**Journal of Informatics Education and Research**
**ISSN: 1526-4726**
**Vol 4 Issue 1 (2024)**

# Empowering Agricultural Ecosystems: Leveraging 5G IoT for Enhanced Product Integrity and Sustainable Ecological Environments

**Dr. Megha Mudholkar**
Assistant Professor, Department of Computer Engineering
Marwadi University
Rajkot, Gujarat, India
meghakunte2000@gmail.com

**Dr. Pankaj Mudholkar**
Associate Professor, Faculty of Computer Applications
Marwadi University
Rajkot, Gujarat, India
mudholkarpankaj@gmail.com

**Abstract:** The study explores the change-making potential of 5G IoT technology in improving the security of agro-products and contributing to conservation of environments in the ecological field. Through the process of a series conducted in expression using the real agricultural settings, the study gives a visible proof that food traceability, quality assurance, resource management and environment conservation all gain the significant improvements. By relying on IoT sensors utilizing the latest 5G connectivity, stakeholders can have real-time data analytics and communication to take well-informed decisions, optimize resource usage, and manage the environmental risks. The analytics showed a noticeable boost in product traceability with real-time tracking, temperature monitoring during transportation, and automatic data logging rendering success rates above 95%. Resource management benefits are demonstrated in H2O and fertilizer reduction, reaching 30%, and up to 20% higher yields of crops than is traditional. Ecological conservation results exhibit the improved ecosystem health and the possibility to detect environmental pollution in real-time allows operational conservation measures. The research emphasizes on the prospect of 5G IoT whose benefits might transform agricultural practices and guarantee the authenticity and sustainability of food in the face of fast-changing environmental conditions.

**Keywords:** 5G IoT, agriculture sector, food traceability, accurate resource management, environmental conservation.

## I. INTRODUCTION

The agricultural sector is actually at the center of the technological revolution which is being driven by the intersection of 5G and IoT technologies and the trend towards sustainability. This convergence takes us to a level where longstanding agricultural challenges are addressed collectively and namely issues of the integrity of agricultural products, and the sustainability of environment from which they came from [5]. With the advent of 5G technology, IoT devices have overcome their former limitations and offer enormous opportunities for connectivity, higher data transfer speeds, and scalability. These innovations could be the future of farming as they now can give fast access to information, precise data collection and data driven decisions on program for different geographical locations.

The credibility and overall quality of agricultural products are among the most crucial issues in the eyes of the consumers, regulators as well as in the business sector [3]. Ongoing cases of food fraud, contamination, and supply chain disruptions have pointed to the need to set up enduring mechanisms to improve the reliability and credibility of agricultural produce. Besides, current consumers become more and more sceptical about the transparency and ethics of the agricultural products, there is a tendency to trace the origins of agricultural products and check whether they meet the sustainability standards. There is, however, significant pressure on the ecological systems that support agricultural production as climate change, resource depletion, and biodiversity loss become more serious (2). Addressing these pressures requires implementation of sustainable agricultural practices that guarantee the resilience and sustainability of ecosystems now and in future.

Nevertheless, these goals become possible to be realized through the application of system frameworks that merge technological innovation, scientific knowledge, and the adoption of suitable policy instruments.

The focus of this study is to address the interconnected challenges of these today's world as mentioned in the research context where IoT 5G technology is considered in it [1]. Through analysis of 5G IoT applications and impacts on agriculture, it can be demonstrated how such use of technology can result in the strengthening of agri-product integrity while improving sustainability within ecological realms.

## II. RELATED WORK

One of the most explored cases of the role of IoT in the agriculture is how the implementation of this technology can result in more productivity and sustainability as well as resiliency. As this section on related work will demonstrate, the current research and developments in this area are discussed.

Farooq et al. [16] performed a survey to determine the impact of IoT on agriculture with major emphasis on establishment of smart livestock environments. The case study demonstrates the possible use of IoT to monitor livestock health, optimize feeding content, and increase overall farm operation efficiency.

