

Next-Gen Agriculture: Revolutionizing Farming with IoT and Sustainability

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Abstract: This review paper examines the potential of Next-Generation Agriculture, which is based on the use of Internet of Things (IoT) technologies to enable sustainable and efficient farming practices. IoT sensors and devices have the potential to revolutionize agriculture by enabling farmers to monitor and manage their crops and livestock with greater precision, efficiency, and sustainability. The paper discusses the key benefits and challenges of IoT-based agriculture, such as improved resource management, increased yields, and reduced environmental impact. It also explores the various applications of IoT in agriculture, including precision farming, smart irrigation, livestock management, and supply chain management. The review paper concludes that Next-Gen Agriculture has the potential to revolutionize the agriculture industry by enabling farmers to achieve sustainability goals, improve yields, and reduce costs, while also addressing key environmental concerns. However, several challenges such as data security, privacy, and infrastructure limitations need to be addressed to realize the full potential of IoT-based sustainable agriculture.

Keywords: Next-Gen Agriculture, Internet of Things, Sustainability, Precision Farming, Livestock Management

1. Introduction

Next-Gen Agriculture is a modern approach to farming that utilizes Internet of Things (IoT)[1] technology to enable sustainable and efficient agricultural practices. This approach leverages various technologies, including sensors, drones, and artificial intelligence, to monitor and manage crops and livestock with greater precision and efficiency. IoT-based agriculture has the potential to revolutionize the agriculture industry by enabling farmers to achieve sustainability goals, improve yields, and reduce costs, while also addressing key environmental concerns. Although Next-Gen Agriculture offers many benefits, it also presents several challenges that need to be addressed. One of the main challenges is the data security and privacy concerns associated with IoT devices. With the large volume of data generated by IoT devices, it becomes difficult to secure and protect the data from unauthorized access. Another challenge is the lack of infrastructure in many rural areas, which may prevent farmers from accessing and utilizing IoT devices.

The motivation behind this review paper is to examine the potential of Next-Gen Agriculture and its impact on the agriculture industry [2]. This review paper

will discuss the key benefits and challenges of IoT-based agriculture, including improved resource management, increased yields, and reduced environmental impact. It will also explore the various applications of IoT in agriculture, including precision farming, smart irrigation, livestock management, and supply chain management. The goal of this review paper is to provide insights into the potential of Next-Gen Agriculture and its impact on the agriculture industry.

The role of technology in next-gen agriculture is an issue that explores how technology, such as precision agriculture and automation, is changing the way we grow and harvest crops. The potential benefits and drawbacks of these new technologies are being examined, including increased efficiency and reduced labor costs, versus potential environmental and social impacts. In addition, there is potential for next-gen agriculture to have economic effects such as changes in supply and demand of agricultural products, as well as impacts on traditional agricultural jobs and industries. Environmental and sustainability considerations also play a role in the adoption of next-gen agriculture, as the potential impact on land use patterns, water usage, and the use of pesticides and fertilizers needs to be examined. Finally, ethical and social considerations are also important, as the implications for farmers, farm workers, and rural

communities need to be considered. These technologies may exacerbate existing inequalities in access to technology and knowledge [3].

Contribution of the Paper: This review paper will contribute to the existing literature on Next-Gen Agriculture by providing insights into the potential of IoT-based agriculture and its impact on the agriculture industry. It will also highlight the challenges associated with IoT-based agriculture, including data security and privacy concerns, lack of infrastructure in rural areas, lack of standardization, and the cost of implementation. By providing a comprehensive overview of Next-Gen Agriculture, this review paper will help researchers and practitioners understand the potential of this technology and its impact on the agriculture industry. In inference, Next-Gen Agriculture is a modern approach to farming that utilizes IoT technology to enable sustainable and efficient agricultural practices. Although IoT-based agriculture offers many benefits, it also presents several challenges that need to be addressed. This review paper aims to provide a comprehensive overview of Next-Gen Agriculture, including its benefits, challenges, applications, and potential impact on the agriculture industry.

