

Cloud Computing: Embracing Resilient and Sustainable Agriculture in the Digital Era

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Short Communication

Approximately 690 million people globally suffer from hunger, an increase of nearly 60 million in five years (The World Bank 2020). The global population is expected to exceed 9.9 billion by 2050, resulting in shifts in dietary patterns and an increase in food and nutrition demand. The consensus is that global agricultural production will need to increase by 60-70% to meet the food demand 2050. The number of people suffering from hunger has increased by nearly 60 million in the past five years and is expected to increase as the population grows. The FAO estimates that there are currently 2.3 billion people facing dangerous levels of food insecurity, which is likely to increase as the population grows. According to the USDA, more than 34 million people in the United States are food insecure. As a result of these challenges, farmers worldwide strive to maximize their resources and employ innovative techniques to meet the increasing demand for food [1].

Climate change is causing alarming shifts in weather patterns throughout the food production system. Climate change has introduced many challenges, including rising temperatures, irregular precipitation patterns, severe weather events, and inadequate water resources. Agriculture and global food production systems have been profoundly affected by these disruptions. Globally, concerted efforts are being made to address this situation. The government, international institutions, concerned individuals and groups, and private organizations are combining their efforts and skills to combat the multifaceted challenges of climate change and safeguard the future of the food supply [2].

Throughout history, agricultural practices have undergone periodic transformations, progressing from conventional to contemporary approaches that utilize advanced tools and

technologies. During the early waves of innovations, emphasis was placed on mechanization, improved hybrid seeds, efficient irrigation systems, and novel agricultural practices. Recent advances in agriculture have taken a different course. We are witnessing a wave of technological advancements like using IOTs, ICTs, sensors, drones, and various mobile applications in the agriculture and allied sectors. These advancements address the issues of agricultural practices, production, and farm and agribusiness management. Also, the latest metrological innovations help institutions and individuals learn and understand climate change's impacts and unpredictable weather patterns. With these advancements, agricultural advisory and extension services are complemented by modern information technology tools and technologies, enabling farmers to produce more food resilient and sustainably [3].

A new generation of farmers is emerging and leveraging the power of digital solutions to revolutionize food production and address formidable challenges in the agricultural sector. The next generation of farmers is adopting innovative mechanization, techniques, tools, and modern digital technologies to maximize productivity. Agriculture communities across developed and developing countries embrace data-driven decision-making to enhance farm management practices wherever possible. Smallholder, medium-scale, and large-scale farms with extensive landholdings benefit from these innovations. In 2017, the world witnessed the first fully machine-operated crop-a significant achievement in digital agriculture, also known as intelligent agriculture. This ground-breaking innovation demonstrated the potential of technology in agriculture by enabling a crop to be planted, managed, and harvested without the involvement of any human being [4].

Cloud farming utilizes cloud-based platforms, Internet of Things devices, data, and advanced analytics to optimize agricultural processes and make data-driven decisions. By integrating weather forecasting models, soil analysis tools, and crop management systems, cloud farmers can mitigate the risks caused by climate change and adapt their farming practices accordingly. Furthermore, these digital tools enable farmers to monitor crop health, water usage, and real-time nutrient management, optimizing resource allocation and reducing waste. As a result of having access to accurate and up-to-date information, cloud farmers can make informed decisions, maximize productivity, and minimize the environmental impact.

With the integration of digital technology, farmers now have access to a wide range of cutting-edge tools and solutions. Using Internet of Things (IoT) devices, remote sensing, and artificial intelligence (AI) algorithms, crop health, soil conditions, and environmental conditions can be monitored in real-time. With this wealth of data, farmers can make informed decisions regarding the best time to plant, irrigation schedules, and pest control strategies, enhancing productivity and maximizing resources. In addition, digital agriculture extends beyond the management of individual farms. The technology revolutionizes the food value chain, from seed production and supply to post-harvest processing and distribution. Farmers can gain greater access to markets, discover better prices, and improve the efficiency of the supply chain as a whole. Access to accurate, timely, and relevant data allows stakeholders across the value chain to make informed decisions, optimize logistics, reduce waste, and ensure food safety and traceability [5].

Cloud computing in agriculture is expected to grow at a compound annual growth rate (CAGR) of 13.5% from USD 307.52 billion in 2023 to USD 745.15 billion by 2030. This growth is attributed to the increasing need for precision farming and the rising demand for smart agriculture. It is also driven by the increasing adoption of Internet of Things (IoT) solutions in agriculture. Cloud computing enables farmers to access data and insights from anywhere and anytime, which helps them make informed decisions. It also helps them reduce costs, save time, and increase efficiency.

