale farming operations (Lima et al., 2021). Brazil's "Agro IoT Hubs" have demonstrated success in improving soybean and sugarcane production. These hubs provide farmers with access to satellite data, IoT sensors, and machine learning models to optimize planting and harvesting schedules. Reports from the Brazilian Agricultural Research Corporation (Embrapa) show that these hubs have boosted productivity by 18% while reducing fertilizer use by 15%(Lima et al., 2021). However, limited access to technology and funding poses obstacles for small-scale farmers in developing regions. However, international organizations like the United Nations Food and Agriculture Organization (FAO) are working to address these challenges by supporting the establishment of IoT-enabled hubs in underserved areas. For example, FAO-backed projects in Southeast Asia have provided farmers with subsidized IoT tools, resulting in improved productivity and food security.

Therefore, the adoption of agriculture hubs worldwide is reshaping farming by integrating IoT technology. Countries such as India, the Netherlands, China, and Brazil have demonstrated the potential of these hubs to enhance productivity, resource efficiency, and sustainability. While challenges persist, the global rise of IoT-enabled agriculture hubs signals a promising future for farming systems, ensuring that they remain resilient and capable of meeting the demands of a growing population.

Leveraging Technology in Precision Farming

Precision farming, supported by the Internet of Things (IoT), has revolutionized modern agriculture by enabling data-driven, accurate, and efficient farming practices. Precision farming focuses on optimizing resources and increasing productivity by applying advanced technologies such as sensors, drones, and big data analytics (Duguma & Bai, 2025). Evidence from numerous studies has established that precision farming is not only improving yields but also minimizing environmental impact. The foundation of precision farming lies in IoT-powered sensors that gather real-time data from the field. These sensors monitor critical factors like soil moisture, nutrient levels, temperature, and crop health. A report by the Food and Agriculture Organization (FAO) highlighted that farmers using precision agriculture systems saw a 20–25% increase in crop yields (Rajak et al., 2023). For example, soil sensors used in wheat farms in Australia allowed farmers to optimize fertilizer application, improving productivity while reducing costs.

One of the most significant advantages of IoT in precision farming is its ability to support targeted interventions. The farmers can create detailed maps of their fields, identifying areas where crops are under stress by using drones and satellite imagery (Duguma & Bai, 2025). According to research from the University of California, drone-based precision farming has reduced pesticide usage by 30% in some cases by targeting specific areas instead of blanket spraying (Morchid et al., 2024). This method ensures healthier crops while minimizing chemical use and its impact on the environment. Automation is a major feature of precision farming that reduces labor requirements and ensures consistent performance (Raj et al., 2021). Smart machinery such as GPS-guided tractors, planters, and harvesters perform tasks with high accuracy. A case study from the United States Department of Agriculture (USDA) reported that GPS-enabled tractors achieved near-perfect planting accuracy, increasing yields by up to 15% in maize fields (Rajak et al., 2023). Automation not only saves time but also helps farmers tackle labor shortages, a growing problem in agriculture worldwide.

Another key benefit of IoT in precision farming is improved irrigation efficiency. Agriculture accounts for 70% of global freshwater use, yet water wastage remains a significant problem (Bolaji et al., 2024). Precision irrigation systems equipped with IoT sensors deliver water exactly where and when it is needed. In India, the use of smart irrigation in sugarcane fields resulted in a 40% reduction in water usage, as reported by the Indian Council of Agricultural Research (ICAR) (Adewusi et al., 2024). Such systems are critical in regions facing water scarcity. Data analytics powered by IoT further enhances precision farming. Farmers can use predictive analytics to plan planting schedules, forecast yields, and manage risks (Marinello et al., 2023a). For example, IoT-based analytics used in rice farming in Japan allowed farmers to predict crop growth stages, improving harvesting efficiency. Big data from IoT devices also supports better decision-making, ensuring that farmers can respond promptly to challenges such as pest outbreaks or unexpected weather events.