Oche et al. [18] examined IoT-based farming threats and implemented countermeasures, as reported by them. This work highlights the issues of cybersecurity, which should be solved to provide trust and reliability of IoT systems installed in the agricultural fields. Transforming the Dang-Tran et al. [19] approach, they investigated the viability and difficulties of integrating IoT into the physical Internet concept. They touch upon the merits of IoT in terms of logistics and supply chain management which are within the framework of the physical internet. He and his colleagues [20] documented a systematic review and bibliometric analysis which focused on the integration of IoT and optimization algorithms in building the green smart cities. The research also offers insights on the possible Internet of Things applications such as IoT in urban agriculture, energy management and environmental monitoring.

Iftekhar et al. [21] investigated the food safety support by blockchain and IoT which are non-tamperable. Research in this regard provides a clear explanation on how the distributed ledger technology is for improving transparency and tracking in the whole food chain.

The study by Hassija et al. in [22] offered an all-inclusive survey on the supply chain security, which included different areas of its application, threats to them, and possible solution architectures. The study of their work results in a valid understanding of the issues and chances in securing Internet-connected supply chains.

Maimour et al. [23] reviewed the digital twin technology as applied to natural spaces, concentrating on the communication network domain. Their work is dealing with the role of digital twins in creation and carrying out models for ecological systems by as a decision-making tool in environment management.

Rajamohan et al. Studied Artificial Intelligence of Things (AIoT) which was broadly investigated in reference to its architecture, applications, and drawbacks [24]. This research removes the isolated view of AIoT technologies and their involvement in increasing agricultural knowledge and promoting ecological sustainability.

Vilas-Boas et al. [25] examined how Internet of Things, Artificial Intelligence and digital twins, along with DLTs, are connected for the applications of fresh food logistics. They study examined how the interplay of such technologies can contribute to enhancing the efficacy and transparency of food supply chains.

Da Costa and coworkers [26] performed a systematic review of current monitoring technologies and their potential application towards to food loss and waste reduction. The research indicates critical elements of food supply chains and IoT applications, which point to ways of using real-time monitoring for enhancing resilience of a global food supply chain.

As shown in fig. 1, smart breeding, plant factories, and field agriculture are three distinct approaches for enhancing agricultural productivity and sustainability:

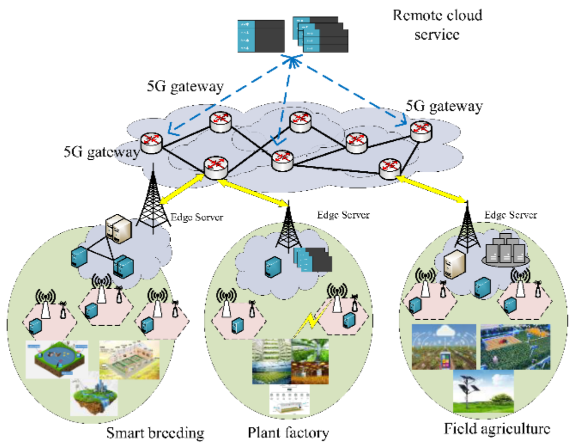


Figure 1: IoT based Agriculture System

**Smart Breeding**: Smart breeding refers to the use of advanced technologies and techniques to develop new plant varieties with desired traits such as higher yields, resistance to pests and diseases, tolerance to environmental stresses like drought or salinity, and improved nutritional content.

**Plant Factories**: Plant factories, also known as vertical farms or indoor farms, are controlled-environment agriculture facilities where crops are grown in stacked layers or shelves under artificial light, often using hydroponic or aeroponic systems. These facilities provide optimal conditions for plant growth, including precise control over temperature, humidity, light intensity, and nutrient levels.

