Cloud Computing in Agriculture: Exploring Methods, Applications, and Impact

[1]Shakiv Pandit, [2]Rajeev Sharma
Scholar, Assistant Professor
[1,2]Department of Computer Science & Engineering
[1,2]Chandigarh Engineering College, Landran (Mohali), Punjab, India

Abstract: The most wealthy countries in the world, such as India and China, rely heavily on agriculture for their wealth and way of life. Both farmers and the country gain from the use of cloud computing technology to enhance maintenance, performance monitoring, and cost management of agricultural production. This article addresses the application of cloud computing, intelligent drones, and computing technologies for crop management, emphasizing the use of real-time data for efficient execution. India's agriculture, whereas commonly utilized in neighboring countries, requires technological modernization to improve output, financial distribution, and cost control. This article talks about a smart agriculture paradigm that makes use of cloud computing and sensors. Additionally, it outlines the different cloud computing techniques and applications utilized in the agricultural industry.

Keywords: *Cloud Computing, Smart Agriculture, Applications, Methods.*

I. INTRODUCTION

The term "cloud computing," which comes from the cloud symbol used in flowcharts and diagrams, describes the delivery of hosted services via the Internet. The three types of services are Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS). With flexibility and scalability, Infrastructure as a Service (IaaS) offers computer infrastructure as a usefulness service. PaaS offers a platform or stack of solutions on a cloud infrastructure that integrates with messaging, middleware, databases, development, and queuing. Through a cloud infrastructure based on the underlying IaaS and PaaS layers, SaaS provides apps via the Internet or intranet [1]. Cloud computing meets customer demand with little effort by providing IT infrastructure through the Internet. Decentralized, antiquated, and sluggish to modernize is India's agricultural production system. This causes a clear disconnect between the agricultural products' supply and demand chains. Both the country's national income and the financial circumstances of farmers will suffer as a result of the circumstances. This bottleneck can be successfully removed in the agricultural sector by implementing cloud computing facilities. To guarantee its accessibility, a centralized storage facility should be set up for all pertinent data, such as information about soil, weather, research, crops, and farmers. End users, including farmers, specialists, consultants, and researchers, can access data from linked devices at any time and from any location due to the cloud system [2].

The earth's ability to support a given crop, market demand knowledge, and the potential for rapid profits are some of the factors that often influence an agriculturalist's crop choice. Inadequate farming choices can put a strain on families' finances and even result in farmer suicides. Farming and linked manufacturing make up about 20.4% of India's Gross Value Added (GVA). A farmer's family as well as the local economy as a whole may suffer from poor choices. For Indian farmers to make educated decisions regarding crop planting, a system that gives them consistent information should be put in place. Farmers are conducting farm health inspections in a completely new way thanks to the Internet and cloud computing. Even though the current methods of monitoring and recording data are ineffective, robotics is becoming a technology that helps with farm health. In particular, precision farming a key component of smart farming is being revolutionized by drone technology. To improve crop development, farmers track environmental factors, nutrient levels, and soil moisture using data analytics and Internet of Things (IoT) devices. Autonomous tractors are another technology that can be used for seeding and field plowing. To reach its full potential, smart agriculture must overcome several challenges, despite the potential advantages it holds for farmers and the food chain. Implementing technologies like sensors, drones, and autonomous tractors can be expensive, which is one of the biggest barriers to smart agriculture.

The adoption of smart agriculture may be hampered in rural areas by the absence of a dependable digital infrastructure, especially for small-scale farmers with limited funding. This includes having access to a fast internet connection. This might make adopting and utilizing these technologies more challenging for farmers. Effective data management is essential for smart agriculture since it produces a lot of data that needs to be arranged and examined. A lack of resources or expertise may make it tough for agriculturalists to handle and interpret this data effectively. Sensitive data is collected and shared in smart agriculture to protect privacy and security. It is vital to guarantee the safety of this data and give farmers authority over how it is used. To participate in smart agriculture, farmers require technical abilities, such as knowledge of technology. To help farmers learn these skills, educational and training programs must be made available.

Drones and autonomous cars are examples of smart agriculture technology that may encounter regulatory obstacles because they require particular licenses or permits. Governments, academic institutions, the commercial sector, agriculture, technology, policy, and finance must work together to support the development, adoption, and affordability of smart agricultural technologies for farmers of all sizes and locations [3]. The many benefits of cloud computing in farming include data availability, data readiness, local and international communication, growth in the economy, GDP growth, security of nutrition, farmer motivation, raised market cost, ease of use data, rural-urban mobility, and a decrease in technological issues for nourishment, seedlings, and other products.