Precision farming is also vital for sustainable agriculture. By optimizing resource use, precision farming reduces the environmental impact of farming practices. The European Environment Agency reported that farms using precision agriculture practices saw a 20% reduction in greenhouse gas emissions, as fewer resources were wasted (Kumar, 2023). Additionally, smart farming technologies promote soil health by avoiding overuse of fertilizers and chemicals, ensuring long-term productivity. Success stories from different countries highlight the potential of

IoT in precision farming. In Israel, IoT technologies have been applied in orchards to monitor tree growth and optimize irrigation. The Ministry of Agriculture and Rural Development in Israel reported that these technologies increased fruit yields by 25% while reducing water use by 35% (Adewuyi et al., 2024). Similarly, in Brazil, precision farming has been widely adopted in soybean production, where IoT-based monitoring systems have enhanced crop quality and profitability. The precision farming offers immense benefits but challenges remain in developing regions where access to technology and funding is limited. However, initiatives by international organizations, such as the World Bank and FAO, are helping to bridge this gap (Adewusi et al., 2024). Subsidized programs have introduced precision farming technologies to smallholder farmers in Africa and Southeast Asia, demonstrating significant improvements in productivity and income.

IoT in Livestock Management

The Internet of Things (IoT) is transforming livestock management by introducing advanced tools for monitoring, tracking, and managing animals. This technology enables farmers to improve productivity, ensure animal welfare, and maintain sustainability. The use of IoT in livestock management has been widely proven through various studies and projects, demonstrating its significant impact on modern farming (Lee et al., 2020). One of the most important applications of IoT in livestock management is real-time monitoring of animal health. IoT-powered wearable devices, such as smart collars and ear tags, collect data on vital signs, activity levels, and eating behavior. According to Saravanan & Saraniya (2018), these devices have helped identify health issues in cattle up to three days before visible symptoms appear. Early detection allows farmers to provide timely treatment, reducing losses caused by diseases and improving overall herd health.

Tracking livestock movement is another key benefit of IoT. GPS-enabled collars allow farmers to monitor the location of animals in real-time, preventing them from wandering into unsafe areas (Saravanan & Saraniya, 2018). This is especially beneficial for large-scale ranches and free-range farming systems. Bolaji et al. (2024) reported that GPS collars reduced livestock losses by 20% in remote grazing areas by helping farmers locate missing animals quickly and efficiently. IoT also enhances feeding management by providing precise data on animal nutrition. Automated feeders, connected to IoT systems, dispense the exact amount of feed required based on an animal's weight, age, and health status (Adewusi et al., 2024). In Denmark, dairy farms using IoT-based feeding systems saw a 15% increase in milk production (Kumar, 2023). These systems ensure that animals receive proper nutrition while minimizing feed wastage.

In addition to individual health and nutrition, IoT facilitates environmental monitoring in livestock farms. Sensors installed in barns measure temperature, humidity, and air quality, ensuring that the living conditions meet optimal standards for animal welfare (Lima et al., 2021). For example, in the Netherlands, pig farms equipped with IoT sensors have significantly reduced the occurrence of respiratory diseases by maintaining proper's ventilation. Traceability and food safety are other critical areas where IoT is making a difference. IoT ensures transparency in the supply chain by tracking the entire lifecycle of livestock, from birth to processing. Sensors and tracking devices record data on breeding, feeding, and medical treatments, which can be accessed by consumers and regulatory authorities (Lee et al., 2020). This level of traceability is essential for meeting food safety standards and boosting consumer confidence. The European Food Safety Authority reported that IoT-enabled traceability systems reduced cases of foodborne illnesses linked to livestock by 18% in monitored regions.

IoT technology is also helping to address sustainability concerns in livestock management. Methane emissions from livestock are a significant contributor to greenhouse gases. IoT systems monitor methane levels and provide insights into feeding practices that can reduce emissions. Bolaji et al. (2024) found that IoT-based solutions helped reduce methane emissions from cattle by 12% on monitored farms in Canada. These technologies play a crucial role in aligning livestock farming with global sustainability goals. Several countries have demonstrated the success of IoT in livestock management (Rehman et al., 2024). In New Zealand, IoT-enabled tracking systems are widely used in sheep farming to monitor grazing patterns and optimize land use. Farmers reported a 20% improvement in pasture management, resulting in healthier sheep and better wool quality (Marinello et al., 2023a). Similarly, in Brazil, large-scale cattle farms have adopted IoT systems to monitor health, location, and feeding, leading to increased productivity and profitability.