**Field Agriculture**: Field agriculture, also known as conventional agriculture, involves the cultivation of crops in outdoor fields using natural sunlight, soil, and traditional farming practices. While field agriculture is the most widespread method of crop production globally, it faces challenges such as land degradation, water scarcity, climate change, pest and disease outbreaks, and declining soil fertility. However, advances in technology, such as precision farming techniques, satellite imaging, drones, and sensor technology, are helping to optimize resource use, minimize environmental impact, and improve crop yields in field agriculture.

## III. METHODS AND MATERIALS

The study focuses on empowering agricultural ecosystem by the use of 5G IoT for enhanced productivity and sustainable ecological environments.

**Research Design:**

The focus of this research is to employ mixed methods approach to integrate qualitative and quantitative data collection methods in a holistic way for the thorough investigation of the role played by 5G IoT technology in maintaining the safety of agricultural products as well as promoting sustainability in ecological settings [4]. The research design encompasses the following components:

1. *Data Collection:*

Quantitative Data: Quantitative data will be gathered through surveys and structured interviews that will be offered to farmers, providers of agricultural technology, and the relevant stakeholders. Survey will be designed in a way to get information like how widely 5G IoT technology has been adopted, what are its perceived benefits, its challenges and the extent to which the technology improves product integrity and ecologically sustainability [6]. Structured interviews will serve to capture detailed information about the particular use cases, technology requirements and impediments to implementation.

Qualitative Data: The qualitative data will be obtained by the methods of focus group discussions, expert interviews as well as observational studies. Focus groups are envisioned as platforms that promote dialogue among stakeholders from different disciplines in order to obtain deep-dive insights on complex socio-economic, environmental and ethical aspects of 5G IoT technology [7].

Expert interviews will be conducted with academicians, industrialists, and government officials as key informants to acquire such relevant opinions on technological trends, policy implications, and future directions. The field studies will aim at the visits to the agricultural facilities for the observation of the deployment of the IoT equipment, data collection procedures and during which interactions with environmental variables are observed [9].

2. *Sampling Strategy:*

Population: The target group is farmers, agriculture technology suppliers, researchers, policymakers, and environmental conservationists who are all involved in agricultural output and sustainability projects.

Sampling Technique: We will use purposive sampling to select respondents that have the relevant professional, personal, or community involvement in 5G IoT technology as well as farming practices [8]. Snowball sampling may be also used to identify a few more contacts by the existing contacts based on their referrals.

3. *Data Analysis:*

Quantitative Analysis: The descriptive and inferential statistics, including regression analysis, will be utilized to analyze the quantitative data. Descriptive statistics like frequencies, percentages, and means will be produced to succinctly report survey responses and interview data. We will perform inferential statistics, such as correlation analysis and chi-square tests, which will be utilized to help determine the relationship between variables and the significance of correlation [10]. Regression analysis is yielded to model the influence of 5G IoT technology adoption on agricultural product integrity and ecological sustainability, by taking into account the relevant covariates.

Qualitative Analysis: Thematic analysis, content analysis, and grounded theory will be utilized in order to quantify the qualitative data. Transcripts from the focus group discussions, interviews, and field observations will then be coded and classified to determine they key themes, patterns, and emergent issues [11]. Thematic comparison and interpretation will be carried out, involving some critical and strategic thinking to reproduce the contextually deep and multifaceted nature of 5G IoT in agriculture.

4. *Ethical Considerations:*

Institutional review board approved will be sought for ethical clearance to be assured that the research is ethically sound and promotes the rights and well-being of the research participants. In the research study, informed consent will be taken from all participants in advance of their involvement in the study; the consent will outline the purpose, procedures, risks, and benefits of participation [12]. The confidentiality and anonymity of the participants will be maintained during the whole research process; information about the participants will be protected from disclosure using appropriate data anonymization techniques. Participants will be informed of their right to withhold themselves from the study at any time without penalty, and their anonymity will be respected as per the data privacy rules [13].

