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Exploration of the Safety and Threats Associated with Smart Agriculture-related Technologies

Dong Hu[1], Jiayue He[1] & Qian Wang[2]

[1] Zhaotong University, Zhaotong, Yunnan Province, China

[2] Suijiang County Vocational Senior High School, Zhaotong, Yunnan Province, China

Correspondence: Qian Wang, Suijiang County Vocational Senior High School, Zhaotong, Yunnan Province, China.

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Abstract

Smart agriculture integrates cutting-edge information technologies such as big data, artificial intelligence, and blockchain, deeply integrating them into production decision-making and circulation links related to agriculture, forming a new agricultural business model and solution with significant advantages of intensification, precision, automation, and informatization. Therefore, properly handling the relationship between Agricultural Big Data technology and data security becomes particularly critical.The concept of Agricultural Big Data, comprehensively analyzing various current viewpoints. Subsequently, through specific cases, it elaborates on the driving role of Agricultural Big Data in various links of the agricultural supply chain. To further delves into the unique characteristics of Agricultural Big Data, including its ubiquity, sociality, and interdisciplinarity. Starting from the common problems of big data, it introduces specific issues in the agricultural field and proposes targeted security solutions based on actual smart agriculture application scenarios. This paper aims to provide a new perspective for future research on solving data security issues in the field of smart agriculture, to promote the more rapid and secure development of smart agriculture.

Keywords: agriculture, smart agriculture, data security, technology

1. Introduction

The progress of production methods in the agricultural field is closely linked to the overall level of social development. It can be said that the level of technological application in agriculture reflects the development of social productive forces. Given the special status of agriculture in providing basic subsistence materials for humans, its development process must not only adapt to changes in social productive forces but also to changes in human needs. Especially with the rapid development of information technology, the digitization, intellectualization, and networking of industrial fields have become an inevitable trend[1]. The term "smart agriculture" refers to the new agricultural business model and solution formed by the deep integration of frontier information technologies such as big data, artificial intelligence, and blockchain with production decision-making and circulation links related to agriculture. Through network technology, it achieves comprehensive interconnection of personnel, agricultural machinery, and crops, thereby realizing real-time monitoring of the agricultural production process, obtaining dynamic data, and promoting the accelerated flow of production factors such as information, technology, and funds through these data. Smart agriculture has the advantages of intensification, precision, automation, and informatization. In this process, it can not only realize intelligent management of agricultural product production and processing but also promote the gradual formation of an efficient and precise production and marketing ecosystem in circulation channels, thus reshaping the agricultural industry chain[2].

Agricultural Big Data is one of the important supports for realizing smart agriculture, providing smart agriculture with a digital foundation, a basis for scientific decision-making, and a source of intelligent capabilities, making agricultural production more intelligent, efficient, and sustainable. In the fields related to agricultural production, the benefits of Agricultural Big Data have gradually emerged: in production and circulation links, it helps accelerate the cultivation of high-quality crop varieties, enhance the transparency of agricultural information, and achieve food traceability; through continuous and extensive collection and correlation analysis of Agricultural Big Data, it becomes the "think tank" of modern agricultural production and management, providing direction guidance for agricultural practitioners in production categories, optimized seed selection, and production planning; in market consumption links, it becomes the vane of modern agricultural market consumption, guiding market trends and agricultural product demand; at the macro level of agricultural policy formulation, it provides diverse and accurate data support and analysis conclusions to assist relevant government departments at all levels in making precise decisions.With the development and promotion of Agricultural Big Data technology, data security issues have also become increasingly prominent, bringing risks and hidden dangers to the construction and development of smart agriculture[3]. The destruction, misuse, and leakage of Agricultural Big Data may synchronously affect agricultural production, supply, and market in the fields where smart agriculture is applied. Therefore, in the field of smart agriculture, it is necessary to combine the common risks of big data technology with the industry characteristics of Agricultural Big Data to conduct in-depth analysis and research on the data security risks of Agricultural Big Data and propose feasible solutions.

