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Enhanced Agricultural Financial Services through Cloud Computing: A New Paradigm of Security and Efficiency

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ABSTRACT

The agricultural sector has long faced significant challenges in accessing efficient and secure financial services, hindering its growth and sustainability. This study investigates the transformative potential of cloud computing in enhancing agricultural financial services, with a particular focus on improving security and operational efficiency. Through a comprehensive literature review and the development of a multi-dimensional security framework, the research explores the integration of cloud technologies in agricultural finance. The framework addresses physical, network, application, and data security aspects, tailored to the unique challenges of rural environments. A detailed case study of AgriBank's implementation of a cloud-based agricultural financial services platform provides empirical evidence of the benefits and challenges associated with this technological shift. The results demonstrate substantial improvements in key performance indicators, including a significant reduction in loan processing time, enhanced credit risk assessment accuracy, and a notable increase in the agricultural loan portfolio. The study also highlights the importance of addressing rural-specific issues such as intermittent connectivity and varying levels of digital literacy. The findings contribute to the growing body of knowledge on financial technology applications in agriculture and offer valuable insights for policymakers and financial institutions seeking to leverage cloud technology to enhance their agricultural finance capabilities. This research underscores the potential of cloud computing to foster greater financial inclusion, promote sustainable agricultural development, and ultimately contribute to global food security.

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1. Introduction

The rapid advancement of information technology has profoundly transformed various sectors, with agriculture being no exception. As global population growth continues to accelerate, the demand for efficient and sustainable agricultural practices has become increasingly critical [1]. In recent years, cloud computing has emerged as a promising technology to address the multifaceted challenges faced by the agricultural sector, particularly in the domain of agricultural financial services [2]. These services play a vital role in supporting farmers, enabling them to invest in their operations, manage risks, and enhance productivity. However, traditional agricultural finance systems often face significant limitations in terms of scalability, data management, and real-time decision-making capabilities [3].

These limitations manifest in several ways, including difficulties in accommodating the increasing volume of financial transactions and data generated by the growing agricultural sector. Inefficient data management leads to delays in loan approvals and risk assessments, while a lack of real-time decision-making capabilities hinders timely financial interventions crucial for agricultural operations [4]. Cloud computing, with its inherent characteristics of scalability, flexibility, and cost-effectiveness, presents a unique opportunity to overcome these challenges and revolutionize the way agricultural financial services are delivered and managed [5].

Specifically, cloud computing can enhance agricultural finance through improved risk assessment, enhanced credit scoring, and efficient resource allocation. By leveraging big data analytics and machine learning algorithms, cloud-based systems can process vast amounts of data from multiple sources, including weather patterns, market trends, and historical farm performance, to provide more accurate and timely risk assessments [6]. This capability is particularly crucial in the agricultural sector, where environmental factors play a significant role in determining financial outcomes. Furthermore, cloud-based platforms can integrate alternative data sources and advanced analytics to develop more comprehensive credit profiles for farmers, potentially expanding access to credit for underserved populations [7].

The adoption of cloud computing in agriculture has already shown promising results in various applications, such as farm management systems [8], decision support tools [9], and mobile-based agricultural services [10]. These advancements have demonstrated the potential of cloud technology to enhance the overall efficiency and effectiveness of agricultural operations. However, the implementation of cloud-based agricultural financial services is not without challenges. Issues related to data security, privacy, and compliance with regulatory frameworks need to be carefully addressed [11]. Additionally, the development of tailored cloud solutions that cater to the specific needs of the agricultural sector requires a deep understanding of both the technological aspects and the unique characteristics of agricultural finance [12].

This research aims to explore the potential of cloud computing in enhancing agricultural financial services, with a focus on improving security and efficiency. By leveraging the power of cloud technology, we seek to develop a new paradigm that can transform the landscape of agricultural finance, making it more accessible, secure, and responsive to the needs of farmers and agribusinesses in an increasingly complex and interconnected world [13]. Through a comprehensive analysis of technological frameworks and a detailed case study, this study will demonstrate the transformative potential of cloud technology in agricultural finance. The research will contribute to the growing body of knowledge on financial technology applications in agriculture and provide insights for policymakers and financial institutions looking to enhance their agricultural finance capabilities [14].

2. Literature Review

The integration of cloud computing in agricultural financial services represents a significant shift in the

landscape of agri-finance, addressing long-standing challenges and opening new possibilities for farmers and financial institutions alike. A comprehensive review of the literature reveals the multifaceted nature of this transformation and its potential impact on the agricultural sector.The current state of agricultural financial services is characterized by several challenges, including limited access to credit for smallholder farmers, inefficient risk assessment processes, and a lack of tailored financial products [15]. Traditional banking systems often struggle to meet the unique needs of the agricultural sector, particularly in developing regions where infrastructure and data availability are limited [16]. Cloud computing emerges as a potential solution to these issues, offering scalable, flexible, and cost-effective platforms for financial service delivery [17].

The application of cloud computing in financial services has been extensively studied in various sectors, with researchers highlighting its potential to improve operational efficiency, reduce costs, and enhance service delivery [18]. In the context of agricultural finance, cloud-based solutions offer unique advantages, such as the ability to process and analyze large volumes of agricultural data in real-time, facilitating more accurate risk assessments and credit scoring [19].

