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The Internet of Things, Applications and Technologies Used: The Case of Blockchain Technology In Smart Agriculture

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The Internet of Things (IoT) constitutes a technological revolution that has fundamentally altered how individuals work, contemplate, and reside. It is an advanced paradigm that requires a range of technologies and infrastructures. This paper presents a literature review on the use of current technologies in various IoT domains, including statistics from recent research works. The statistical results show that blockchain technology is under-researched compared to other technologies, and less used in agriculture than in other sectors, because this technology was initially associated with crypto and did not recognize its importance for other fields, such as agriculture. So, we will later in this study focus on the importance of on the benefits of use of blockchain technology in smart agriculture, and in particular the potential contribution of this technology to supply chains.
Keywords: IoT technologies, blockchain, agriculture, supply chain, transparency, traceability, agri-food.

INTRODUCTION

The proliferation of the Internet of Things (IoT) has led to the pervasive integration of interconnected devices into diverse domains among them is the agricultural field. There are a significant number of researches that have utilized various IoT technologies, but not enough of them have investigated blockchain technology, especially in the agricultural field. In this paper, we are interested in showing the importance of researching the possibilities that this technology offers in the development of smart farming and in tracking the quality of production in supply chains. The rest of the article is organized as follows: Section 2 introduces the general context of the study by talking about the technologies used in IoT and in the field of agriculture. Section 3 gives statistics on the application of the IoT technologies in the field of agriculture and in two other well-known fields, i.e. health and smart cities, with a view to making a comparison. Section 4 presents the results of the statistics. Section 5 discusses the results of statistics made. Section 6 deals with the possibilities offered by Blockchain technology in smart agriculture and finally a conclusion. Crucial IoT technologies (sensors, wireless communication, WSN, cloud computing, Edge computing, Machine learning and big data) (Atlam *et al*., 2018). The IoT is a heterogeneous network comprising various devices such as electronic appliances, mobiles, industrial equipment and others. The most common IoT communication protocols are ZigBee, Bluetooth, Z-Wave, 6LOWPAN and NFC (Shi *et al.*, 2019)The smart technologies in agriculture include the IoT, cloud computing, machine learning, and artificial intelligence. The examples of real-life applications of these technologies in agriculture are to collect weather data, monitor crop growth, detect diseases in crops at an early stage, prevent crop wastage through efficient harvesting, track livestock behavior, monitor the location of animals both inside and outside the farm, and enhance production for both crops and livestock (Idoje *et al*., 2021).

In this literature review the initial screening process involved reviewing titles and abstracts to eliminate irrelevant studies. Full-text analysis was conducted on selected papers to assess their relevance based on predefined research questions and themes. A data extraction table was employed to systematically record study details, including authorship, publication year, methodology, key findings, and identified research gaps.

NOTICES MATERIALS:

This literature review was conducted following a systematic approach to ensure comprehensive coverage of relevant studies.

Database and Search Strategy: Electronic databases such as PubMed, Scopus, Web of Science, and Google Scholar were utilized for literature retrieval. The search strategy incorporated a combination of keywords and Boolean operators to refine the results.

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***Inclusion and Exclusion Criteria*:** Studies were included if they addressed the key research question or provided relevant theoretical insights. Exclusion criteria encompassed articles lacking rigorous methodology or empirical data, studies published in non-indexed journals or with limited accessibility and duplicates or secondary citations without original contributions.

***Data Extraction and Synthesis*:** Key variables included study design, sample size, main findings, and limitations. The data were synthesized using a thematic analysis approach, identifying patterns, gaps, and emerging themes within the literature.

LITERATURE REVIEW

The articles were selected from recognized academic databases, such as Scopus and Web of Science because of their wide range of scientific publications and their relevance to the subject studied, and the articles chosen are all recently published. A content analysis was carried out on twenty articles from the field of agriculture, compared with twenty others articles from two fields just as important as agriculture, namely health and smart cities.

The Internet of Things (IoT) has rapidly evolved, influencing various sectors through its applications. Here's an analysis of key application areas:

***Agriculture*:** Population growth is forcing farmers to increase yields. Thus, contemporary agricultural methods and systems are essential for detecting and preventing the spread of various crop diseases. A tool is proposed to help farmers identify fruit diseases by working on the example of a pomegranate (Bhange and Hingoliwala, 2015). To enhance the precision of weed and crop recognition, a novel approach utilizing a graph convolutional network (GCN) is proposed. This approach contributes by incorporating a semi-supervised learning technique, where features from unlabeled vertices are combined with those of neighbouring labelled vertices. A GCN graph is subsequently constructed based on the extracted CNN features and the associated set of vertices (Jiang *et al*., 2020).