2. Analysis of Data Security Risks in Smart Agriculture

2.1 Security Risks in Agricultural Big Data Collection

Agricultural Big Data covers various aspects of the entire crop production cycle, including breed selection, farming techniques, and management measures. These links are comprehensively influenced by various factors such as meteorology, resources, the environment, the market, transportation, and safety. Taking rice breed selection as an example, the considerations include meteorological conditions such as temperature, humidity, and precipitation; resource conditions such as organic matter content, nutrient content, and pH value in the soil; as well as economic factors such as market demand and transportation efficiency. Data collection refers to the process of inputting external data into the system through a certain medium. Active collection involves human intervention and is a conscious and targeted data collection behavior; passive collection usually occurs through automated tools and systems without direct human participation. Survey questionnaires and experimental records are common methods in active collection. However, due to the professional competence or insufficient attention of staff, the collected data may be useless or incomplete[4]. To solve this problem, improvements need to be made in questionnaire design, survey planning, and professional competence training for interviewers. Common passive collection methods include web crawlers, sensor information collection, and system data collection. Due to the extensive scope, complexity, and high degree of automation involved in passive collection, there are risks such as intellectual property rights infringement, infringement of personal privacy data, violation of data owner rights, unreliable data sources, and uncontrollable data quality. It is necessary to clarify the collection scope, quantity, and depth according to the purpose and use of the data collection and follow the principle of data minimization to ensure data compliance; on the other hand, data classification and identification should be implemented in the data collection stage to ensure data security and traceability of data provenance quality[5].

In specific scenarios of smart agriculture, agricultural sensors are installed in various locations, making Agricultural Big Data have significant comprehensive characteristics during data collection and bringing corresponding risks. To solve these problems, physically, protective devices such as protective covers can be considered for sensors, and technically, a device monitoring system can be established to ensure the normal operation of the devices, and password verification and other identity verification mechanisms can be added to the collectors to ensure the security and reliability of configuration modifications. Satellite remote sensing has unique advantages in obtaining information such as crop coverage, vegetation growth status, and land use in the agricultural field, but it also faces risks of incomplete and inaccurate data collection at the data security level. For example, when clouds are thick, ground radiation cannot penetrate the cloud layer, resulting in incomplete imaging results of remote sensing satellites; the mixed effect of ground objects makes it difficult for remote sensing satellites to accurately distinguish between ground object types, leading to biases in crop coverage statistics; in addition, the wireless transmission characteristic of satellite remote sensing data also makes it vulnerable to attacks where intruders can invade and tamper with the data. These issues are potential risks inherent in satellite remote sensing technology.

2.2 Security Risks in Data Storage and Transmission

Data transmission involves transmitting data from its source to its destination through one or multiple data links according to established procedures. This process includes both wired and wireless transmission technologies, each with its advantages. Wired technologies, such as Ethernet, USB, and HDMI, provide stable transmission channels; while wireless technologies, such as Wi-Fi, Bluetooth, and Z-wave, break through the limitations of physical connections, bringing convenience to mobile devices and remote communications. However, data transmission also faces various risks, including information leakage caused by attackers intercepting and interpreting the data during transmission, data integrity destruction through man-in-the-middle attacks that hijack and tamper with data, and distributed denial-of-service attacks that block communication channels, making information unreachable. To address these risks, it is necessary to develop appropriate data transmission security strategies and procedures based on specific scenarios and adopt corresponding security measures to ensure the identity authentication of the transmitting and receiving entities, verify data integrity, have data recovery control measures, and audit and monitor changes to security strategies.Agricultural Big Data is ubiquitous and social, encompassing a wide range of data that includes sensitive information critical to the security of national agricultural development strategies, such as soil, geology, water quality, topography, hydrological conditions, and climate. If this information is transmitted in plaintext or using weak encryption protocols and algorithms, it can easily be stolen by domestic and foreign criminals or hostile organizations, posing a threat to national agricultural security and national security. To mitigate such risks, the use of trusted encryption technologies should be mandated to establish secure encryption channels, utilizing trusted algorithms for data encryption and employing technologies such as digital signatures and digital certificates to verify the identities of communicating parties[6-8].