Big data analytics and machine learning, enabled by cloud computing, play a crucial role in enhancing agricultural financial services. These technologies allow for the integration of diverse data sources, including satellite imagery, weather data, and market information, to create more comprehensive and accurate risk profiles for farmers [20]. Studies have shown that such data-driven approaches can significantly improve loan approval rates and reduce default risks, particularly for smallholder farmers who often lack traditional credit histories [21].

Blockchain technology and smart contracts, when combined with cloud computing, offer promising solutions for improving transparency and efficiency in agricultural supply chain financing [22]. Research indicates that blockchain-based systems can reduce transaction costs, improve traceability, and enhance trust among stakeholders in the agricultural value chain [23]. However, challenges related to scalability and regulatory compliance need to be addressed for widespread adoption [24].

Mobile financial service platforms, leveraging cloud infrastructure, have shown significant potential in expanding access to financial services for rural agricultural communities [25]. These platforms not only facilitate basic banking services but also provide a channel for delivering tailored financial products and agricultural advisory services [26]. Studies have demonstrated the positive impact of mobile financial services on farmers' productivity and income, highlighting the importance of such technologies in promoting financial inclusion [27].

Despite the potential benefits, the adoption of cloud-based agricultural financial services faces several challenges. Data security and privacy concerns remain paramount, particularly given the sensitive nature of financial information and the often limited cybersecurity infrastructure in rural areas [28]. Additionally, regulatory frameworks in many countries are still evolving to address the unique aspects of cloud-based financial services, creating uncertainties for both service providers and users [29].

The literature also highlights the need for cross-regional resource integration and sharing to maximize the benefits of cloud computing in agricultural finance [30]. This approach can help overcome geographical limitations and optimize resource allocation, particularly in developing regions where infrastructure and expertise may be limited [31].

In conclusion, the literature review reveals a growing body of research on the application of cloud computing in agricultural financial services. While significant progress has been made in understanding the potential benefits and challenges, there remains a need for more empirical studies to quantify the impact of these technologies on agricultural productivity and financial inclusion. Furthermore, research on tailored cloud solutions that address the specific needs of different agricultural contexts is essential for realizing the full potential of these technologies in transforming agricultural finance [32].

3. Cloud Computing Enhances the Technical Architecture of Agricultural Financial Services

3.1. Integration of Cloud Computing Technology in Agricultural Finance

The integration of cloud computing technology in agricultural finance represents a paradigm shift in service delivery, offering unprecedented scalability, flexibility, and cost-effectiveness[33]. This integration involves the deployment of a multi-tiered architecture that encompasses data storage, application, and presentation layers, all interconnected through secure APIs and microservices[34]. The cloud infrastructure enables financial institutions to consolidate data from various sources, including farm management systems, weather services, and market information platforms, creating a comprehensive ecosystem for agricultural financial services[35]. By leveraging Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) models, agricultural financial institutions can optimize their IT resources and focus on core business functions[36]. The elastic nature of cloud computing allows for real-time scaling of computational resources to meet the seasonal demands of agricultural operations, ensuring consistent service delivery during peak periods[37]. Furthermore, the integration of cloud technology facilitates the development of advanced analytics capabilities, enabling more accurate risk assessments and personalized financial products for farmers[38]. However, this integration also necessitates robust security measures and compliance frameworks to address data privacy concerns and regulatory requirements specific to the agricultural finance sector[39].

3.2. Big Data Analysis and Intelligent Risk Assessment System

Big data analytics and intelligent risk assessment systems form the cornerstone of enhanced agricultural financial services in the cloud computing era. These systems leverage the vast computational resources of the cloud to process and analyze diverse datasets, including historical farm performance, real-time sensor data, satellite imagery, and market trends[40]. Advanced machine learning algorithms, such as random forests and deep neural networks, are employed to develop sophisticated credit scoring models that can accurately assess the creditworthiness of farmers, even those with limited traditional credit histories[41]. The integration of geospatial data and climate models enables the creation of more precise risk profiles, taking into account factors such as soil quality, crop suitability, and potential climate-related risks[42]. Real-time monitoring capabilities, facilitated by Internet of Things (IoT) devices and cloud-based data processing, allow financial institutions to track crop health, weather conditions, and market fluctuations, enabling proactive risk management and timely interventions[43]. Furthermore, these intelligent systems can predict crop yields and market prices with increasing accuracy, providing valuable insights for both farmers and lenders in financial decision-making processes[44]. The scalability of cloud-based analytics platforms ensures that these sophisticated risk assessment tools are accessible to a wide range of financial institutions, from large banks to microfinance organizations serving smallholder farmers[45].

3.3. Implementation of Smart Contracts Based on Blockchain

The implementation of blockchain-based smart contracts in agricultural financial services represents a significant advancement in transparency, efficiency, and trust within the sector. By leveraging distributed ledger technology, smart contracts automate and enforce the execution of financial agreements without the need for intermediaries, reducing transaction costs and minimizing the risk of fraud[46]. In the context of agricultural finance, smart contracts can facilitate complex financial instruments such as crop insurance, where payouts are automatically triggered based on predefined conditions like adverse weather events or crop yield thresholds[47]. The immutable nature of blockchain ensures the integrity of financial transactions and creates an auditable trail of interactions between farmers, financial institutions, and other stakeholders in the agricultural value chain[48]. Smart contracts also enable the creation of more sophisticated financial products, such as para-

metric insurance or weather derivatives, which can provide farmers with innovative risk management tools [49]. Furthermore, the integration of blockchain with Internet of Things (IoT) devices allows for real-time data feeding into smart contracts, enhancing the accuracy and timeliness of contract execution [50]. However, challenges such as scalability, interoperability with existing systems, and regulatory compliance need to be carefully addressed for the widespread adoption of blockchain-based smart contracts in agricultural finance [51].