This paper outlines as a literature survey in sec 2, application and relationship b/w cloud computing and agriculture in sec 3. Section 4 describes various cloud computing methods and sec 5 represents the conclusion and future scope.

II. PRIOR WORK

Several articles were analyzed with different research methodologies with outcomes. **Sriveni Namani et al. (2020) [4]** described sensors as a smaller used in a wider range of fields as a result of the development of contemporary technologies. The development of numerous "Smart" systems was greatly influenced by the combination of IoT and cloud computing. This adoption was observed in agriculture, which is a significant source of revenue for nations such as China and India. In particular, the use of smart drones for crop management was examined along with the possible benefits of combining cloud computing and the IoT in the agricultural industry. Incorporating real-time drone data with cloud computing and IoT tools can help create a sustainable Smart Agriculture system, according to the study. **Shubo Liu et al. (2019) [5]** described various concerns related to product quality and environmental pollution. To enhance China's modern agricultural safety and efficiency, the study investigates an integrated framework system. They developed contemporary agricultural applications that integrate cloud computing, IoT, and data mining technologies. The simulation design and experimental setup indicate that the fundamental features of the IoT agricultural monitoring system could be achieved. Significant innovation results from integrating different technologies, which also lowers system development costs and ensures security and dependability. **Sandeep Rathor et al. (2021) [6]** maximized Farmland potential using modern technology, but traditional agricultural methods were inefficient. It's critical to maximize yields due to the growing population and resource exploitation. The IoT could be assisted by implementing cutting-edge technologies to maximize yields and optimize resource use, improving overall agricultural efficiency. It adds intelligence by tying tangible objects to the internet. IoT-enabled smart systems combined with cloud computing have the potential to revitalize the agricultural sector. **Lakshmi Narayana Thalluri et al. (2020) [7]** developed an IoT system that uses IaaS cloud architecture for real-time agricultural applications. It consists of a server with a pre-configured database, an ARM11 processor, and six Wi-Fi-enabled sensor nodes linked to five sensors. The MySQL-created database stores output values, collects data, permits only authorized access, and analyzes data daily. A networked computer that uses a public IP to host a website is termed a server. It uses HTML programming to create pages and PHP to embed them, and it runs a database. The HTTP protocol makes it possible to communicate with the internet, giving the agriculture industry access to real-time data analysis and insights. **Anat Goldstein et al. (2022) [8]** described precision farming techniques and the collection of data. The proposes a agricultural model using cloud computing. The framework facilitates data visualization, analysis, and integration and was a cloud-based infrastructure created for precision agriculture. Based on questionnaires, interviews, and a review of the literature, it was created in a top-down and bottom-up manner. Iterative revisions were made to the original architecture, and different use cases that represent various data integration needs and services were used to illustrate how it can be applied. The architecture of the framework was modified to satisfy evolving user requirements. **Subhendu Chatterjee (2021) [9]** described India's rural and smaller towns hold the key to the country's future, as cloud computing technology can help close the gap between rural and urban areas. Both the national economy and the rural economy will benefit from this. Indians rely mostly on agriculture for their income, so this industry was the main focus of ICT development. Cloud computing technology was a new kind of network-based computing that runs online and gives users and apps a straightforward graphical user interface. It has improved the agricultural industry and associated services that these platforms offer. Table I describes various existing methods with proposed methods, problems, platforms, tools, and outcomes.

TABLE I
ANALYSIS BASED ON THE PRIOR REVIEW

Author's Name	Proposed Method	Problems	Platform/Tool	Outcomes
Sriveni Namani et al. (2020) [4]	Smart Drone model	Limited accuracy and lack of smart features	CloudSIm	In a controlled establishment, limited functionality Comprehensive testing is required.
Shubo Liu et al. (2019) [5]	IoT-Cloud-based monitoring system	Poor quality and limited safety.	Oracle Zigbee	This model reduces the development cost and provides reliability.
Sandeep Rathor et al. (2021) [6]	IoT-Cloud-based agriculture model	Limited resource utilization	_	This model provides accurate data and performance.
Lakshmi Narayana Thalluri et al. (2020) [7]	IoT system using IaaS cloud Computing	Limited Security	MySQL, PHP	This model provides better performance than the existing model.
Anat Goldstein et al. (2022) [8]	Developed a model to integrate and analyze agricultural data	More Data overflow	HTML, SQL	This model efficiently analyzed the data from different sources.
Subhendu Chatterjee (2021) [9]	Agriculture model using Cloud computing	Technical and unemployment issues	-	This model reduces the development cost and provides reliability.