A Smart Farming decision support system has been developed for plant disease detection with improved classification accuracy by proposing a feature selection algorithm optimized by multi-level parameters based on the improved AG for the ELM classifier (IGA-ELM) (Kale and Sonavane, 2019). An intelligent agricultural management system, WALLeSMART, based in the Walloon Region of Belgium, has been developed to address the challenges associated with acquiring, processing, storing, and visualizing large-scale data (Big Data). It is based on the Lambada architecture and comprises three layers (batch, speed and service) (Roukh *et al*., 2020). This article presents an optimized version of the Kappa architecture for faster, more efficient data management in smart farming, by improving the data processing time of the classic Kappa architecture by optimizing the Apache Kafka message queue (Nkamla *et al*., 2021). Frost damage, a significant driver of land use change,

Table 1. Technologies used in study research articles for the intelligent agriculture field.

Articles	IoT Technologies used				
	Wireless communication	IOT sensors	IA and machine learning	Blockchain	Big data & cloud computing
Idoje *et al.* (2021)	✓	✓	✓		
Bhange and Hingoliwala (2015)	✓	✓	✓		
Jiang *et al.* (2020)	✓	✓	✓		
Kale and Sonavane (2019)	✓	✓			✓
Roukh *et al.* (2020)	✓	✓			✓
Nkamla *et al.* (2021)	✓	✓	✓		
Castañeda-Miranda and Castaño-Meneses (2020)	✓	✓			
Skotadis *et al.* (2020)	✓	✓			
Podder *et al.* (2021)	✓	✓			
Doshi *et al.* (2019)	✓	✓			✓
Castillejo *et al.* (2020)	✓	✓		✓	✓
Alshehri (2023)	✓	✓		✓	
Mathi *et al.* (2022)	✓	✓	✓		
Bouarourou *et al.* (2023)	✓	✓	✓		
M S and Kuzhalvaimozhi (2024)	✓	✓			
Montoya-Munoz *et al.* (2022)	✓	✓			✓
Zidi *et al.* (2024)	✓	✓	✓		
Karn *et al.* (2024)	✓	✓	✓		
Hajjaji *et al.* (2023)	✓	✓	✓		
Alonso *et al.* (2020)	✓	✓			✓

poses risks to public health and results in substantial agricultural losses. A smart frost protection irrigation management system is developed to address this issue. It is based on an artificial neural network (ANN) to predict internal greenhouse temperatures and soil temperatures. These predictions guide decisions regarding the activation of the anti-frost water distribution system (Castañeda-Miranda and Castaño-Meneses, 2020). The increased use of pesticides worldwide is having a major impact on public health. The PestGaz detection system proposed offers significant advantages over its competitors because it is a highly sensitive sensor (detection in the ppb range, cost-effective, low power consumption) (Skotadis *et al.*, 2020). IoT solutions offer innovative ways to collect and manage data related to agricultural field monitoring. In the realm of urban agriculture, the IoT-based Smart AgroTech system is introduced, contributing to agricultural technology by enhancing real-time irrigation monitoring and management, thereby improving overall production (Podder *et al.*, 2021). A Plug and Sense warning device will help farmers to better manage their resources by using three means to warn farmers, i.e. the visual LED alert, the Blynk mobile application that allows live feed monitoring, and the various small buzzer sub-alerts (Doshi *et al*., 2019). Additionally, the ECSEL AFarCloud (Aggregate Farming in the Cloud) project provides a distributed platform for autonomous farming. It facilitates the integration and real-time cooperation of cyber-physical farming systems to improve farmers' quality of life (Castillejo *et al.*, 2020).