The remainder of this paper is organized as follows. In Section 2, we will provide an overview of IoT-based agriculture and sustainability, discussing the key benefits and challenges associated with this technology. In Section 3, we will explore the various applications of IoT in agriculture, including precision farming, smart irrigation, livestock management, and supply chain management. We will discuss how these applications can improve efficiency and sustainability in agriculture. In Section 4, we will delve into the challenges associated with implementing IoT-based sustainable agriculture, such as cost, complexity, and security concerns. Finally, in Section 5, we will summarize our findings and offer conclusions on the potential of IoT-based sustainable agriculture to transform the industry.

2. IoT-based agriculture and sustainability

2.1 IoT Technologies for Sustainable and Efficient Farming Practices

The Internet of Things (IoT) is revolutionizing farming practices by enabling sustainable and efficient agricultural operations. IoT technologies can help farmers optimize resource usage, monitor crop health, and improve yields, while reducing environmental impact. In this response, we will explore how IoT technologies can enable sustainable and efficient farming practices in five

paragraphs.



Figure 1. Smart Farming with IoT [4]

IoT technologies can help farmers monitor and manage water usage, an essential resource for agriculture. Smart irrigation systems can be installed on farms, which utilize sensors and weather data to optimize water usage, prevent water waste, and reduce energy consumption [5]. This is especially important in areas where water scarcity is a concern. By reducing water usage, farmers can save money on their water bills and reduce their environmental impact.

IoT technologies can improve crop management by providing farmers with real-time data on crop health. Smart sensors can be placed on crops to monitor soil moisture, temperature, and other environmental factors that affect plant growth [6]. This data can be analyzed to identify potential issues before they become major problems, allowing farmers to take proactive measures to protect their crops. This can reduce the need for harmful pesticides and other chemicals, resulting in more sustainable farming practices.

IoT technologies can enable precision agriculture, which allows farmers to target specific areas of their farms that require attention. By using data analytics and machine learning, farmers can identify the optimal time to plant and harvest their crops, which can improve yields and reduce waste. This approach can also reduce the use of fertilizers and other chemicals, as they can be applied more precisely, reducing runoff and protecting water quality [7].

IoT technologies can enable automation of various farming operations, including planting, harvesting, and monitoring. This can reduce the need for manual labor, improve efficiency, and reduce costs. For instance, robots and drones can be used to collect data and monitor crops, while also performing tasks such as planting and harvesting [8]. This can free up farmers to focus on higher-value tasks, such as strategic decision-making and marketing.

IoT technologies can help farmers reduce waste and increase recycling. Smart waste management systems can be implemented on farms, which utilize sensors to track waste and recycling, and provide real-time data on how much waste is generated and how much is being recycled [9]. This can help farmers reduce their environmental impact by reducing waste and increasing recycling, while also saving money on disposal costs.

IoT technologies have immense potential to enable sustainable and efficient farming practices. By optimizing resource usage, improving crop management, enabling precision agriculture, automating farming operations, and reducing waste, farmers can increase yields, reduce costs, and minimize their environmental impact. As technology continues to evolve, it is expected that more advanced and innovative IoT applications will emerge, further driving the adoption of sustainable and efficient farming practices.

2.2 IoT-based Agriculture: Benefits and Challenges

1. Improved Resource Management: IoT-based solutions have enabled farmers to monitor different aspects of farming, including soil quality, water usage, plant health, and weather conditions, in real-time, which results in a more efficient use of resources such as fertilizers, pesticides, and water. With the help of IoT sensors, farmers can precisely monitor and adjust the amount of fertilizer used and the quantity of water used for irrigating a field. This helps to optimize irrigation and fertilization, reducing water usage and fertilizer waste and ultimately leading to improved crop yields and reduced costs. [10]

2. Increased Productivity: Farmers can maximize their crop productivity by using sensor data to monitor and analyze crop growth and health [9]. Early identification of potential issues allows farmers to take necessary actions to prevent yield losses, ultimately increasing productivity. By leveraging insights gained from sensor data, farmers can make informed decisions about planting, harvesting, and managing pests and diseases, leading to higher crop yields.[11]

3. Increased yields: By monitoring and analyzing data from various sensors, farmers can gain insights into the health and growth of crops. This can help them make more informed decisions about planting, harvesting, and managing pests and diseases, ultimately leading to higher crop yields [12].