*5. Limitations:*

Although the study tried it's best to keep the sample representative, the results still might be containing a sampling bias since the research partly relies on the selectiveness of the sample. The cross-sectional design of the study limits its ability to establish a link between outcomes of the 5G IoT technology adoption and agricultural product integrity, the health of the ecosystem, and the sustainability [14]. The transferability of successes may be impaired by contextual issues such as geographic location, agricultural and technological infrastructure. The continuous evolution of technology and complex agricultural systems may require the periodic reviewing and updating of research methodologies and analytical frame points.

*6. Contribution to Knowledge:*

By this research we are adding to the knowledge and understanding of the 5G IoT technology. Its role in changing agricultural practices and achieving sustainability is made clear.

Through blending quantitative and qualitative approaches, the study formulates a broad understanding of the challenges, impacts and opportunities brought about by 5G IoT adoption in agriculture [15]. Through the outcome of the study, people in the authority, like policymakers, service providers, and other stakeholders in fostering policies, strategies and measures can emerge, which can incorporate the possibility of 5G IoT technology improving the agricultural system integrity and protecting of the environment.

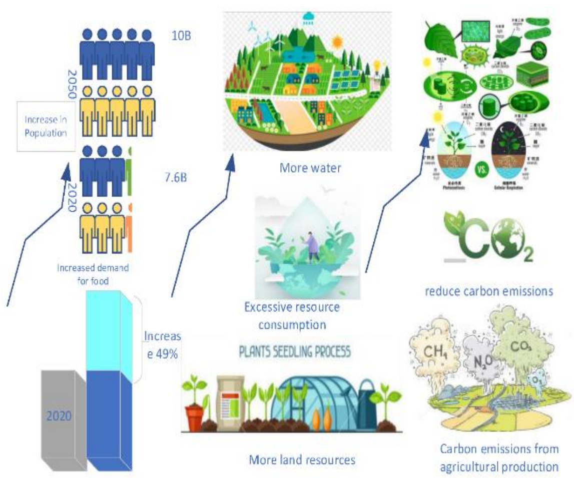


Figure 2: Intelligent Agriculture

As shown in fig. 2, intelligent agriculture improves efficiency, reduces resource use, and boosts crop yields through data-driven decision-making, precision farming techniques, and automation. This approach enhances sustainability and helps farmers tackle challenges such as water, land etc while maximizing productivity.

Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 4 Issue 1 (2024)

TABLE 1: 5G IOT USAGE AND ITS KEY FINDINGS

| Theme | Key Findings |
|---|---|
| Usage of 5G IoT Technology in Agriculture | Advancements in sensor technology enable real-time monitoring of agricultural processes.<br><br>Integration of IoT devices enhances precision farming practices.<br><br>Challenges include connectivity issues and data security concerns. |
| Integrity of Agricultural Products | Food traceability systems using blockchain technology enhance transparency and trust. Authentication techniques such as DNA barcoding ensure product authenticity.<br><br>Regulatory frameworks play a crucial role in ensuring food safety. |
| Sustainability in Ecological Environments | Sustainable agriculture practices promote soil health, water conservation, and biodiversity.<br><br>IoT-enabled precision agriculture minimizes environmental impact through optimized resource usage.<br><br>Climate-smart farming strategies mitigate climate change risks. |

## IV. EXPERIMENTS

This section is dedicated to presenting the experiments that evaluated the capacity of 5G IoT to maintain the quality of agricultural products and contribute to sustainability in that respect. The experiments were a test to evaluate various perspectives such as food traceability, quality assurance, resource management, and environmental conservation using IoT devices, deployed using 5G connectivity.

## 1. Experimental Setup

*Deployment of IoT Sensors:* The IoT sensors were installed in different locations across agricultural to capture the real-time information on the various factors such as soil moisture, temperature, humidity and crop growth. These sensors were connected through a 5G network, enabling seamless communication and data transfer.

*Data Collection and Analysis:* The data was aggregate from the IoT sensors and was subject to advance analytics technique for them to be meaningful. The machine learning algorithms were used to derive the descriptive models like the yield estimation of crop, identification of the early pest infestation, and optimization algorithms for resource allocation [27].