A framework uses blockchain technology to create an intelligent breeding system (IoT-BC-SLF), enabling transparent and secure exchange between farmers (Alshehri 2023). The proposed system uses machine-learning algorithms to predict accurately the amount of water required by fields and automatic pest identification to accurately predict plant diseases (Mathi *et al.*, 2022). A research initiative seeks to integrate a tailored neural network module designed to identify atypical crop diseases and irregular weather patterns. This module will function as an early warning system to enhance agricultural yield and the resilience and sustainability of agricultural ecosystems (Bouarourou *et al.*, 2023). This initiative aspires to extend network lifespan and improve target coverage by addressing load balancing and hotspot issues. It plans to achieve this by introducing an energy and delay-aware routing (EDAR) scheme for heterogeneous IoT sensors. The scheme will leverage uneven network clustering and employing multipath routing for IoT applications (MS and Kuzhalvaimozhi, 2024). Additionally, a model is suggested to optimize the reliability and, consequently, the continuity of services in smart farms based on the IoT-Fog-Cloud continuum. This model aims to determine the ideal number of fog nodes necessary for deploying agricultural services while considering the diversity of fog capabilities, resource demands, redundancy techniques, and reliability requirements (Montoya-Munoz *et*

Table 2. Technologies used in study research articles for the field of health.

Articles	**IoT technologies used**				
	Wireless communication	**IoT sensors**	**IA and machine learning**	**Blockchain**	**Big data & cloud computing**
Saba *et al.* (2020)	✓	✓	✓		
Aslam and Curry (2021)	✓	✓			✓
Rahman *et al.* (2022)	✓	✓	✓		
Khan and Abaoud (2023)	✓	✓	✓	✓	
Bhuvaneshwari *et al.* (2024)	✓	✓	✓		
Hemalatha *et al.* (2022)	✓	✓	✓		
Gupta *et al.* (2023)	✓	✓			✓
Ahmed *et al.* (2021)	✓	✓			✓
Rahman *et al.* (2023)	✓	✓	✓		✓
Feng and Tan (2020)	✓	✓			✓
Deperlioglu *et al.* (2020)	✓	✓	✓		
Hamidi (2019)	✓	✓	✓		
Santos *et al.* (2015)	✓	✓			✓
Mao *et al.* (2023)	✓	✓	✓		
Ramesh Babu and Balasubramaniam (2023)	✓	✓	✓		
Wu *et al.* (2024)	✓	✓	✓		
Mukherjee *et al.* (2020)	✓	✓			✓
Popkova and Sergi (2022)	✓	✓	✓		✓
Insan and Samopa (2024)	✓	✓			
Zhang *et al.* (2024)	✓	✓		✓	

al., 2022). Furthermore, a smart intrusion detection system (IDS) is proposed to detect cyberattacks on the Internet of Agricultural Things (IoAT). This system uses a novel method known as Downsized Kernel Partial Least Square (DKPLS) to extract and minimize the dimensionality of data features, thereby enhancing detection performance (Zidi *et al.*, 2024). A framework is developed to automate irrigation using a comprehensive analysis of various parameters. This work demonstrates that precision water management based on artificial intelligence and IoT improves crop yield and also water quality with reduced human intervention (Karn *et al.*, 2024). An innovative approach is proposed for sustainable palm cultivation using advanced technologies for early detection and management of the red weevil (destructive palm insect) (Hajjaji *et al.*, 2023). A platform has been developed to enable real-time monitoring of dairy cattle conditions and feed grains, ensuring traceability and sustainability throughout the production processes. The implementation of Edge Computing is shown to reduce data traffic and enhance the reliability of communications between IoT-Edge layers and the cloud (Alonso *et al.*, 2020).

***Health*:** Due to the widespread acceptance of IoT and its multiple applications, including remote monitoring and medical device integration, the healthcare industry has witnessed a revolutionary transformation. A proposed framework aims to reduce the communication overhead and energy consumption between bioservices and e-healthcare systems while improving the security of patient data (Saba *et al.*, 2020). This article aims to propose a real-time monitoring system for athletes' posture with the main objective of physical rehabilitation treatment in medical centres and injury prevention in the training of professional athletes (Aslam and Curry 2021). Another study introduces a digital health and monitoring system utilizing the IoT and AI to timely identify cases of COVID-19 and dengue fever, to improve prevention and control strategies in Bangladesh (Rahman *et al.*, 2022). Although the Internet of Medical Things (IoMT) has advanced patient care, remote health monitoring, and personalized medical interventions, it continues to face challenges related to data privacy and security breaches. This paper presents a novel approach that combines federated learning and blockchain to comprehensively address privacy, security, data integrity, and effective real-time surveillance within IoMT environments (Khan and Abaoud, 2023). A deep learning approach, IoHT-SC-PCCNN-RNT-EXPSO, enables the identification and classification of skin cancer. It employs a progressive cyclic convolutional neural network with ResNexT50 transfer learning, optimized using an exponential particle swarm algorithm. This method reduces computation time and improves accuracy compared to existing techniques (Bhuvaneshwari *et al.*, 2024). A complete blood cell count is crucial in medical analysis for assessing overall health status. The classification of blood cells uses the K-means algorithm and image processing techniques, coupled with an enhanced CNN that offers higher accuracy than conventional CNNs (Hemalatha *et al.*, 2022).