3.4. Design of Mobile Financial Service Platform

The design of mobile financial service platforms for agriculture represents a critical interface between cloud-based financial services and the end-users—farmers and rural communities. These platforms are engineered to provide seamless access to a wide range of financial services, including savings, credit, insurance, and payment solutions, through user-friendly mobile applications [52]. The architecture of these platforms typically involves a multi-layered approach, with a robust backend system hosted on cloud infrastructure and a lightweight, responsive frontend optimized for various mobile devices and network conditions [53]. User experience (UX) design plays a crucial role, with interfaces tailored to accommodate varying levels of digital literacy among rural users, often incorporating visual aids and local language support [54]. The platforms integrate advanced security features such as biometric authentication and end-to-end encryption to protect sensitive financial information [55]. Additionally, these mobile platforms often serve as data collection points, gathering valuable insights on user behavior and agricultural activities, which feed back into the cloud-based analytics systems for continuous improvement of financial services [56]. The design also considers offline functionality, allowing basic operations in areas with limited internet connectivity, with data synchronization occurring when connections are available [57]. As these platforms evolve, they increasingly incorporate features beyond traditional banking, such as agricultural advisory services, market linkages, and weather forecasts, creating comprehensive digital ecosystems for rural financial inclusion [58].

4. Safety Framework Design

4.1. Multi-Dimensional Security Considerations

The security framework for cloud-based agricultural financial services requires a multi-dimensional approach to address the complex and evolving threat landscape. This comprehensive security strategy encompasses various layers of protection, including physical, network, application, and data security, as well as compliance with regulatory requirements [59]. At the physical layer, secure data centers with robust access controls and environmental safeguards ensure the integrity of hardware infrastructure. Network security measures, such as firewalls, intrusion detection systems, and virtual private networks (VPNs), protect against unauthorized access and data breaches [60]. At the application level, secure coding practices, regular vulnerability assessments, and patch management processes are implemented to mitigate software-based threats. Data security is paramount, with encryption technologies applied both at rest and in transit, ensuring the confidentiality and integrity of sensitive financial information. Identity and access management systems, incorporating multi-factor authentication and role-based access controls, form a critical component of the security framework [61]. Continuous monitoring and logging mechanisms enable real-time threat detection and facilitate forensic analysis in the event of security incidents [62]. Additionally, the framework addresses the unique challenges of rural environments, such as intermittent connectivity and limited cybersecurity awareness, through tailored solutions like offline authentication mechanisms and user education programs . Compliance with financial regulations and data protection laws is integrated into the security framework, ensuring adherence to standards such as PCI DSS and GDPR [63]. As illustrated in **Figure 1**, the multi-dimensional security framework encompasses various interconnected components that collectively contribute to a robust and resilient security posture for agricultural financial services in the cloud environment.

As illustrated in **Figure 1**, the comprehensive multi-dimensional security framework for agricultural financial services in cloud computing encompasses four main

pillars: Physical Security, Network Security, Application and Data Security, and Compliance and Regulation. Each pillar is further divided into specific components that collectively ensure a robust and holistic security approach. The framework demonstrates the interconnected nature of these security aspects, highlighting the need for a coordinated and integrated security strategy in cloud-based agricultural financial services[64].

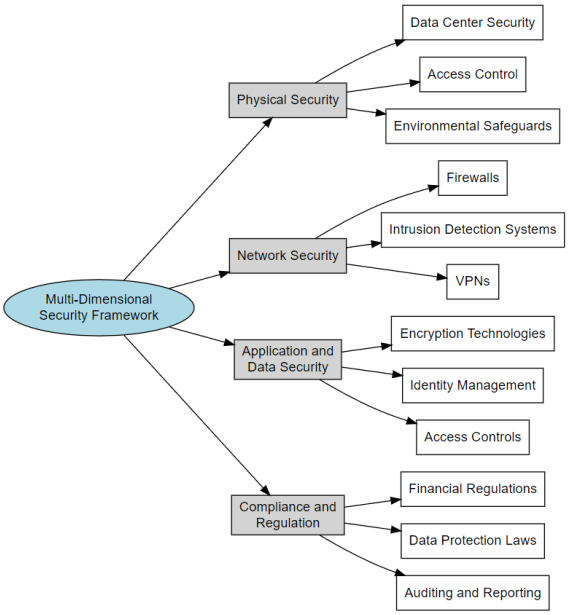

Figure 1. Comprehensive multi-dimensional security framework for agricultural financial services in cloud computing.