III. SMART AGRICULTURE APPLICATIONS AND RELATIONSHIP BETWEEN CLOUD COMPUTING AND AGRICULTURE

3.1 Applications

Smart agriculture increases agricultural yields and productivity by leveraging modern innovations like sensors, drones, and big data analytics. Cloud computing technology can greatly enhance agricultural development by removing barriers to information sharing and modernization, removing technological and knowledge barriers, cutting down on duplication, and optimizing resource use. Increased productivity and efficiency can be achieved by addressing regional variations in small-scale production and agriculture's reliance on natural climate vulnerability [3]. Among the applications of smart agriculture are the following:

A. Precision Farming

GPS and sensors are used in precision farming to track soil conditions, crop growth, and weather. Various resources like water and fertilizer are more effectively utilized by farmers. They increase yields and lowering costs. Sensors and meteorological data are used by smart irrigation systems to modify watering volumes and schedule plant needs and ecological factors. Smart agriculture minimizes water waste and ensures the best possible water supply for plants by using sensors to monitor the productivity, health, and behavior of animals. Farmers can use less feed and water, improve animal welfare monitoring, and detect health problems early.

B. Management of Pests and Diseases

An essential component of efficiently controlling diseases and pests is smart agriculture. Drones and sensors can identify early signs of infestation, and big data analytics can spot trends and forecast epidemics. This could reduce the need for hazardous chemicals and boost agricultural yields.

C. Supply Chain Management

It can be optimized through smart agriculture. In addition to tracking inventory levels, shipment schedules, and demand forecasting.

3.2 The Relationship between Cloud computing and Agricultural

In addition to addressing regional disparities and reliance on natural climate vulnerability, cloud computing technology can improve agricultural modernization and information, alleviate knowledge and technology constraints among agricultural producers, minimize duplication, and optimize resource utilization. There are three components to agricultural modernization:

- Make extensive use of modern agricultural machinery and production equipment.
- Make extensive use of the latest planting technology, weather monitoring, and forecasting.
- Make use of modern invention groups and controlling techniques, etc.

The objective of agricultural mechanization has been accomplished, but many management and technological problems remain. A major problem is the absence of service organizations, technical advice, and assistance in breeding, pollutant-free crop cultivation. As a result, farmers are mindlessly adopting new technology. Integration of agriculture is difficult due to the low level of specialization and ineffective organization in agricultural production areas. Farmers have difficulties with information gathering, business decision-making, logistics management, and market forecasting. These difficulties can cause supply-demand imbalances, harm their interests, and impede market growth.

IV. CLOUD COMPUTING METHODS USED IN AGRICULTURE FIELD

Table II describes various cloud computing methods utilized in the Agriculture field. This table describes the goal of methods, advantages, disadvantages etc.

TABLE II
ANALYSIS OF SEVERAL CLOUD COMPUTING METHODS USED IN AGRICULTURE

Methods	**Goal**	**Advantages**	**Disadvantages**
Top-Down Bottom Approach [11]	The model uses cloud computing to integrate and analyze agricultural data, improving the solutions' scalability, flexibility, affordability, and maintainability.	The model provides cloud-based infrastructure that facilitates data integration, analysis, and decision support to farmers.	Due to space limitations, only the first three use cases are covered in this paper.
Cloud-based Monitoring model using 4duino [12]	The goal of this research is to create a cloud-based platform for agricultural resource monitoring, though there is room for additional implementations.	It provides better performance and efficiency.	Limited controlled and scalability issues.
Remote Mobile Control System in Smart Planting [13]	To offer a system initiative to define a reference architecture for intelligent planting management, incorporating and scalable industrial system.	This model provides smart services for plant development.	This tool supports limited resources and inaccurate services.
MISSENARD Index [14]	This work provides a better understanding of the integration of IoT into measurement science.	This model was useful for appliances and consumer electronics to increase device intelligence and human comfort.	More burden in the server storage.
CLAY-MIST measurement (CMM) index [15]	This model provides precise decisions and simultaneous data.	The measurement analysis is stable, accurate, and has an error rate below 6%.	Limited functionality Data analytics required
AGRICLOUD [16]	They suggest a novel approach that formats files in the cloud.	This method is very stable in the case of processing tasks.	More Execution Time

V. CONCLUSION

Cloud computing tools for example sensors, IoT devices, and data analytics have the potential to transform food production in the quickly growing agriculture sector. Smart agriculture benefits the world's expanding population by improving food security, increasing farmer productivity and profitability, and reducing environmental impact. It is anticipated that smart agriculture technologies will create sophisticated algorithms for sensors and data analytics, and make decisions using cloud computing methods. These developments can aid in addressing problems with the global food system. More food can be produced with fewer resources are managed more efficiently, and food systems can become more resilient to changing conditions by leveraging data and technology.