4. Accurate Data Analysis: IoT-based solutions provide farmers with accurate data on crop performance, weather patterns, and other relevant factors. This data can be used to make informed decisions and optimize farm operations.[13]

5. Automation: IoT devices can automate tasks such as irrigation, fertilization, and pest control, reducing the need for manual labor and increasing efficiency.[14]

6. Improved Crop Quality: IoT-based solutions can help farmers identify the best time to harvest crops, leading to higher-quality produce.[15]

7. Reduced environmental impact: IoT-based agriculture can help reduce the use of water and other resources, thereby reducing the environmental impact of agriculture. Additionally, by using precision farming techniques, farmers can reduce the amount of pesticides and fertilizers needed, which can help reduce pollution and improve soil health[16].

Now, let's discuss some of the key challenges of IoT-based agriculture:

1. Connectivity: One of the foremost concerns in IoT-based agriculture is connectivity. Connecting devices, applications, and cloud platforms can be challenging in areas with poor network coverage.[17] The foremost challenge of IoT-based agriculture is ensuring connectivity between devices, applications, and cloud platforms. This is critical for ensuring that data is collected and analyzed in real-time to support timely decision-making. Poor connectivity can lead to delays in decision-making, reducing the effectiveness of IoT-based agriculture [18].

2. Data Security: IoT devices generate a large amount of data that needs to be stored and processed. Ensuring the security of this data is crucial to prevent data breaches and cyber attacks. [19]

3. Data management and analysis: With the large amount of data generated by IoT sensors, it can be challenging to effectively manage and analyze this data. This requires robust data management and analytics systems to ensure that data is processed quickly and accurately to support decision-making [20] .

4. Cost: Implementing an IoT-based agriculture system can be expensive, particularly for small-scale farmers. The cost of sensors, actuators, and other IoT devices can be a barrier to adoption, particularly in developing countries[21].

5. Lack of Expertise: Many farmers may lack the technical expertise needed to implement and maintain IoT-based solutions. Training and support may be needed to ensure that farmers can take full advantage of these technologies[22].

6. Integration: Integrating different IoT devices and applications can be challenging, especially if they are developed by different manufacturers and use different communication protocols. [23]

In summary, IoT-based agriculture presents numerous benefits, including improved resource management, increased productivity, and accurate data analysis. However, it also comes with some key challenges, such as connectivity, data security, cost, lack of expertise, and integration. Overcoming these challenges will be crucial for the widespread adoption of IoT-based solutions in agriculture.

3. Applications of IoT in Agriculture

Internet of Things (IoT) is an advanced technology that is transforming the way various industries operate, including agriculture. The applications of IoT in agriculture are vast and include precision farming, smart irrigation, livestock management, and supply chain management. Here's a more detailed explanation of each:

Precision Farming: Precision farming, also known as smart farming or Agriculture 3.0, is an agricultural management strategy that utilizes advanced technologies like GPS, drones, sensors, and data analytics to collect and process agricultural data, which offers insights to farmers to optimize and increase soil quality and productivity [24]. Precision agriculture data points assist farmers in making informed decisions and improve farmland and farm produce across several dimensions. The pursuit of precision agriculture and its associated agricultural technology has led to the development of new farming methods and tools [25]. Innovations like GPS guidance systems and auto-steer technology are tools that can be used to find the most efficient routes around a field, eliminating skips and overlaps on the field, and can lend to setting a consistent wheel traffic pattern[26]. Precision farming helps farmers increase their yields, save time and reduce costs, and decrease their environmental impact.

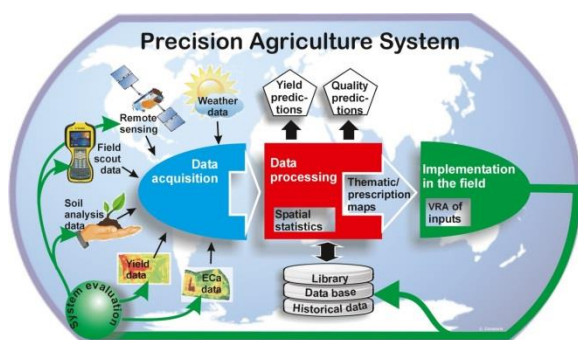


Figure 2. Precision Farming system

Smart Irrigation: Smart irrigation is a technique of applying the right amount of water at the right time and place. It uses real-time data from sensors, weather forecasts, and other sources to optimize irrigation schedules, reducing water wastage and improving plant growth [25]. Typical agricultural water needs include personal and livestock use, as well as irrigation, which requires a large quantity of water. Precision irrigation systems can help in monitoring and conserving water resources, while also optimizing crop yields. For instance, automated irrigation systems can adjust watering schedules and amounts based on plant growth, weather patterns, and soil moisture levels.