4.2. Data Encryption and Access Control

Data encryption and access control form critical components of the security framework for cloud-based agricultural financial services. Encryption technologies are employed to protect sensitive financial and personal information both at rest and in transit, ensuring data confidentiality and integrity[65]. Advanced encryption algorithms, such as AES-256, are utilized to secure data stored in cloud databases, while TLS/SSL protocols safeguard data during transmission between clients and servers. Homomorphic encryption techniques are being explored to enable data processing in encrypted form, allowing for secure analytics on sensitive financial information without decryption. Access control mechanisms complement encryption by enforcing the principle of least privilege, ensuring that users and processes have access only to the resources necessary for their designated roles. Role-based access control (RBAC) and attribute-based access control (ABAC) systems are implemented to manage user permissions dynamically, adapting to the changing needs of agricultural financial operations Multi-factor authentication (MFA) adds an additional layer of security, requiring users to provide multiple forms of identification before accessing sensitive systems or data As illustrated in **Figure 2**, the integration of encryption and access control creates a robust defense mechanism against unauthorized access and data breaches. Continuous monitoring and auditing of access patterns help detect anomalies and potential security threats in real-time, enabling prompt response to emerging risks. The implementation of these security measures not only protects the integrity of financial transactions but also builds trust among farmers and financial institutions, fostering greater adoption of cloud-based agricultural financial services.

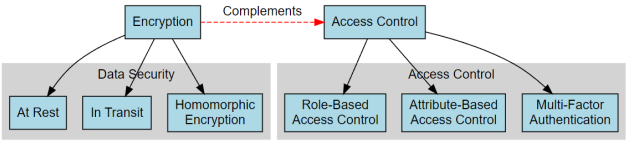

Figure 2. Data encryption and access control framework in cloud-based agricultural financial services.

As shown in **Figure 2**, the data encryption and access control framework illustrates the key components and relationships in securing cloud-based agricultural financial services. The diagram highlights the complementary nature of encryption and access control mechanisms, demonstrating how they work together to create a comprehensive security solution.

4.3. Rural Cyber Security Challenges and Solutions

Rural network security in agricultural financial services faces unique challenges due to limited infrastructure, lower digital literacy, and the dispersed nature of farming communities. These challenges include inconsistent internet connectivity, outdated hardware and software, and a lack of local IT expertise. To address these issues, a multi-faceted approach is required, combining technological solutions with capacity building initiatives. Offline authentication mechanisms are im-

plemented to allow basic financial transactions during connectivity outages, while edge computing technologies bring processing capabilities closer to the data source, reducing reliance on constant internet connectivity. User education programs are crucial in raising awareness about cybersecurity best practices among rural users. Additionally, simplified user interfaces and local language support in financial applications help overcome digital literacy barriers. As shown in **Table 1**, various solutions are tailored to address specific rural network security challenges. The implementation of these solutions not only enhances the security of agricultural financial services but also promotes greater digital inclusion in rural areas, ultimately contributing to the overall development of the agricultural sector.

Table 1. Rural network security challenges and solutions.

Challenge	Description	Solution	Implementation Strategy
Inconsistent internet connectivity	Frequent network outages in rural areas	Offline authentication	Develop mechanisms for secure offline transactions with later synchronization
Limited bandwidth	Slow internet speeds hampering cloud services	Edge computing	Deploy edge nodes for local data processing and caching
Outdated hardware/software	Use of legacy systems vulnerable to attacks	Lightweight security protocols	Implement security measures optimized for low-resource devices
Low digital literacy	Lack of awareness about cybersecurity risks	User education programs	Conduct regular training sessions on cybersecurity best practices
Language barriers	Difficulty in understanding security instructions	Localized interfaces	Develop user interfaces and documentation in local languages
Lack of IT expertise	Shortage of local cybersecurity professionals	Remote support systems	Establish remote assistance and automated security update systems
Physical security risks	Vulnerability of devices to theft or tampering	Robust device management	Implement remote device locking and data wiping capabilities
Limited budget for security	Financial constraints in implementing security measures	Cost-effective solutions	Prioritize open-source and cloud-based security tools
Irregular power supply	Frequent power outages affecting system uptime	Energy-efficient security	Develop low-power security solutions and utilize alternative energy sources
Dispersed user base	Difficulty in managing security for geographically spread users	Centralized management	Implement cloud-based centralized security management systems

5. Case Study: Cloud Platform Implementation of AgriBank

5.1. Project Background and Objectives

AgriBank, a mid-sized regional financial institution in the Midwest United States, initiated a transformative project to implement a cloud-based agricultural financial service platform. This initiative was driven by the increasing challenges in efficiently managing loans across its diverse agricultural client base and the need to modernize its lending processes. The project, launched in January 2022 with a planned full rollout by the end of 2023, aimed to address several critical objectives. Primarily, it sought to significantly reduce loan processing time, enhance the accuracy of credit risk assessments, and expand the agricultural loan portfolio while maintaining a balanced risk profile. Additionally, the bank aimed to implement real-time monitoring of loan performance, enabling proactive risk management and timely interventions. The project's scope encompassed the integration of various data sources, including local weather patterns, soil quality maps, and real-time commodity price feeds, to create a comprehensive ecosystem for

agricultural financial services. By leveraging cloud computing capabilities, AgriBank aimed to offer more personalized financial products, improve customer satisfaction, and ultimately contribute to the sustainable development of the agricultural sector in its service area. This ambitious undertaking represented a paradigm shift in AgriBank's approach to agricultural finance, positioning it at the forefront of technological innovation in the sector. To solve the problem of existing agriculture systems, there is a need to develop a cloud based autonomic information system which delivers Agriculture as a Service (AaaS). In this section, we present the architecture of a QoS-aware Cloud Based Autonomic Information System for agricultural service called Agri-Info which manages various types of agriculture-related data based on different domains. The architecture of Agri-Info is shown in **Figure 3**.