This paper also proposes a secure remote healthcare monitoring framework using NDN communication, integrating IoT with edge computing. The content security is ensured through hashing and encryption mechanisms. The effectiveness of this framework is evidenced by improved content retrieval times and reduced costs associated with accessing required data (Gupta *et al.*, 2023). An ECU-IoHT dataset that leverages an IoHT environment experiencing different attacks that exploit various vulnerabilities, was designed to help the healthcare security community analyze attack behavior and develop counterattacks. -robust measures. Anomaly detection was performed using common algorithms. The results indicated that nearest-neighbour-based algorithms were better at identifying attacks than clustering, statistical, and core-based anomaly detection algorithms (M. Ahmed *et al.*, 2021).

Furthermore, an intelligent health monitoring and diagnosis system for COVID-19 patients with critical cardiac arrhythmia is proposed. The system utilizes an intelligent fuzzy algorithm trained on ECG data from the MIT-BIH database, achieving high diagnostic accuracy and minimizing the need for human intervention (Rahman *et al.*, 2023). The proposed system collects information for tracking, monitoring and managing athletes and medical devices using the ADTT method. The proposed system is modeled and controlled by a Xilinx FPGA device (Feng and Tan, 2020). A secure IoHT system was introduced to act as a clinical decision support system for the diagnosis of cardiovascular diseases. The system uses deep learning algorithms to enhance the accuracy of diagnosis without the need for complex hybrid models. It also ensures secure data processing through a multi-authentication and Tangle-based approach (Deperlioglu *et al.*, 2020). A new standard has been proposed to apply biometric technology to the development of smart healthcare using IoT. Utilizing biometrics and rapid identity standards offers a more reliable method for accessing IoT, promising substantial improvements in smart healthcare systems (Hamidi, 2019). A system is proposed allowing doctors to share information in home networks and with the Internet based on the CoAP protocol. The test results of this system showed that the network overhead is approximately 50% lighter compared to other protocols (Santos *et al.*, 2015). A powerful and smart IoMT system has been developed by combining adaptable handheld triboelectric sensors with deep learning-enhanced data analysis to monitor and analyze movements in individuals with Parkinson's disease (Mao *et al.*, 2023). An image encryption algorithm has been developed by adopting a set of QVNNs solutions to generate the secret keys. It can be used in IoT applications for real-time monitoring, healthcare and other surveillance systems (Ramesh Babu and Balasubramaniam, 2023).

A strategy is suggested that utilizes the normal-field Dirichlet process mixture model alongside the unidentified protocol of the IoT. Additionally, it sets forth behavioural standards that apply the least-squares method of logical inference to infer the specifics of the target protocol. The objective is to enhance data quality, which currently lacks a self-supervisory mechanism, effectively prevent intrusions into the external network, and strengthen the management authority verification system (Wu *et al*., 2024). In the proposed fog computing-based system, we aim to reduce average delay, average jitter and latency on remote cloud servers (Mukherjee *et al*., 2020). Based on the dataset concerning COVID-19 and the 2020 economic crisis figure, an intellectual monitoring solution and a technology-driven, intelligent digital public health management system have been developed and applied through research (Popkova and Sergi, 2022). To address authentication challenges on constrained devices, a digital envelope method is developed for an authentication scheme. This method employs encryption to safeguard data transmitted via the digital envelope technique. The performance levels achieved are acceptable, as the authentication scheme successfully delivers essential security services, including authentication, data confidentiality, data integrity, and non-repudiation (Insan and Samopa, 2024). Additionally, a decentralized data transmission framework is introduced, integrating the capabilities of SAGIN (the Space-Air-Ground Integration Network) with blockchain technology. This framework leverages the enhanced computing and communication abilities of low-earth orbit satellites. Simulation results indicate that the proposed system demonstrates outstanding performance regarding latency and throughput, all while ensuring secure data transmission (Zhang *et al*., 2024).