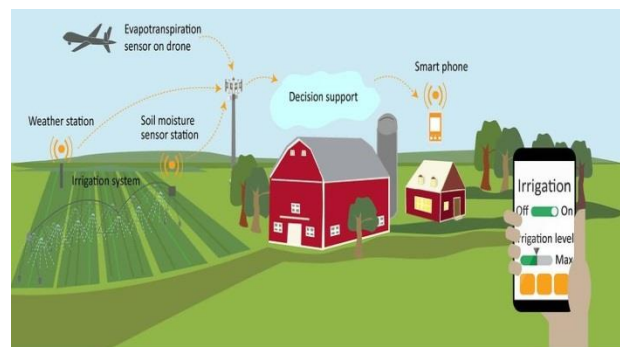


Figure 3. Evalutuniory Smart Irrigation System

Livestock Management: Livestock management is the process of managing farm animals and optimizing their growth, health, and productivity. Modern livestock management techniques use IoT devices, sensors, and data analytics to monitor and track animal behavior, health, and growth, providing real-time information to farmers[26]. This helps farmers make informed decisions about feed, medication, and other factors that can impact animal health and productivity. Livestock monitoring systems can alert farmers about any changes in behavior, such as reduced feed intake, that may indicate an illness. This early warning system can help farmers prevent the spread of disease and improve animal welfare.

Supply Chain Management: Supply Chain Management (SCM) refers to the management of the flow of goods and services from the raw materials stage to the final delivery of the product or service to end-users [27]. SCM involves several activities, including sourcing raw materials, transportation, manufacturing, warehousing, distribution, and retailing. The SCOR (Supply Chain Operations Reference) model is widely used in planning SCM systems, which includes five overall stages, including planning, sourcing, making, delivering, and returning. Modern technologies like IoT, blockchain, and artificial intelligence are transforming SCM, enabling real-time tracking, monitoring, and optimizing of supply chain operations. These technologies can help reduce waste, improve efficiency, and lower costs for businesses.



Figure 3. Supply chain Management

Overall, the applications of IoT in agriculture are numerous and varied. By leveraging IoT technology, farmers can optimize their operations, reduce costs, and improve the quality and yield of their crops and livestock.

3.1 IoT Applications for Enhancing Efficiency and Sustainability in Agriculture

Increasing revenue: Increasing revenue by selling more products at a higher price can help farmers and agricultural businesses invest in new technologies and practices that improve efficiency and sustainability. This can include investing in precision agriculture technologies that optimize crop yields, reduce waste, and minimize the use of water, fertilizer, and pesticides. Additionally, increased revenue can help farmers invest in renewable energy sources, such as solar or wind power, which can reduce greenhouse gas emissions and improve sustainability.

Knowledge management: Implementing a knowledge management program can help farmers and agricultural businesses share best practices, collaborate on research, and improve communication between different stakeholders. This can lead to more efficient use of resources, such as water and fertilizer, and more sustainable farming practices. By sharing knowledge and expertise, farmers can also learn from each other and

adopt new technologies and practices that improve efficiency and sustainability.

Cloud software: Cloud software can help farmers and agricultural businesses manage their operations more efficiently by providing real-time data and analytics on crop yields, soil conditions, and weather patterns. This can help farmers make more informed decisions about when to plant, irrigate, and harvest crops, which can reduce waste and improve efficiency. Additionally, cloud software can help farmers monitor and optimize their energy usage, reducing greenhouse gas emissions and improving sustainability.

Process improvement: Implementing process improvement steps, such as evaluating existing processes, can help farmers and agricultural businesses identify inefficiencies and opportunities for improvement. By streamlining processes and reducing waste, farmers can improve efficiency and reduce their environmental footprint. For example, by optimizing irrigation systems and using precision agriculture technologies, farmers can reduce water usage and improve sustainability.