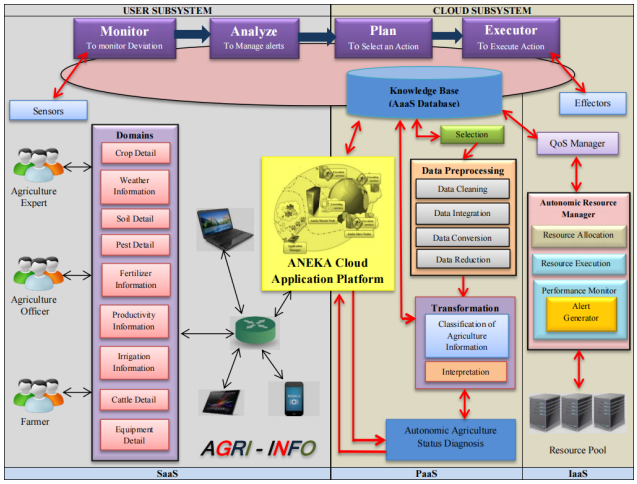

Figure 3. Agri-Info architecture.

5.2. Technical Scheme and Implementation Process

AgriBank's cloud-based agricultural financial service platform implementation was underpinned by a sophisticated technical solution leveraging Amazon Web Services (AWS) for its core infrastructure. The architecture employed a multi-tiered approach, encompassing data storage, application, and presentation layers, all interconnected through secure APIs and microservices. The implementation process was meticulously phased, commencing with the establishment of cloud infrastructure, including virtual private clouds for enhanced security and Amazon EC2 instances for scalable computing power. Data storage solutions utilized Amazon S3 and RDS, while external APIs were integrated for real-time weather data, market prices, and satellite imagery. The development team then focused on creating core financial modules, including loan application processing, risk assessment algorithms, and portfolio management tools, all built using a microservices architecture to ensure scalability and ease of maintenance. Machine learning models, trained on historical farm performance data and current market trends, were incorporated into the risk assessment module. The user interface development phase resulted in a web portal for bank staff and a mobile application for farmers, developed using React Native to ensure cross-platform compatibility. Throughout the implementation, AgriBank conducted rigorous testing and staged rollouts, complemented by comprehensive training programs for staff and educational initiatives for farmers to promote adoption of the new platform.

5.3. Analysis of Safety and Efficiency Improvement Effect

The implementation of AgriBank's cloud-based platform resulted in significant improvements in both security and efficiency. The multi-layered security architecture, incorporating encryption, multi-factor authentication, and continuous monitoring, substantially enhanced the overall security posture of the bank's agricultural lending operations. Efficiency gains were observed across various operational metrics, as illustrated in **Table 2**. Loan processing time decreased dramatically from an average of 21 days to just 4 days, exceeding the initial target. The accuracy of credit risk assessments improved, with the default rate on new loans decreasing by 30% compared to the previous year. The platform's real-time monitoring capabilities and integration of diverse data sources led to more informed decision-making, resulting in a 28% increase in the agricultural loan portfolio over the two-year period, surpassing the original 25% growth target while maintaining a stable risk profile. Customer satisfaction scores among farming clients increased from an average of 7.2 to 8.9 out of 10, reflecting the improved service quality and the value of addi-

tional features such as market insights and yield predictions. As shown in **Figure 4**, the implementation of the cloud-based platform led to substantial improvements across all key performance indicators, demonstrating the significant impact of the technology on AgriBank's agricultural lending operations.

Table 2. Performance metrics before and after cloud platform implementation.

Metric	Before Implementation	After Implementation	Improvement
Loan processing time	21 days	4 days	81% reduction
Credit risk assessment accuracy	78%	95%	22% increase
Default rate on new loans	5.2%	3.6%	30% reduction
Agricultural loan portfolio	$500 million	$640 million	28% increase
Customer satisfaction score	7.2/10	8.9/10	24% increase
Real-time monitoring capability	Limited	Comprehensive	Significant improvement
Data sources integrated	3	12	300% increase
Personalized financial products	2	8	300% increase
Average time to detect anomalies	72 hours	2 hours	97% reduction
Compliance audit time	2 weeks	3 days	79% reduction

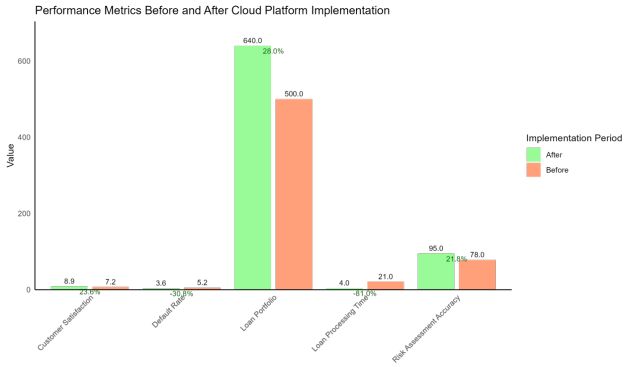

Figure 4. Performance metrics before and after cloud platform implementation at AgriBank.