In this digital revolution, cloud computing, or cloud technology, has emerged as a critical player. Several major IT companies and enterprises, including Google, Microsoft, Amazon Web Services (AWS), and IBM, offer cloud services to individual farmers, farmer groups, and agricultural organizations. These companies provide users access to online digital infrastructure facilities, enabling them to collect, store, and share data generated on farms. Through a pay-as-you-go model, users can access these services for a fee based on their storage space and resources. Cloud technology can be beneficial for agriculture in several ways. It securely facilitates the storage of vast amounts of data, eliminating the need for physical storage devices and reducing the risk of data loss [6].

In addition to enabling farmers to access real-time data from any location or device connected to the internet, cloud computing also provides convenient access to data from anywhere with an internet connection. Data is collected from various sources through

connected sensors, including soil composition, pH levels, nutrient levels, satellite imagery, weather stations, and temperature conditions. Farmers can access critical information using sensors to make informed decisions and manage their farms effectively. The data on soil conditions, crop growth, fertilizer application, harvest yields, and financial matters is valuable. Farmers can gain valuable insights into their crop practices by analyzing and using this data. It allows them to review their farm business's performance, identify improvement areas, and evaluate losses and benefits. By understanding the specific water and fertilizer requirements of their crops, farmers can avoid excessive application, minimizing environmental impacts while optimizing resource usage. This level of precision helps farmers achieve optimal yields, reduce waste, and mitigate agricultural ecological footprint [7].

By integrating AI and machine learning algorithms with cloud technology, farmers can maximize the value of their data. These advanced technologies can analyze large datasets, uncover patterns, and provide predictive analytics for decision-making at various stages of the farming process. Utilizing AI and machine learning capabilities, farmers can optimize planting times, adjust irrigation schedules, implement targeted pest management strategies, and make informed decisions regarding the timing of harvesting and post-harvest activities. Additionally, cloud technology facilitates the collaboration and sharing of data among farmers, researchers, and industry stakeholders. Cloud-based platforms allow individuals and organizations to exchange insights, best practices, and research findings, fostering a culture of knowledge sharing and promoting innovation. Cloud services offer farmers added flexibility and scalability. The ability to scale up or down their usage on a seasonal basis allows them to optimize resource allocation and minimize costs. Cloud computing also provides the computational power needed for complex data analysis, allowing farmers to derive meaningful insights from large datasets, such as weather patterns, soil conditions, and crop yields. By optimizing resource utilization and implementing precision farming techniques, farmers can minimize waste, limit the use of chemical inputs, and promote sustainable agricultural practices [8].

Despite this, the digital revolution is not without its challenges. To ensure the inclusiveness and sustainability of digital agriculture, adoption barriers such as limited access to technology, a lack of digital literacy, and concerns about privacy and security need to be addressed. Promoting the equitable dissemination of digital solutions through collaboration among governments, technology providers, researchers, and farmers is crucial. As the agriculture industry embraces digital transformation, the integration of cloud technology is poised to revolutionize farming practices and enhance productivity. Addressing potential data privacy, security, and connectivity challenges in remote agricultural areas is essential. Collaborative efforts between technology providers, policymakers, and farmers are crucial to ensure the effective and equitable implementation of cloud computing in agriculture, enabling farmers to harness the full potential of these digital advancements for sustainable and resilient food production. Although cloud computing solutions in agriculture offer many benefits, their high costs make them unaffordable for smallholder farmers. Many small

and medium-scale farmers may be unable to afford the pay-as-you-go model. A further challenge with cloud computing is the lack of internet connectivity, particularly in rural areas.

The government plays an important role in facilitating the development of robust Internet infrastructure and ensuring affordable Internet access for rural communities. Governments can enhance the availability of telecommunications services by investing in expanding telecommunications networks, encouraging private sector participation, and implementing policies that promote Internet connectivity in remote areas. Private sector entities should also significantly grow network coverage, create affordable data plans, and develop tailored cloud computing solutions to address smallholder farmers' specific needs and limitations. In agriculture, cloud computing can be significantly enhanced by removing cost barriers and improving internet connectivity. Smallholder farmers can access valuable resources, utilize data-driven insights, and leverage digital tools to optimize their farming operations. As a result, rural communities can benefit from increased productivity, improved resource management, and sustainable agricultural practices [9].

Government and private sector collaborations are essential for cloud computing to be widely adopted in agriculture. Building tall mobile towers and expanding high-speed internet infrastructure is vital to reaching rural farming communities. Farmers can maximize

the benefits of cloud technology, access essential data, and utilize digital tools when connectivity is improved in rural areas. Training and capacity building on the use of digital technologies by farmers and end users is crucial for the success of the digital revolution in agriculture to produce more in less.

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Conflict of Interest

No conflict of interest.

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