Data storage refers to the process of statically preserving data in various data media and formats, providing capabilities for management, retrieval, and destruction. Stored objects include collected data, analysis and processing result data, and temporary procedural data. In the context of big data, significant differences between big data storage technologies and traditional data storage technologies should be noted. Currently, commonly used big data storage technologies, such as distributed file systems, column-based databases, and SQL databases, can store unstructured, semi-structured, and structured data, catering to the volume, velocity, and variety characteristics of big data, and offering advantages over the centralized storage model of traditional databases. However, as big data storage technologies develop, security risks also gradually emerge, including unauthorized data access leading to leaks, ransomware attacks following data encryption or corruption, and issues such as unclear and insufficiently granular user security permission control rules. The intersectionality and comprehensiveness of Agricultural Big Data allow attackers to derive critical information through correlation analysis of centrally stored data, compromising data confidentiality. For example, attackers may infer the location of solar power generation facilities by querying non-sensitive data and public information in combination. During the data storage phase, security controls should be developed to use correlation models and analysis scripts for security rule detection of centrally stored data, requiring strong business modeling capabilities. Furthermore, homomorphic encryption technology can effectively address the issues arising from the intersectionality and comprehensiveness of Agricultural Big Data, allowing for operations such as search, filtering, and computation on data in an encrypted state without the need for decryption, thereby protecting data privacy[9-10].

2.3 Security Risks in Data Processing and Computing of Agricultural Big Data

In the realm of data processing, it is imperative to closely monitor the entire lifecycle of data processing, encompassing both the handling of data content and the outcomes of data anonymization processes. At the inception of the processing workflow, given the multi-source nature of big data, data processors must first ensure the security of data sources. In accordance with relevant legal provisions, data processors should require data providers to specify the origins of the data. Failure to verify data sources prior to processing vast amounts of data may introduce malicious data, which can lead to incorrect associations during data aggregation and correlation processing, subsequently misleading subsequent data analysis and computation, and potentially providing attackers with opportunities to implant malicious code or launch attacks through the malicious data. Therefore, formulating stringent data source review strategies to ensure data security and compliance is of paramount importance. Prior to anonymization, it is essential to explicitly list the data assets requiring anonymization and establish corresponding classification, grading standards, and anonymization procedures based on the business characteristics of relevant industries. Appropriate anonymization techniques, such as generalization, suppression, and pseudonymization, should be selected for different data types[11]. However, due to the vast volume of big data, attackers may infer anonymized personal privacy data through correlation mining analysis. Consequently, establishing corresponding validation methods for anonymization effectiveness is necessary after anonymization processing to avoid the inclusion of recoverable sensitive data in the processing results, ensuring the effectiveness and compliance of data anonymization, and documenting the anonymization process to meet subsequent security audit requirements.

During the handling of data outliers, attention must be paid to the risk of unauthorized access by data processors, which could lead to data breaches. The capability of data preprocessing often relies on the data platform, and data processors need to ensure data traceability. Nevertheless, vulnerabilities in the platform can compromise data availability. Although data analysis and data computing are distinct, they are interconnected. Data analysis focuses on interpreting data using statistical methods to extract knowledge for business decision-making, while data computing emphasizes processing, analyzing, inferring data, or generating new information using mathematical and computer science methods, with a strong emphasis on technical implementation and computational efficiency.

In practice, data analysis and computing often work synergistically, contributing to intelligent decision-making, problem mining, business process optimization, result prediction, and efficiency enhancement[12].