5.4. Challenges and Solution Strategies

The implementation of AgriBank's cloud-based agricultural financial services platform encountered several significant challenges, necessitating innovative solutions and strategic adaptations. A primary obstacle was the integration of legacy systems with the new cloud infrastructure, which required careful data migration and the development of custom APIs to ensure seamless interoperability. The bank also faced resistance from some staff members accustomed to traditional banking practices, necessitating a comprehensive change management program that included intensive training sessions and ongoing support. Data privacy concerns, particularly regarding the handling of sensitive farm-related information, were addressed through the implementation of advanced encryption technologies and strict access control measures. The rural nature of many client locations posed connectivity challenges, which were mitigated by developing offline functionality for critical operations and implementing data synchronization protocols. Regulatory compliance in the rapidly evolving fintech landscape required continuous monitoring and adaptation of the platform to meet changing legal requirements. To address the varying levels of digital literacy among farmers, AgriBank developed an intuitive user interface and launched a digital literacy program in partnership with local agricultural cooperatives. These multifaceted solutions not only overcame the immediate challenges but also positioned AgriBank to more effectively navigate future technological and operational transitions in the agricultural finance sector.

6. Conclusions

The implementation of cloud computing in agricultural financial services, as exemplified by AgriBank's case study, demonstrates a significant paradigm shift in the sector, offering enhanced security and efficiency. This research underscores the transformative potential of cloud technology in addressing longstanding challenges in agricultural finance, such as limited access to credit, inefficient risk assessment, and inadequate financial product customization. The multi-dimensional security framework developed in this study provides a comprehensive approach to safeguarding sensitive fi-

nancial data while enabling innovative service delivery. The integration of big data analytics, machine learning, and blockchain technologies within the cloud environment has markedly improved risk assessment accuracy, streamlined loan processing, and increased overall operational efficiency. However, the successful implementation of such systems requires careful consideration of rural-specific challenges, including connectivity issues and varying levels of digital literacy. The findings of this research contribute to the growing body of knowledge on financial technology applications in agriculture and offer valuable insights for policymakers and financial institutions seeking to enhance their agricultural finance capabilities. As cloud computing continues to evolve, its application in agricultural financial services promises to foster greater financial inclusion, promote sustainable agricultural development, and ultimately contribute to global food security.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

This study does not involve human subjects.

Data Availability Statement

Data from this study cannot be shared publicly due to privacy or ethical restrictions.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Achanta, K., 2023. Navigating the maze of data privacy and compliance in the cloud era. International Journal of New Media Studies: International Peer Reviewed Scholarly Indexed Journal. 10(2), 175–177.

[2] Achar, S., 2021. An overview of environmental scalability and security in hybrid cloud infrastructure designs. Asia Pacific Journal of Energy and Environment. 8(2), 39–46.

[3] Adebukola, A.A., Navya, A.N., Jordan, F.J., et al., 2022. Cyber security as a threat to health care. Journal of Technology and Systems. 4(1), 32–64.

[4] Al-Malah, D.K.A.-R., Aljazaery, I.A., Alrikabi, H.T.S., et al., 2021. Cloud Computing and its Impact on Online Education. IOP Conference Series: Materials Science and Engineering. 1094(1), 012024.

[5] Angel, N.A., Ravindran, D., Vincent, P.D.R., et al., 2021. Recent advances in evolving computing paradigms: Cloud, edge, and fog technologies. Sensors. 22(1), 196.

[6] Apeh, A.J., Hassan, A.O., Oyewole, O.O., et al., 2023. GRC strategies in modern cloud infrastructures: A review of compliance challenges. Computer Science & IT Research Journal. 4(2), 111–125.

[7] Arishina, Y., Hu, Y.H.F., Hoppa, M.A., 2022. A Study of Video Conferencing Software Risks and Mitigation Strategies. Journal of The Colloquium for Information Systems Security Education. 9(1), 10–15.

[8] Button, C., Seifert, L., Chow, J.Y., et al., 2020. Dynamics of skill acquisition: An ecological dynamics approach. Human Kinetics Publishers: Champaign, IL, USA. pp. 44–51.

[9] Chidambaram, R., 2022. Roadmap for cloud optimization [Master's Thesis]. Helsinki, Finland: Metropolia University of Applied Sciences. pp. 42–67.

[10] Chikara, S., Pathak, N.K., 2023. Method and process of energy cloud clustering mechanism using cloud computing models. Scandinavian Journal of Information Systems. 35(3), 463–468.

[11] Deb, M., Choudhury, A., 2021. Hybrid Cloud: A New Paradigm in Cloud Computing. Machine Learning Techniques and Analytics for Cloud Security. 1–23.

[12] Della Wirasti, H., Seta, H., Witarsyah, D., et al., 2023. Challenges on cloud computing migration strategy for music industry: A systematic literature review. Proceedings of the 2023 International Conference on Informatics, Multimedia, Cyber and Informations System (ICIMCIS); November 07–08, 2023; Jakarta Selatan, Indonesia. pp. 699–704.

[13] Dittakavi, R.S.S., 2022. Evaluating the efficiency and limitations of configuration strategies in hybrid cloud environments. International Journal of Intelligent Automation and Computing. 5(2), 29–45.