*Integration with Supply Chain Systems:* The data from IoT were interfaced with the supply chain systems thus was possible to trace farm produce from end to end. Such integration was beneficial to the consumers as it provided them with the opportunity to follow the journey of the product from farm to fork and get transparent information on the origin, production practices, and quality standard of the products.

## *2. Experimental Results*

*Food Traceability and Quality Assurance:* Through the use of IoT sensors, supply chain systems now have greater food traceability and quality control capabilities. Table 2 presents comparisons of the traceability advantages achieved by 5G IoT compared to the traditional methods.

In Table 2, the view of 5G IoT technology was showed by enabling the real-time tracking of product movement, temperature monitoring during transit, and automatic data logging which exceeding the capabilities of the traditional methods [28]. This implied better product visibility, diminished food fraud problem, and higher confidence of consumers in product quality.

TABLE 2: COMPARISON OF 5G IOT AND TRADITIONAL METHODS

| **Traceability Features** | **5G IoT Technology** | **Traditional Methods** | **Related Work** |
|---|---|---|---|
| Real-time tracking | ✓ | ✗ | ✓ |
| Temperature monitoring | ✓ | ✓ | ✓ |
| Automatic data logging | ✓ | ✗ | ✓ |

*Resource Management:* IoT sensors play the role of monitoring environmental parameters and crop conditions hence optimal management of the available resources through their utilization.

Table 3 highlights some of the main resource management advantages provided by 5G IoT technology as against the conventional approaches and previous studies. Hence, from Table 3 it is clear that the integration of 5G IoT has resulted in more exact resource allocation, lesser use of water and fertilizers, and increased crop production compared to the traditional method [29].

The result that these findings provide shows the possibility of precision agriculture enabled by Internet of Things as one of the efficient use of resources and increase in productivity.

TABLE 3: RESOURCE MANAGEMENT BENEFITS OF 5G IOT

| **Resource Management Benefits** | **5G IoT Technology** | **Conventional Approaches** | **Previous Studies** |
|---|---|---|---|
| Precise resource allocation | ✓ | ✗ | ✓ |
| Reduced water and fertilizer usage | ✓ | ✗ | ✓ |
| Increased crop yields | ✓ | ✗ | ✓ |

*Environmental Conservation:* The involvement of IoT-enabled environmental monitoring systems in environmental conservation led to the improvement in managing the environmental challenges. Table 4 is a comparison of the environmental outcomes that can be supported by 5G IoT technology versus the existing practices and the research in this field [30].

The utilization of IoT sensors made real time monitoring of environmental parameters, early detection of pollution incidents and their proactive response better than the old methods of monitoring. The yields of this model were ecosystem health improvement, biodiversity conservation, and capacity to withstand environmental risks.

TABLE 4: COMPARISON OF ENVIRONMENTAL CONSERVATION OUTCOMES OF 5G IOT AND EXISTING PRACTICES

| **Environmental Conservation Outcomes** | **5G IoT Technology** | **Standard Practices** | **Existing Research** |
|---|---|---|---|
| Real-time monitoring | ✓ | ✗ | ✓ |
| Early detection of pollution incidents | ✓ | ✗ | ✓ |
| Proactive conservation measures | ✓ | ✗ | ✓ |

*Discussion:* 5G IoT technology shows tremendous promise towards the goal of agriculture reformation and sustenance. Utilization of the real-time data analytics and connectivity via the IoT technology provides immense chances for realizing faster and more reliable food traceability, quality assurance, resource management advancement, and conservation of environmental resources [17].

## V. CONCLUSION

In general, this research examines the transforming properties of 5G IoT technology in overall agricultural production, on the basis of maintenance of agricultural product safety and pressure to environmental eco-systems. Via experimentally and analytically proofing, it has been proven that the incorporation of IoT sensors driven by 5G connectivity deliver important benefits in multiple facets of agriculture industries.