Personal development skills: Developing personal skills such as time management, organization, and communication can help farmers and agricultural businesses improve efficiency and sustainability. For example, by setting goals and prioritizing tasks, farmers can make better use of their time and resources, reducing waste and improving efficiency. Additionally, by improving communication with suppliers, customers, and other stakeholders, farmers can collaborate more effectively and adopt new technologies and practices that improve sustainability.

Overall, these applications can help farmers and agricultural businesses improve efficiency and sustainability by increasing revenue, sharing knowledge and expertise, providing real-time data and analytics, optimizing processes, and developing personal skills. By adopting these applications and practices, farmers can reduce waste, improve productivity, and minimize their environmental footprint, ultimately leading to a more sustainable and profitable agricultural sector.

Table : the parameters of efficiency and sustainability in agriculture

Statement	Efficiency in Agriculture	Sustainability in Agriculture
Increasing revenue	Implementing precision agriculture technologies and practices to maximize yield and profits.	Focusing on sustainable practices such as conservation tillage and cover cropping to improve soil health and reduce environmental impact.
Knowledge management	Utilizing precision agriculture data analysis tools to optimize crop management decisions.	Encouraging knowledge sharing and collaboration among farmers to promote sustainable and efficient practices.
Cloud software	Utilizing cloud-based farm management software to streamline record-keeping and increase productivity.	Adopting sustainable energy solutions such as renewable energy sources to reduce reliance on non-renewable resources.
Process improvement	Implementing lean management principles to improve operational efficiency and reduce waste.	Implementing sustainable irrigation practices and crop rotation strategies to reduce water usage and preserve soil health.

Personal development skills	Encouraging continuous learning and training opportunities to improve skill sets and promote innovation.	Promoting equitable and sustainable labor practices, including fair wages and safe working conditions for farm workers.
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It's important to note that these are just a few examples, and there are many more ways to approach efficiency and sustainability in agriculture.

4. Challenges of IoT-based sustainable agriculture

- IoT has revolutionized various industries by enabling the collection, analysis, and utilization of real-time data.
- The agricultural sector can benefit greatly from IoT-based technologies, which can lead to more sustainable and efficient farming practices.
- IoT-based sustainable agriculture has enormous potential, but there are several challenges that need to be addressed to realize its full potential.
- One major challenge is data security and privacy.
- IoT-based sustainable agriculture relies heavily on the collection and transmission of real-time data from various sources such as sensors, drones, and other IoT devices.
- This data is crucial for making informed decisions related to irrigation, pest management, soil health, and other farming practices.
- The collection and transmission of such sensitive data raise concerns about data privacy and security.
- Farmers and other stakeholders need assurance that their data is secure and will not be misused or accessed by unauthorized entities.
- To address this challenge, it is important to implement appropriate data security measures and protocols to safeguard the data collected from IoT devices in agriculture.
- Additionally, it is crucial to develop policies and regulations that protect the privacy of farmers and other stakeholders and ensure the ethical use of their data.

5. Concussion

In conclusion, Next-Gen Agriculture has the potential to revolutionize the agriculture industry by enabling farmers to achieve their sustainability goals, improving yields, and reducing costs while also addressing key environmental concerns. Through the use of innovative technologies and practices, such as precision agriculture, vertical farming, and genetic engineering, Next-Gen Agriculture can help farmers produce more food with less land, water, and energy inputs. Moreover, it can help them reduce the use of harmful chemicals, prevent soil erosion, and mitigate the impacts of climate change on crops. While there are still

challenges and uncertainties associated with Next-Gen Agriculture, such as regulatory issues, ethical concerns, and social acceptance, the benefits it offers are too significant to ignore. Therefore, policymakers, researchers, and stakeholders should work together to promote the adoption and development of Next-Gen Agriculture in a responsible and sustainable manner. By doing so, we can ensure a more food-secure, environmentally-friendly, and equitable future for all.

The Internet of Things (IoT) has become an integral part of many industries, including agriculture. However, to fully realize the potential of IoT-based sustainable agriculture, it is essential to address the challenges that come with it. Some of these challenges include interoperability, security, and decision-making.

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