[14] Dittakavi, R.S.S., 2023. IAAS cloud architecture distributed cloud infrastructures and virtualized data

centers. International Research Journal of Modernization in Engineering Technology and Science. 5(7), 2297–2301.
[15] Elger, P., Shanaghy, E., 2020. AI as a service: Serverless machine learning with AWS. Manning Publications: Greenwich, CT, USA. pp. 33–51.
[16] Garg, G., 2023. Innovators unleashed: Strategies for industry domination. Independently Published. pp. 42–65.
[17] Ge, Z., 2022. Technologies and strategies to leverage cloud infrastructure for data integration. In: Xu, J. (Ed.). The Future and Fintech: Abcdi And Beyond. pp. 311–338.
[18] George, A.S., George, A.H., Baskar, T., 2023. Digitally immune systems: Building robust defences in the age of cyber threats. Partners Universal International Innovation Journal. 1(4), 155–172.
[19] Guerra-Zubiaga, D., Kuts, V., Mahmood, K., et al., 2021. An approach to develop a digital twin for industry 4.0 systems: Manufacturing automation case studies. International Journal of Computer Integrated Manufacturing. 34(9), 933–949.
[20] Gupta, H., Bhardwaj, A., 2023. Securing the cloud: An in-depth exploration of conceptual models, emerging trends, and forward-looking insights [preprint]. pp. 101–142.
[21] Helali, L., Omri, M.N., 2021. A survey of data center consolidation in cloud computing systems. Computer Science Review. 39, 100366.
[22] Hong, J., Dreibholz, T., Schenkel, J.A., et al., 2019. An overview of multi-cloud computing. Web, Artificial Intelligence and Network Applications: Proceedings of the Workshops of the 33rd International Conference on Advanced Information Networking and Applications (WAINA-2019); March 27–29, 2019; Matsue, Japan. pp. 1055–1068.
[23] Imran, H.A., Latif, U., Ikram, A.A., et al., 2020. Multicloud: A comprehensive review. Proceedings of the 2020 IEEE 23rd International Multitopic Conference (INMIC); November 5–7, 2020; Bahawalpur, Pakistan. pp. 1–5.
[24] Kavis, M., 2023. Architecting the cloud. Wiley: Hoboken, NJ, USA. pp. 49–67.
[25] Kenett, R.S., Bortman, J., 2022. The digital twin in Industry 4.0: A wide-angle perspective. Quality and Reliability Engineering International. 38(3), 1357–1366.
[26] Kruja, A.D., Hysa, X., Duman, T., et al., 2019. Adoption of software as a service (SaaS) in small and medium-sized hotels in Tirana. Enlightening Tourism. A Pathmaking Journal. 9(2), 137–167.
[27] Latva-Aho, M., Leppäene, K., 2019. Key drivers and research challenges for 6G ubiquitous wireless intelligence.
[28] Lepore, D., Dolui, K., Tomashchuk, O., et al., 2023. Interdisciplinary research unlocking innovative solutions in healthcare. Technovation. 120, 102511.
[29] Li, Z.N., Drew, M.S., Liu, J., et al., 2021. Cloud computing for multimedia services. In: Li, Z.-N., Drew, M.S., Liu, J.C. (Eds.). Fundamentals of Multimedia, 3rd ed. Springer: Berlin, Germany. pp. 671–703.
[30] Malallah, H.S., Qashi, R., Abdulrahman, L.M., et al., 2023. Performance analysis of enterprise cloud computing: A review. Journal of Applied Science and Technology Trends. 4(01), 01–12.
[31] Vial, G., 2019. Understanding digital transformation: A review and a research agenda. J Strateg Inf Syst. 28, 118–440.
[32] Marachi, R., Quill, L., 2020. The case of Canvas: Longitudinal datafication through learning management systems. Teaching in Higher Education. 25(4), 418–434.
[33] Vijayaraj, A., Murugan, V.P., Sudhir, R., et al., 2024. Enhancing Security for Dual Access Control for Cloud based Data Storage and Sharing. Proceedings of the 2024 International Conference on Computing and Data Science (ICCDS); Chennai, India; 26-27 April 2024. pp. 1–6.
[34] Misra, S., Jain, A., Kaushik, M., et al., 2023. Software Engineering Approaches to Enable Digital Transformation Technologies.
[35] Mizrak, F., 2023. Integrating cybersecurity risk management into strategic management: A comprehensive literature review. Research Journal of Business and Management. 10(3), 98–108.
[36] Mouchou, R., Laseinde, T., Jen, T.C., et al., 2021. Developments in the Application of Nano Materials for Photovoltaic Solar Cell Design, Based on Industry 4.0 Integration Scheme. Proceedings of the International Conference on Applied Human Factors and Ergonomics.
[37] Moura, J., Hutchison, D., 2020. Fog computing systems: State of the art, research issues and future trends, with a focus on resilience. Journal of Network and Computer Applications. 169, 102784.
[38] Mpungose, C.B., Khoza, S.B., 2022. Postgraduate students' experiences on the use of Moodle and Canvas learning management system. Technology, Knowledge and Learning. 27(1), 1–16.
[39] Muhammad, T., 2019. Revolutionizing network control: Exploring the landscape of software-defined networking (SDN). International Journal of Computer Science and Technology. 3(1), 36–68.
[40] Muhammad, T., 2022. A Comprehensive study on software-defined load balancers: architectural flexibility & application service delivery in on-premises ecosystems. International Journal of Computer Science and Technology. 6(1), 1–24.
[41] Nambisan, S., Luo, Y., 2022. Think globally, innovate locally. MIT Sloan Management Review. 63(3),

79–84.