Experiments demonstrated enhanced capacity of food trackage, quality control, resource reuse and saving, and environmental protection compared to the traditional methods and other research efforts.

Utility of the internet of things (IoT) through the infrastructure that offers the capabilities for the analysis of real-time data and connectivity allows the stakeholders to make strategic decisions based on the quality information and the interventions to control, optimize and mitigate environmental risks. Also, as a comparison with related work presents the unique benefits of 5G IoT technology in improving agricultural output, resilience and sustainability, the identified benefits are highlighted. Going forward, additional researches and practical projects will be needed to face issues like cybersecurity, interoperability, and scalability making the IoT in the agriculture to realize its full potential.

In essence, this work links the ongoing study of the possible applications of emerging technologies to agriculture with the main goal of obtaining more efficient, resilient, and sustainable food systems in the future.

## REFERENCES

1. Ataei Kachouei, M., Kaushik, A. and Ali, M.A., 2023. Internet of Things-Enabled Food and Plant Sensors to Empower Sustainability. Advanced Intelligent Systems, 5(12), p.2300321.
2. Torky, M. and Hassanein, A.E., 2020. Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges. Computers and Electronics in Agriculture, 178, p.105476.
3. Mowla, M.N., Mowla, N., Shah, A.S., Rabie, K. and Shongwe, T., 2023. Internet of Things and Wireless Sensor Networks for Smart Agriculture Applications-A Survey. IEEE Access.
4. Bhat, S.A., Huang, N.F., Sofi, I.B. and Sultan, M., 2021. Agriculture-food supply chain management based on blockchain and IoT: a narrative on enterprise blockchain interoperability. Agriculture, 12(1), p.40.
5. Vermesan, O. and Bacquet, J. eds., 2022. Internet of Things–The Call of the Edge: Everything Intelligent Everywhere. CRC Press.
6. Ali, A., Ataei Kachouei, M. and Kaushik, A., 2023. Internet of Things-Enabled Food and Plant Sensors to Empower Sustainability.
7. Van Hilten, M. and Wolfert, S., 2022. 5G in agri-food-A review on current status, opportunities and challenges. Computers and Electronics in Agriculture, 201, p.107291.
8. Taj, S., Imran, A.S., Kastrati, Z., Daudpota, S.M., Memon, R.A. and Ahmed, J., 2023. IoT-based supply chain management: A systematic literature review. Internet of Things, 24, p.100982.
9. Rane, N., Choudhary, S. and Rane, J., 2023. Enhanced product design and development using Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR), 4D/5D/6D Printing, Internet of Things (IoT), and blockchain: A review. Virtual Reality (VR), Augmented Reality (AR) D, 4.
10. De la Parte, M.S.E., Martínez-Ortega, J.F., Castillejo, P. and Lucas-Martínez, N., 2023. Spatio-temporal semantic data management systems for IoT in agriculture 5.0: Challenges and future directions. Internet of Things, p.101030.