3. Discussion on Technological Risks in Smart Agriculture

3.1 Social Trust Risks in Smart Agricultural Technologies

Social trust risk refers to the risk of negative ethical impacts on social trust due to improper application of technologies, such as abuse or misuse. Take blockchain technology as an example. Its core function is to create trust, providing a relatively low-cost means to establish complex trust relationships. In the agricultural sector, particularly in the consumption process, the application of blockchain technology is mainly embodied in agricultural product traceability.By recording information on every link of agricultural products from production to consumption on the blockchain, it ensures information security, transparency, and authenticity, enabling consumers to comprehensively monitor the quality of agricultural products and thereby establishing a solid trust mechanism among producers, suppliers, and consumers. Blockchain traceability technology has obvious advantages: firstly, the information on the chain is immutable; secondly, it reduces the workload of inspection and quarantine, avoids repeated inspections due to distrust, and lowers costs[13].

However, technological ethical risks still exist and require governance. The zero-state problem arises when the accuracy of the data in the first block of the blockchain is questioned. This can occur if there is no third-party service to protect stakeholders, if proper due diligence is not conducted on the data, or if the person entering the data makes errors or maliciously alters the information. For example, in a blockchain used to track crop information in a supply chain, the first block may erroneously indicate that a truck is loaded with crops from a specific origin, while in reality, the crops come from another origin. Individuals involved with the truck's contents may have been deceived or bribed along the way. Current blockchain technology can only ensure that uploaded data is not tampered with but cannot guarantee the authenticity of the data. In the absence of third-party supervision, if the items recorded on the blockchain have historically been targets of fraud, bribery, and hacking, then the agricultural information traceability system built on blockchain will lose social trust, leading to serious social ethical issues. Furthermore, the vast amount of data itself can lead to a certain degree of loss of control. Big data is extremely complex in content and form, to the extent that a single ordinary computer cannot process it, requiring the support of distributed technologies and cloud computing, which inherently poses a high technical threshold. As technology develops, big data continues to change in scale, dimensions, and types, exposing various imperfections. With the enhancement of human data capture capabilities, big data continues to grow and become more complex, making it practically very difficult to comprehensively analyze all data, beyond the reach of human capabilities. Therefore, our ability to control big data is limited, and big data is, to some extent, out of human control. On the one hand, there is the issue of agricultural data privacy, where farmers' personal information should be used and protected reasonably to prevent data from being out of control, i.e., abused or leaked. On the other hand, the raw data of Agricultural Big Data is generated by farmers during the production process, but individual farmers do not have the capability to process this data. Therefore, the processing of such big data is usually done by powerful large enterprises. In some countries, after large enterprises obtain and use the data generated by farmers, the farmers are unaware of this[14]. The neglect of data ownership has sparked widespread concern among farmers.

3.2 Ecological and Environmental Issues in Smart Agricultural Technologies

Although many promotions and advertisements for smart agriculture often emphasize its green and safe characteristics and focus on protecting the ecological environment, smart agriculture and green agriculture are actually two different concepts. Without specific attention to ecological safety, smart agriculture can also pose ecological risks. In terms of technology application, smart agriculture utilizes smart sensors to monitor soil moisture, uses drones for farmland patrols, and leverages artificial intelligence to identify crop pests and diseases. In contrast, green agriculture emphasizes the harmonious coexistence of environmental protection and agricultural production. Green agriculture tends to adopt environmentally friendly and sustainable production methods, such as using organic fertilizers instead of chemical fertilizers, to reduce environmental pollution. In terms of focus, smart agriculture primarily aims to improve production efficiency and yield while reducing labor costs to enhance economic benefits. Green agriculture, on the other hand, pays more attention to environmental protection and improving the quality of agricultural products, aiming to promote agricultural development while ensuring environmental protection and the green purity of agricultural products. Smart agriculture focuses more on the application of modern technology and the improvement of production efficiency, while green agriculture emphasizes environmental protection and the quality and safety of agricultural products. Therefore, in the development process of smart agriculture, it is necessary to increase attention to ecological and environmental safety risks[15].