***Smart cities*:** Structural health monitoring (SHM) has become a paramount necessity in civil engineering to improve the operational performance of ageing infrastructures. The proposed research develops a digital twin (DT) to present real-time static and dynamic data in a richly populated BIM database (Sakr and Sadhu, 2023).

A 3D-printed structure inspired by the vorticella-kirigami (VK) has led to the creation of a highly sensitive 3D vibration sensor intended for structural health monitoring (SHM). These VK-inspired vibration sensors are capable of identifying impacts from the epicentre on delicate structural elements through the Message Queue Telemetry Transport (MQTT) protocol (Kim*et al*., 2023). IoT-SPMS-LoRaWAN introduces a new intelligent parking management system SPMS using LoRaWAN (Long Range Wide Area Network) technology to optimize parking lot use and raise public awareness of the importance of road safety (Jabbar *et al*., 2024). A new anomaly detection and classification technique is proposed based on billiard optimization and deep learning (BBODLADC) in IoT-assisted sustainable smart cities to recognize and correctly classify anomalies in the IoT (Manickam *et al*., 2023). An EMV-SDN data centre network traffic prediction algorithm is suggested, based on the principle of high-precision traffic prediction to improve data

Table 3. Technologies used in smart city research papers.

Articles	IoT technologies used				
	Wireless communication	**IoT sensors**	**IA and machine learning**	**Blockchain**	**Big data & cloud computing**
Sakr and Sadhu (2023)	✓	✓			✓
Kim *et al*. (2023)	✓	✓			
Jabbar *et al*. (2024)	✓	✓	✓		
Manickam *et al.* (2023)	✓	✓	✓		
Cheng *et al*. (2022)	✓	✓	✓		
Zhang (2020)	✓	✓			✓
Zhang *et al.* (2020)	✓	✓		✓	
Tariq *et al* (2021)	✓	✓			✓
Rathore *et al.* (2016)	✓	✓			✓
Chen *et al.* (2021)	✓	✓	✓		
Kolhe *et al.* (2023)	✓	✓	✓		✓
Shankar and Maple (2023)	✓	✓	✓		
Baucas and Spachos (2020)	✓	✓			✓
Singh *et al.* (2022)	✓	✓	✓		
Gheisari *et al.* (2020)	✓	✓			✓
Ahmed and Rani (2018)	✓	✓			
Teng *et al.* (2019)	✓	✓			
Faieq *et al.* (2017)	✓	✓			✓
Vu Khanh *et al.* (2023)	✓	✓			✓
Salih *et al.* (2023)	✓	✓			✓

centre network energy conservation in smart cities (Cheng *et al.*, 2022).

A proposed IoT architecture that utilizes fog computing addresses the challenges of big data management and network scalability. It enhances the coordination, efficiency, and harmony of urban operations through various smart sensing, data processing, and information technology applications (C. Zhang 2020). A lightweight data consensus algorithm based on blockchain technology is proposed with fewer data transmission hops, to reduce the probability of data theft and target data accuracy as well as low energy consumption (W. Zhang *et al.*, 2020). A framework proposed for gathering security requirements in the early development stages of cloud-assisted, IoT-enabled smart city applications. The framework features a three-layer architecture comprising Privacy-Preserved Stakeholder Analysis (PPSA), Security Requirement Modeling and Validation (SRMV), and Secure Cloud Assistance (SCA)(Tariq *et al.*, 2021).

A combined IoT-based system with full functionality for smart city development using Big Data analytics. The proposed system is implemented using Hadoop with Spark, voltDB , Storm or S4 (Rathore *et al.*, 2016). The use of a flood-forecasting model based on a convolutional neural network (CNN) with two-dimensional (2D) convolutional operation provides more accuracy in predicting the flood peak and the time of arrival of the flood (Chen *et al.*, 2021). The solution put forward relies on a machine-learning algorithm known as Advanced Random Forest (ARF). The Adaptive Cloud Virtual Machine Resource Allocation (ACC-VMRA) method is utilized for conducting multi-criteria optimization. Experimental results demonstrate the superior efficiency of the recommended optimization algorithm compared with other techniques currently in use (Kolhe *et al.*, 2023). The SSCI-BDL architecture for IoT networks in smart cities integrates blockchain technology with deep learning to enhance privacy and trustworthiness. Simulation outcomes indicate that this system achieves impressive security levels of 99.5% and maintains a minimal latency rate of 4.1% when compared to current models (Shankar and Maple, 2023).