The adoption of IoT in livestock management faces challenges, such as high costs and the need for technical expertise. However, governments and organizations are working to address these barriers (Rehman et al., 2024). For instance, the African Development Bank has launched initiatives to provide subsidized IoT devices to livestock farmers in developing countries, enabling them to improve their practices and outcomes (Klerkx et al., 2019). Thus, IoT is revolutionizing livestock management by offering innovative solutions for health monitoring, feeding, environmental control, and traceability. Evidence from various regions highlights the effectiveness of these technologies in improving productivity, ensuring animal welfare, and promoting sustainability. As IoT continues to evolve, it is set to play an even greater role in shaping the future of livestock farming.

Future Trends in IoT Agriculture and Smart Farming

The future of agriculture is being shaped by advancements in the Internet of Things (IoT) and other emerging technologies. IoT is expected to play an even more significant role in addressing global challenges such as climate change, resource scarcity, and food security (Duc Ha et al., 2023). Future trends point to greater integration of IoT with artificial intelligence (AI), blockchain, robotics, and advanced sensors, creating a smarter and more sustainable agricultural ecosystem. One of the key trends is the integration of IoT with artificial intelligence (AI) for predictive analytics and decision-making (Marinello et al., 2023). IoT devices generate vast amounts of data from farms, including weather conditions, soil health, and crop growth. AI algorithms analyze this data to provide accurate predictions and recommendations. According to Baumüller (2017), AI-powered IoT systems can increase crop yields by up to 25% by enabling better planning and risk management. For instance, farmers can use AI to predict pest infestations and take preventive measures, reducing losses and ensuring healthy crops.

Blockchain technology is another emerging trend that is transforming supply chain transparency in agriculture. By combining IoT devices with blockchain, farmers can create secure and transparent records of agricultural products (Lee et al., 2020). This ensures traceability from farm to table, meeting consumer demands for ethical and sustainable food. A study published by the International Food Policy Research Institute (IFPRI) highlighted that blockchain-IoT systems reduced fraudulent practices in the supply chain by 30%. Such systems also improve efficiency by streamlining processes like inventory management and payment transactions (Saravanan & Saraniya, 2018). Robotics is becoming an integral part of IoT agriculture, particularly in labor-intensive tasks such as planting, weeding, and harvesting. IoT-enabled robots equipped with cameras and sensors can operate autonomously, increasing efficiency and reducing labor costs. In Japan, strawberry farms have adopted robotic harvesting systems that use IoT technology to identify ripe fruits with high precision.

Advanced sensors and remote monitoring tools are expected to become more sophisticated in the future. These devices will provide farmers with even more detailed data, such as detecting early signs of crop diseases and monitoring soil nutrient levels at a micro level (Bolaji et al., 2024). The European Commission has identified IoT-enabled nutrient management systems as a priority for achieving sustainable farming practices. Pilot projects in Europe have demonstrated that such systems can reduce fertilizer use by 20%, minimizing environmental impact while maintaining high productivity (Adewusi et al., 2024). IoT technology is also likely to expand its applications in climate-smart agriculture. Climate-smart farming focuses on adapting to and mitigating the effects of climate change. IoT weather stations and climate models will provide farmers with accurate forecasts and actionable insights, helping them make informed decisions. For example, in sub-Saharan Africa, IoT-based climate tools are being tested to assist farmers in coping with erratic rainfall patterns (Marinello et al., 2023). Early results indicate that these tools can improve crop resilience and reduce losses caused by extreme weather events.

Vertical farming, supported by IoT, is gaining attention as a solution to urbanization and land scarcity. Vertical farms use IoT systems to control lighting, temperature, and nutrient delivery in indoor environments. A study conducted by the University of Arizona found that IoT-enabled vertical farms produce 70% more food per square meter compared to traditional farms, with 90% less water usage (Kumar, 2023). This approach is particularly valuable in urban areas, where space is limited, and demand for fresh produce is high. Another promising trend is the development of IoT-powered smart greenhouses (Kumar, 2023). These greenhouses use sensors and automated systems to create optimal growing conditions for crops. In the United Arab Emirates, smart greenhouses equipped with IoT technology have successfully grown vegetables in desert environments.