4. Solutions to Risks in Smart Agriculture

4.1 Information Sharing and Mechanism Improvement

In traditional trust-building mechanisms, product quality certification and consumer rights protection are avenues through which consumers place significant trust. However, with technological advancements, information sharing has gradually become a powerful guarantee for enhancing trust between supply and demand due to its ability to significantly reduce the risks associated with information asymmetry. The more information agricultural producers disclose, the better consumers understand agricultural products, leading to enhanced security and trust. Therefore, producers should proactively ensure information openness and transparency. For example, they can establish accounts on social media platforms to disclose production information. Surveys have shown that some consumers choose agricultural products from a particular company because it provides the most comprehensive production information on its online platform. Additionally, interaction and participation are crucial ways to build trust. Allowing consumers to participate in producers' activities can significantly increase their trust in the producers. Therefore, practical ways to effectively enhance corporate trust include inviting consumers to visit production sites or farms in person or engaging with consumers through online platforms. Strengthening the cultivation of information technology talents in the agricultural sector and guiding enterprises to actively participate in the development of specialized software and socialized service technologies for smart agriculture through professional institutions can provide more technical support for information sharing between producers and consumers.

4.2 Integration of Smart Agriculture and Ecological Agriculture

Ecological agriculture, as an agricultural model that meets ecological environmental requirements, helps improve the ecological environment, reduce soil erosion and land degradation, and thereby maintain the stability and healthy operation of ecosystems by minimizing the negative impact of human activities on the natural environment. At the same time, it can protect the diversity and interrelationships of ecosystems, enhance the self-restoration capability of agricultural ecosystems, and rebuild damaged ecological environments. The integration of smart agriculture and ecological agriculture embodies a systems and holistic perspective. Smart agriculture emphasizes technological innovation and informatization application, while ecological agriculture emphasizes ecological environmental protection and resource conservation in agricultural production processes. The integration and innovation of smart and ecological agriculture can bring more opportunities for agricultural development. Through the comprehensive integration of technologies, rather than relying on a single technology, the optimization of the large agricultural system can be achieved. The shift from purely pursuing economic benefits to achieving comprehensive improvements in economic, social, and ecological benefits forms a sustainable composite agricultural ecosystem. Furthermore, if smart agriculture fails to comprehensively consider the use of new technologies, it may lead to a distorted societal perception of agriculture's role. In fact, in the continuous pursuit of new technology applications, human productivity has been greatly enhanced. Alongside choosing the integration of smart and ecological agriculture, under today's efficient social production conditions, there is ample room to accommodate some low-efficiency ecological agriculture. This approach not only meets the diversified needs of the market but also, more importantly, ensures stability at the societal values level[16-17].

5. Conclusion

In reality, many large technology companies are also important governance entities. It is precisely because these technology companies actively govern the commercial and technological platforms they control that they can jointly promote the healthy operation of the entire society in the current digital economy era. At the same time, as an important cornerstone of social governance, the public should also actively participate in the governance of technological ethical risks, especially by proactively safeguarding their legitimate rights and interests. Therefore, the governance of technological ethical risks involves multiple entities and requires collaborative and joint efforts from various parties. In summary, as a new model that further liberates productive forces and enhances the level of agricultural modernization, smart agriculture has become a major trend in future agricultural development. However, it should be noted that smart agriculture itself is a combination of a series of advanced and cutting-edge technologies that are still developing, often accompanied by a series of technological ethical risks that deserve our attention and vigilance, and more importantly, require solutions for governance. Therefore, by continuously innovating the governance system, proactively taking responsibility, and persistently exploring effective ways to solve problems, we can achieve healthier development of smart agriculture. Establishing a framework for big data security risks in smart agriculture scenarios, we can derive specific issues based on proprietary features in the agricultural sector from the common problems of big data. In exploring strategies for Agricultural Big Data security issues, the strategies for data security issues in the field of smart agriculture are still in the preliminary exploration stage, requiring cross-disciplinary talents with knowledge of both agricultural technology and data security. Only by deeply understanding the characteristics and features of Agricultural Big Data can we propose targeted security solutions for actual scenarios to ensure the secure application of Agricultural Big Data in the supply chain, thereby promoting the rapid development of smart agriculture.

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