Ensuring that fog computing remains a dependable choice for IoT applications. an IoT-based sensing framework is developed utilizing an urban sound classification model. By implementing active low and high power states along with resource reallocation, a network configuration is created and tested (Baucas and Spachos, 2020). The development of an evolutionary algorithm and its integration into the Differential Evolution (DE) algorithm aims to optimize communication services for smart healthcare within the IoT context of a smart city. This proposed approach outperforms traditional evolutionary algorithms in IoT applications by requiring fewer function evaluations and reducing traffic services. Furthermore, it enhances efficiency by reducing energy loss for each service while also alleviating load and delay (Singh *et al.*, 2022). A framework is proposed to address the issue of IoT device heterogeneity and privacy preservation at the network edge using a proposed new ontological data model, on the principle of obtaining a privacy-preserving method by frequently modifying the privacy-preserving behaviours of IoT devices (Gheisari *et al.*, 2020). A proposed urban IoT framework begins with a data layer, where the sensor platform employs the optimized AODV-SPEED protocol. This hybrid approach has demonstrated enhancements in delay, energy consumption, packet transmission failure rates, and packet delivery rates compared to the traditional SPEED protocol, making it well-suited for IoT applications (Ahmed and Rani, 2018). This study introduces a novel, cost-effective code dissemination model designed to distribute updated code throughout the city employing mobile vehicles and an opportunistic communication style. To enhance the efficacy of this code dissemination model, a coverage-based greedy deployment strategy for code stations, along with an optimized code selection algorithm, is suggested. The objective is to maximize code dissemination coverage efficiently and economically within a short timeframe (Teng *et al.*, 2019).

After analyzing the complex interrelationships among various technologies and paradigms pertinent to the smart city concept, a context-centric approach is advocated to provide a comprehensive perspective of a smart city from multiple viewpoints, encompassing Cloud, IoT, and Big Data. This aims to establish a framework that integrates the elements of different enablers, exploiting their strengths to create and advance smart applications and services (Faieq *et al.*, 2017). This research introduces a highly effective management mechanism for edge computing tailored for IoT applications within smart cities. These edge servers store data about edge services through a compact database. Consequently, when mobile end-users transition to areas served by a new edge server, relevant properties concerning the edge service are shared between the servers. Experimental findings indicate that this mechanism enhances both service response time and energy efficiency (Vu Khanh *et al.*, 2023). Additionally, an

Table 4. Percentage of IoT technologies used by field.

Fields	**Percentage of IoT technologies used**				
	Wireless communication	**IoT sensors**	**IA and machine learning**	**Blockchain**	**Big data and cloud computing**
Agriculture	100%	100%	45%	10%	30%
Health	100%	100%	60%	10%	40%
Smart city	100%	100%	35%	5%	50%

information-centric networking framework employing Multiaccess Edge Computing (ICNMEC) aims to minimize compute load shedding while optimizing data traffic. Furthermore, an OMNM algorithm (Optimized Memory Network Management) has been developed to improve network traffic control and storage utilization. System modelling tests reveal that it operates efficiently, featuring minimal delays and an optimal network traffic-to-storage ratio (salih *et al.*, 2023).

RESULTS

The table 4 combines the data from the three tables (1, 2 & 3): highlights the varying adoption rates of IoT technologies across three key fields: Agriculture, Health, and Smart Cities. And the graph of figure 1 representing the results of the study:

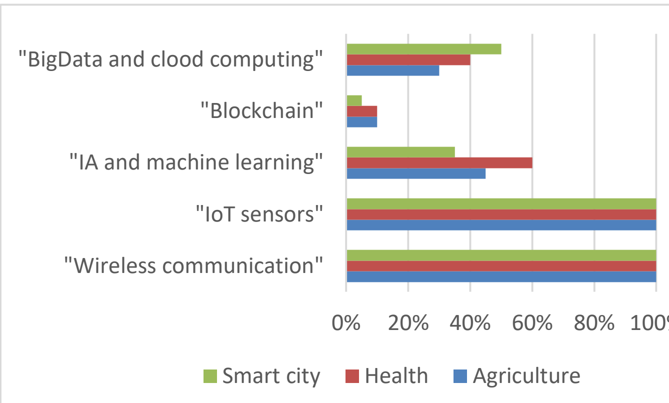

Figure 1. Percentage of technology use by field in articles studied.