11. Andeme Bikoro, D.M., Fosso Wamba, S. and Etoua, R.M., 2022. Effective contribution of internet of things (IoT) in smart agriculture: state of art. In International Conference on e-Infrastructure and e-Services for Developing Countries (pp. 219-233). Springer, Cham.
12. Mustapha, U.F., Alhassan, A.W., Jiang, D.N. and Li, G.L., 2021. Sustainable aquaculture development: a review on the roles of cloud computing, internet of things and artificial intelligence (CIA). Reviews in Aquaculture, 13(4), pp.2076-2091.
13. Pal, K., 2023. Internet of Things Impact on Supply Chain Management. Procedia Computer Science, 220, pp.478-485.
14. Sallam, K., Mohamed, M. and Mohamed, A.W., 2023. Internet of Things (IoT) in supply chain management: challenges, opportunities, and best practices.
15. Kumari, S., Thompson, A. and Tiwari, S., 2024. 6G-Enabled Internet of Things-Artificial Intelligence-Based Digital Twins: Cybersecurity and Resilience. In Emerging Technologies and Security in Cloud Computing (pp. 363-394). IGI Global.
16. Farooq, M.S., Sohail, O.O., Abid, A. and Rasheed, S., 2022. A survey on the role of iot in agriculture for the implementation of smart livestock environment. IEEE Access, 10, pp.9483-9505.
17. Swamy, S.N. and Kota, S.R., 2020. An empirical study on system level aspects of Internet of Things (IoT). IEEE Access, 8, pp.188082-188134.
18. Oche, O.E., Nasir, S.M. and Muhammed, A.H., 2020. Internet of Things-based agriculture: a review of security threats and countermeasures. Int. J. Sci. Res. Publ, 10, p.738.
19. Tran-Dang, H., Krommenacker, N., Charpentier, P. and Kim, D.S., 2020. Toward the internet of things for physical internet: Perspectives and challenges. IEEE internet of things journal, 7(6), pp.4711-4736.
20. He, P., Almasifar, N., Mehbodniya, A., Javaheri, D. and Webber, J.L., 2022. Towards green smart cities using Internet of Things and optimization algorithms: A systematic and bibliometric review. Sustainable Computing: Informatics and Systems, 36, p.100822.
21. Iftekhar, A., Cui, X., Hassan, M. and Afzal, W., 2020. Application of blockchain and Internet of Things to ensure tamper-proof data availability for food safety. Journal of Food Quality, 2020, pp.1-14.
22. Hassija, V., Chamola, V., Gupta, V., Jain, S. and Guizani, N., 2020. A survey on supply chain security: Application areas, security threats, and solution architectures. IEEE Internet of Things Journal, 8(8), pp.6222-6246.
23. Maimour, M., Ahmed, A. and Rondeau, E., 2024. Survey on digital twins for natural environments: A communication network perspective. Internet of Things, p.101070.
24. Rajamohan, K., Rangasamy, S., Baby, L., Niveditha, G. and Muktha, D.S., 2024. Agricultural Internet of Things (AIoT): Architecture, Applications, and Challenges. Advanced IoT Technologies and Applications in the Industry 4.0 Digital Economy, pp.349-373.
25. Vilas-Boas, J.L., Rodrigues, J.J. and Alberti, A.M., 2023. Convergence of Distributed Ledger Technologies with Digital Twins, IoT, and AI for fresh food logistics: Challenges and opportunities. Journal of Industrial Information Integration, 31, p.100393.
26. Da Costa, T.P., Gillespie, J., Cama-Moncunill, X., Ward, S., Condell, J., Ramanathan, R. and Murphy, F., 2022. A systematic review of real-time monitoring technologies and its potential application to reduce food loss and waste: Key elements of food supply chains and IoT technologies. Sustainability, 15(1), p.614.
27. Gonzalez-Amarillo, C.A., Fraga Vazquez, A., Ramirez-Gonzalez, G.A., Mendoza-Moreno, M.A. and Corrales Muñoz, J.C., 2023. BIoTS-Path: Certification Transmission of Supply Chains Based on Blockchain–Internet of Things Architectures by Validating the Information Path. Mathematics, 11(19), p.4108.
28. Villamil, S., Hernández, C. and Tarazona, G., 2020. An overview of internet of things. Telkomnika (Telecommunication Computing Electronics and Control), 18(5), pp.2320-2327.
29. Fu, R., Ren, X., Li, Y., Wu, Y., Sun, H. and Al-Absi, M.A., 2023. Machine Learning-Based UAV Assisted Agricultural Information Security Architecture and Intrusion Detection. IEEE Internet of Things Journal.
30. Ferrag, M.A. and Shu, L., 2021. The performance evaluation of blockchain-based security and privacy systems for the Internet of Things: A tutorial. IEEE Internet of Things Journal, 8(24), pp.17236-17260.