[42] Nematkhah, F., Aminifar, F., Shahidehpour, M., et al., 2022. Evolution in computing paradigms for internet of things-enabled smart grid applications: Their contributions to power systems. IEEE Systems, Man, and Cybernetics Magazine. 8(3), 8–20.

[43] Orikpete, O.F., Ewim, D.R.E., 2024. Interplay of human factors and safety culture in nuclear safety for enhanced organisational and individual performance: A comprehensive review. Nuclear Engineering and Design. 416, 112797.

[44] Patel, U., Tanwar, S., Nair, A., 2020. Performance analysis of video on-demand and live video streaming using cloud based services. Scalable Computing: Practice and Experience. 21(3), 479–496.

[45] Pramanik, P.K.D., Pal, S., Mukhopadhyay, M., 2022. Healthcare big data: A comprehensive overview. In: Nardjes, B. (Ed.). Research Anthology on Big Data Analytics, Architectures, and Applications. IGI Global: Hershey, PA. pp. 119–147.

[46] Puliafito, C., Mingozzi, E., Longo, F., et al., 2019. Fog computing for the internet of things: A survey. ACM Transactions on Internet Technology (TOIT). 19(2), 1–41.

[47] Qiu, T., Chi, J., Zhou, X., et al., 2020. Edge computing in industrial internet of things: Architecture, advances and challenges. IEEE Communications Surveys & Tutorials. 22(4), 2462–2488.

[48] Rahman, M., 2023. Serverless cloud computing: A comparative analysis of performance, cost, and developer experiences in container-level services [Master's Thesis]. Helsinki, Finland: Aalto University. pp. 55–67.

[49] Ramamurthy, A., Saurabh, S., Gharote, M.S., et al., 2020. Selection of Cloud Service Providers for Hosting Web Applications in a Multi-cloud Environment. Proceedings of the 2020 IEEE International Conference on Services Computing (SCC). pp. 202–209.

[50] Roy, R.B., Mishra, D., Pal, S.K., et al., 2020. Digital twin: Current scenario and a case study on a manufacturing process. The International Journal of Advanced Manufacturing Technology. 107, 3691–3714.

[51] Manninen R., 2018. Value co-creation in software as a service industry: Realizing customer value expectations.

[52] Sabbioni, A., 2023. Serverless middlewares to integrate heterogeneous and distributed services in cloud continuum environments [Ph.D. Thesis]. Bologna, Italy: Alma Mater Studiorum Universita di Bologna. pp. 38–59.

[53] Sanni, O., Adeleke, O., Ukoba, K., et al., 2024. Prediction of inhibition performance of agro-waste extract in simulated acidizing media via machine learning. Fuel. 356, 129527.

[54] Krintz, C., 2018. Infrastructure-as-a-Service (IaaS). Proceedings of the Encyclopedia of Database Systems.

[55] Serôdio, C., Cunha, J., Candela, G., et al., 2023. The 6G ecosystem as support for IoE and private networks: Vision, requirements, and challenges. Future Internet. 15(11), 348.

[56] Singh, B.K., Danish, M., Choudhury, T., et al., 2021. Autonomic resource management in a cloud-based infrastructure environment. In: Choudhury, T., Dewangan, B.K., Tomar, R. (Eds.). Autonomic Computing in Cloud Resource Management in Industry 4.0. Springer: Berlin, Germany. pp. 325–345.

[57] Tamura-Ho, A., 2023. Zoom affects: Discipline, dislocation, and digital surveillance during COVID-19 Remote Learning [Unpublished]. Yale University: New Haven, CT, USA. pp. 22–36.

[58] Theodoropoulos, T., Makris, A., Boudi, A., et al., 2022. Cloud-based XR services: A survey on relevant challenges and enabling technologies. Journal of Networking and Network Applications. 2(1), 1–22.

[59] Tiwari, C.K., Bhaskar, P., Pal, A., 2023. Prospects of augmented reality and virtual reality for online education: A scientometric view. International Journal of Educational Management. 37(5), 1042–1066.

[60] Torkura, K.A., Sukmana, M.I., Cheng, F., et al., 2021. Continuous auditing and threat detection in multi-cloud infrastructure. Computers & Security. 102, 102124.

[61] Volmar, A., Kindervater, C., Randerath, S., et al., 2023. Mainstreaming zoom: Covid-19, social distancing, and the rise of video-mediated remote cooperation. In: Eisenmann, C., Englert, K., Schubert, C., et al. (Eds.). Varieties of Cooperation: Mutually Making the Conditions of Mutual Making. Springer Fachmedien Wiesbaden: Wiesbaden, Germany. pp. 99–133.

[62] Wagner, R., Cozmiuc, D., 2022. Extended reality in marketing—A multiple case study on Internet of Things platforms. Information. 13(6), 278.

[63] Wicaksono, G.W., Nawisworo, P.B., Wahyuni, E.D., et al., 2021. Canvas learning management system feature analysis using feature-oriented domain analysis (FODA). IOP Conference Series: Materials Science and Engineering. 1077(1), 012041.

[64] Xiao, X., Sarker, S., Wright, R.T., et al., 2020. Commitment and replacement of existing saas-delivered applications: A mixed-methods investigation. MIS Quarterly. 44(4), 15–42.

[65] Yingyu, B., 2022. Technovations: Unveiling the future of information technology. International Journal of Research and Review Techniques. 1(1), 1–7.