Below is a breakdown of key observations:

1. Ubiquity of Wireless Communication and IoT Sensors (100% Adoption Rate). Wireless communication and IoT sensors are universally used across all three fields. This indicates that real-time data collection and transmission are fundamental across industries utilizing IoT. The widespread use of these technologies suggests that connectivity (e.g., LPWAN, 5G, Wi-Fi) and sensor-based monitoring (e.g., temperature, humidity, biometric sensors) form the core infrastructure of IoT applications.

2. In adoption of AI and Machine Learning (Varies from 35% to 60%). The health sector (60%) has the highest use of AI and machine learning, likely due to its applications in predictive diagnostics, personalized medicine, and medical imaging. Agriculture (45%) utilizes AI for precision farming, crop monitoring, and automated irrigation systems. The smart city sector (35%) has the lowest adoption, which suggests that while AI is used for traffic optimization, energy efficiency, and security, it may not yet be as deeply integrated as in healthcare.

3. Limited Use of Blockchain Technology (5% to 10%) Blockchain adoption remains low across all fields, with health and agriculture at 10%, and smart cities at 5%. This suggests that while blockchain offers advantages in security, transparency, and data integrity, its implementation challenges (e.g., scalability, cost, and complexity) may be hindering widespread adoption.

4. Big Data and Cloud Computing (30% to 50%)

Smart cities (50%) lead in big data and cloud computing adoption due to the need for real-time urban monitoring, traffic flow analysis, and large-scale IoT data processing. Healthcare (40%) follows closely, benefiting from electronic health records, cloud-based diagnostics, and telemedicine platforms. Agriculture (30%) has the lowest usage, which may be due to less centralized data processing needs compared to smart cities and healthcare.

DISCUSSION

The results of the study show that the IoT sensors and wireless communication technologies that made the IoT possible were used in 100% of the articles studied, followed by artificial intelligence and machine learning, which was used in 47% of articles, then Big data and Cloud technologies in 40% of articles studied, and lastly Blockchain technology in 8.3% of articles. Agriculture uses fewer technologies than healthcare and smart cities. The use of blockchain technology is limited in the IoT, despite its importance in the fight against fraud and unauthorized activities. That's why this study is interested into the exploitation of blockchain technology for the benefit of agriculture.

***Blockchain in smart agriculture*:** Modern agricultural systems face two challenging issues. Firstly, the data is collected by humans, making it hard to ensure its authenticity, which leads to low credibility. Secondly, this data is housed in a centralized data centre that is susceptible to tampering and hard to oversee. These challenges can be addressed through the integration of blockchain technology and the IoT. This combination will enable transactions to be carried out between several players, guaranteeing anonymity and absolute certification of all exchanges, without the intervention of a trusted third party. The use of blockchain in agriculture will make it possible to increase the level of technicality to produce more and better, while rationalizing costs.

***Blockchain in agricultural systems*:** Significant advancements have been made in intelligent agricultural systems. However, a primary challenge in research remains the development of a dependable autonomous system, as current efforts often struggle with maintaining reliable communication during network congestion. The model put forward explores the application of blockchain security principles to incorporate a trust system aimed at minimizing communication disruptions (Martínez-Castañeda and Feijoo, 2023).

A proposed security solution for autonomous and intelligent mobile devices, including drones and robots used in smart agriculture, is a location verification (LV) protocol that incorporates a blockchain-based secure leasing mechanism for drones (Saba *et al.*, 2023). Incorporating the High-Performance Edwards Curve Aggregate Signature (HECAS) into a blockchain ecosystem results in a 10% improvement in the transaction flow, a 10% increase in block validation, and a 40% decrease in storage expenses compared to an equivalent system without HECAS (Lee and Shin, 2023a).

A suggested system leverages blockchain technology to guarantee confidentiality, security, and easy access to information. It allows individuals to employ natural resources more effectively while minimizing soil and water pollution caused by pesticides and fertilizers. This is achieved by using data stored in the knowledge base (Jayabalasamy and Koppu, 2022).

***Blockchain in supply chains*:** A blockchain- and IoT-based tracking system for agricultural products aims to track the entire agricultural production process, primarily to ensure data security for companies integrated in the agri-food supply chain using blockchain (Sakthi and DafniRose, 2022).