However, challenges such as high costs, data privacy concerns, and limited infrastructure in developing regions must be addressed. Governments, private sectors, and international organizations are working to overcome these barriers (Morepje et al., 2024). Initiatives such as IoT subsidies, capacity-building programs, and partnerships are helping smallholder farmers access cutting-edge technologies and benefit from their potential (Morepje et al., 2024). Therefore, the future of IoT in agriculture is highly promising, with advancements in AI, blockchain, robotics, sensors, and climate-smart tools driving the transformation. These trends are set to make agriculture more efficient, resilient, and sustainable, ensuring the industry is prepared to meet the demands of a growing global population.

Findings

The findings reveal that IoT technologies have significantly transformed agriculture by enhancing productivity, sustainability, and decision-making through real-time data collection. In precision farming, IoT tools such as sensors and drones have increased crop yields by 20–25%, while reducing water use by up to 40% in regions like India (Adewusi et al., 2024; Rajak et al., 2023). Automated irrigation and fertilization systems ensure optimal resource application, cutting waste and costs (Duguma & Bai, 2025). In livestock management, wearable IoT devices monitor animal health, improving early disease detection and reducing mortality rates by up to 20% (Saravanan & Saraniya, 2018; Bolaji et al., 2024). Smart feeding systems and environmental sensors have boosted milk production and overall livestock well-being (Kumar, 2023). Globally, countries like Brazil and the Netherlands have demonstrated the scalability of IoT in agriculture hubs, improving both large-scale and smallholder operations (Lima et al., 2021; Sharma et al., 2023). Furthermore, blockchain integration with IoT has improved food traceability and reduced spoilage (Lee et al., 2020). Challenges persist, particularly in developing regions, due to high costs and infrastructure limitations (Choruma et al., 2024). Nonetheless, these findings underscore IoT's capacity to drive agricultural innovation and sustainability, supporting global food security and environmental goals.

Unique Contribution to Theory, Practice, and Policy

This study contributes uniquely to agricultural theory by framing IoT as a socio-technical innovation that reshapes traditional farming paradigms through digital transformation. It expands theoretical discourse on precision agriculture by integrating multidisciplinary perspectives linking ICT, sustainability, and food systems. Practically, the study underscores IoT’s effectiveness in improving resource allocation, crop management, and livestock monitoring. For instance, the deployment of AI-IoT systems in orchards and rice fields has proven to boost productivity and reduce environmental degradation (Adewuyi et al., 2024; Kumar, 2023). In livestock, wearable health monitors and automated feeders promote efficiency and animal welfare (Bolaji et al., 2024). These findings provide a blueprint for farmers and agribusinesses to optimize operations using data-driven tools. On a policy level, the research supports the formulation of inclusive agricultural technology frameworks. Recommendations include investing in IoT infrastructure in rural areas, offering subsidies for smallholder farmers, and establishing public-private partnerships to enhance access to digital tools. Moreover, governments are encouraged to adopt smart farming policies aligned with global sustainability goals. International institutions such as FAO and the African Development Bank are urged to scale their support for digital agriculture through grants and training programs (Morepje et al., 2024). Collectively, these contributions can inform a global transition toward climate-resilient, tech-enabled agriculture.

Conclusion

The Internet of Things (IoT) has firmly established itself as a key driver of change in agriculture, addressing the challenges of feeding a growing population while protecting the environment. Evidence from various studies and successful implementations across the globe highlights the transformative power of IoT in improving efficiency, productivity, and sustainability in farming systems. IoT has been proven to optimize critical aspects of agriculture, including precision farming, livestock management, and resource allocation through agriculture hubs. For instance, precision agriculture driven by IoT has improved crop yields by up to 25%, according to the Food and Agriculture Organization (FAO). Similarly, IoT-based livestock monitoring systems have reduced animal health issues and enhanced productivity, as documented in case studies from Europe and North America. These innovations demonstrate the adaptability and effectiveness of IoT technologies in overcoming the limitations of traditional farming practices. Furthermore, emerging trends in IoT agriculture, such as AI integration, blockchain-enabled transparency, and climate-smart tools, promise to strengthen the sector's ability to meet future demands. Evidence shows that these advancements are already addressing critical challenges such as climate change impacts, water scarcity, and supply chain inefficiencies. For example, IoT-driven vertical farming in urban areas has increased food production per square meter while reducing water usage by 90%, as reported by agricultural research institutions.

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