The goal of smart agriculture is to create integrated systems to solve the intricate problems that farmers and the food system face. Experts in data science, engineering, agriculture, and policy must work together, and innovation and ongoing development must be prioritized.

VI. REFERENCES

[1] Pallavi P. P., & Patil P. P. (2021). Roll of Cloud Computing In Agriculture. *Journal of Emerging Technologies and Innovative Research (JETIR), 8(7),b 181-b186.*

[2] Choudhary, S. K., Jadoun, R. S., & Mandoriya, H. L. (2016). Role of cloud computing technology in agriculture fields. *Computing*, *7*(3), 1-7.

[3] Kishor, K., & Verma, R. K. (2023). Cloud computing-based smart agriculture. In *Convergence of Cloud Computing, AI, and Agricultural Science* (pp. 120-136). IGI Global.

[4] Namani, S., & Gonen, B. (2020, March). Smart agriculture based on IoT and cloud computing. In *2020 3rd International Conference on Information and Computer Technologies (ICICT)* (pp. 553-556). IEEE.

[5] Liu, S., Guo, L., Webb, H., Ya, X., & Chang, X. (2019). Internet of Things monitoring system of modern eco-agriculture based on cloud computing. *Ieee Access*, *7*, 37050-37058.

[6] Rathor, S., & Kumari, S. (2021, October). Smart agriculture system using iot and cloud computing. In *2021 5th International Conference on Information Systems and Computer Networks (ISCON)* (pp. 1-4). IEEE.

[7] Thalluri, L. N., Ayodhya, J. P., Prasad, T. A., Raju, C. Y., Vadlamudi, S., & Babu, P. B. (2020, January). A Novel and Smart IoT System for Real Time Agriculture Applications with IaaS Cloud Computing. In *2020 International Conference on Computer Communication and Informatics (ICCCI)* (pp. 1-6). IEEEZ

[8] Goldstein, A., Fink, L., & Ravid, G. (2022). A Cloud-Based Framework for Agricultural Data Integration: A Top-Down-Bottom-Up Approach. *IEEE Access*, *10*, 88527-88537.

[9] Chatterjee, S. (2020). Cloud computing in agricultural development of rural India. *International Journal of Information Science and Computing*, *7*(1), 29-36.

[10]Prasad, M. S. V. K. V., Kumar, G. J., Naidu, V. V. S., & Nagaraju, G. J. (2013). Use of cloud computing in agricultural sector, a myth or reality. *Int. J. Eng. Res. Technol.(IJERT)*, *2*(10), 831-834.

[11] Goldstein, A., Fink, L., & Ravid, G. (2022). A Cloud-Based Framework for Agricultural Data Integration: A Top-Down-Bottom-Up Approach. *IEEE Access*, *10*, 88527-88537.

[12]Adetunji, K. E., & Joseph, M. K. (2018, August). Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture. In *2018 International conference on advances in big data, computing and data communication systems (icABCD)* (pp. 4849-4854). IEEE.

[13]Ji, C., Lu, H., Ji, C., & Yan, J. (2015, November). An IoT and mobile cloud based architecture for smart planting. In *2015 3rd International Conference on Machinery, Materials and Information Technology Applications* (pp. 1001-1005). Atlantis Press.

[14]Ray, P. P. (2016). Internet of things cloud enabled MISSENARD index measurement for indoor occupants. *Measurement*, *92*, 157-165.

[15]Mekala, M. S., & Viswanathan, P. (2019). CLAY-MIST: IoT-cloud enabled CMM index for smart agriculture monitoring system. *Measurement*, *134*, 236-244.

[16]Junaid, M., Shaikh, A., Hassan, M. U., Alghamdi, A., Rajab, K., Al Reshan, M. S., & Alkinani, M. (2021). Smart agriculture cloud using AI based techniques. *Energies*, *14*(16), 5129.