In effect, the European Union's Common Agricultural Policy (CAP) aims to distinguish products based on their quality and enhance transparency regarding food origins, since January 2023. The application of blockchain technology appears pertinent to the agri-food sector in Spain. Most current projects are interested in the traceability of products with higher added value. However, before widespread adoption can occur, several challenges must be addressed, including insufficient information regarding production conditions, the management or organization of the data necessary to ensure those conditions, the lack of established standards, and the narrow range of projects eligible for funding (Sunmola and Burgess, 2022). The principles underlying the design of blockchain-based supply chains are examined through the lens of transparency. This exploration employs a systematic literature review alongside data-driven analysis. The findings offer a framework for establishing transparency within blockchain-based supply chains, presenting key principles (Ferrández-Pastor *et al.*, 2022).

Using blockchain for the supply chain makes farming easier and more transparent to track products from farm to store while lowering financial risks and promoting inclusive trade. This article highlights the advantages of implementing blockchain technology within the supply chain (Kumar and Sharma, 2022). The suggested model establishes a sanctioned blockchain that considers the different participants involved in value chain planning within the hemp sector. It also formulates services utilizing applications featuring human-machine interfaces. It implements a network of interconnected devices that are outfitted with IoT protocols and control algorithms, allowing automated access to the blockchain for traceability services. This model offers an innovative strategy for creating value-added services, by merging digital systems with compatible human activities (Lee and Shin, 2023b).

Re-localizing food systems entails returning them to local communities. This leads to shorter supply chains that counteract the perceived drawbacks of global food systems. This paper intends to introduce a blockchain-driven quality management framework designed specifically for short food supply chains (Burgess *et al.*, 2022).

The idea of the proposed architecture is to offer all agricultural stakeholders secure storage by automating multiple processes using brilliant code to reduce risk and error. The suggested scheme applies blockchain, source code and IoT on an agricultural network to improve the analysis of agrarian datasets and product tracking to increase the productivity of agro-industrial supply chains (Mane *et al.*, 2024).

Sustainability within the food supply chain can be enhanced through blockchain technology. This research introduces an architectural framework based on blockchain for reliable communication regarding the sustainability features of food items. The framework outlines a multi-tiered structure that utilizes blockchain-enabled traceability to convey to consumers the credible sustainability characteristics of specific food products (Patel *et al.*, 2022).

The results of a study suggest that traceability is the most important reason for implementing blockchain technology in supply chains, followed by auditability, immutability and provenance (Kamble *et al.*, 2020).

A peer-to-peer architecture is proposed based on blockchain integrating sovereign identity (SSI) and a decentralized key management system (DKMS) aimed at reliable traceability for agricultural food products in supply chain networks (Hasan *et al.*, 2023).

A blockchain application, "ASBlock", is being developed to manage the agricultural supply chain. The aim is to provide transparency and security for all participating users of the application, with improved performance in terms of smart contract execution times (Panigrahi *et al.*, 2024).

A tailored blockchain approach designed to address big data challenges within fisheries supply chains offers an innovative perspective that maintains the core attributes of anonymity and immutability intrinsic to blockchain technology. Furthermore, the suggested solution combines the traceability of product supply chains with the monitoring of carbon footprints, facilitating a thorough evaluation grounded in quality, sustainability, and carbon footprint metrics (Alwi *et al.*, 2024).

The study's findings indicate that a supply chain using a blockchain-based platform promotes increased investments in sustainability and green efforts to create greener products. Additionally, both the buyer and the producer can benefit from the blockchain platform. However, the expenses associated with adopting and maintaining the blockchain-based platform can outweigh the benefits to the producer (Cao *et al.*, 2022).

A suggested framework for evaluating the maturity level of blockchain enables organizations to measure their advancement in utilizing this technology and its capabilities. The agri-food supply chain participants —including farmers, gardeners, producers, distributors, and food sellers—can determine their preparedness for adopting and implementing blockchain technology. To do this, they can use the blockchain maturity model. This assessment allows them to strategically plan the progression of blockchain technology adoption, aiming to achieve a higher maturity level (Ronaghi, 2021).

***Conclusion*:** Despite its great importance, blockchain technology is under-researched due to several challenges concerning its widespread adoption in the field of scientific research, including the field of agriculture. Current literature shows that blockchain technology can make a significant contribution to smart agricultural supply chains, but there are still challenges to overcome, such as system interoperability and integration cost. A future study will focus on blockchain traceability in supply chains to improve risk management and build trust between trading partners and consumers.

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