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Impact of 5G in Agricultural Networks: A Review of Improvement Strategies and Publication Trends

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Abstract

This study presents a systematic literature review of the impact of fifth-generation (5G) wireless networks on agriculture, focusing on publication trends, challenges, and opportunities from Scopus papers published between 2015 and 2025. The findings reveal a rapid annual growth rate of 34.93% in research outputs, with 274 documents published across 96 sources, indicating rising global interest in 5G-enabled smart farming technologies. However, persistent challenges include infrastructural limitations in rural farm areas, high costs of implementation, and digital literacy gaps among smallholder farmers. The bibliometric analysis highlights strong international collaboration (28.47%) and dominant contributions from India, China, and the USA. Emerging research trends focus on artificial intelligence (AI), edge computing, and hybrid connectivity models, signaling future directions for 5G-based agricultural innovations. Beyond mapping publication trends, this study synthesizes technical integration pathways and policy-relevant strategies for deploying resilient 5G-enabled agricultural networks in underdeveloped regions.

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A. Introduction of the Study

The agricultural sector is undergoing a profound transformation driven by digital technologies, particularly those that enable smart farming and precision agriculture. These innovations promise to enhance productivity, sustainability, and resource efficiency while addressing the increasing global demand for food security [1]. At the core of this agricultural revolution lies the fifth generation (5G) wireless network, which is celebrated for its high-speed connectivity, low latency, and wide coverage. The integration of 5G with agricultural practices is rapidly reshaping farming landscapes by enabling real-time data transmission, remote monitoring, autonomous machinery, and smart supply chain management [2], [3].

Despite its transformative potential, the deployment of 5G in agriculture presents several challenges. Rural and remote farming regions often suffer from limited connectivity infrastructure, which hampers the ability of farmers to fully leverage 5G-enabled technologies. Weak signals coverage and network dead zones disrupt critical operations such as precision irrigation, livestock monitoring, and automated machinery [4]. Furthermore, the high costs of infrastructure, end-user devices, and service tariffs present barriers for small-scale farmers, even though large-scale implementation may eventually reduce costs [5]. Addressing these infrastructural and economic challenges is essential if farmers, particularly in developing regions, are to realize the benefits of digital agriculture [6]. For instance, studies have demonstrated its role in enabling autonomous tractors, drones, and robotics for farm management [7]. Similarly, integration with the Internet of Things (IoT) and artificial intelligence enhances predictive analytics, allowing farmers to optimize crop yields, reduce resource wastage, and increase resilience to climate variability[8], [9]. However, while the body of literature is expanding, there remains a need to systematically synthesize publication trends to identify research gaps and future opportunities.

Against this backdrop, this study conducts a systematic literature review on the impact of 5G in agriculture. By examining publication trends, challenges, and opportunities, the study seeks to provide insights into how 5G can be harnessed to support sustainable precision agriculture. This systematic literature review study contributes both to academic literature and practical recommendations, particularly for policymakers and telecommunication industries in all African countries, where expanding 5G coverage could enable farmers to feed a rapidly growing population. The study is guided by the following three research objectives:

- To systematically review and analyse publication trends on the application of 5G technology in agriculture between 2015 and 2025.
- To identify the opportunities and challenges associated with integrating 5G into precision agriculture.
- To propose strategic recommendations for enhancing 5G adoption in the agricultural sector.

B. Related Literature Review

Figure 1 illustrates how 5G networks can transform agriculture by enabling real-time connectivity across various smart farming technologies. Through ultra-low latency and high-speed communication, 5G supports autonomous tractors, drones, and soil sensors to optimize precision farming tasks. By integrating IoT

devices with 5G, agriculture becomes more sustainable, cost-effective, and productive. These innovations demonstrate how 5G underpins smart farming ecosystems, improving automation, monitoring, and predictive capabilities for both crop and livestock production [2]; [6], [7], [10].

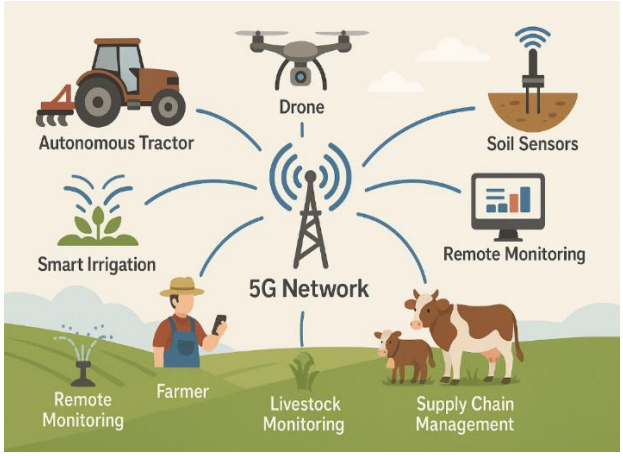

Figure 1. 5G Technology in the Context of Smart Farming

Numerous studies have emphasized the potential of 5G technology in the context of smart farming or precision agriculture. The research by Li et al. [11] elucidates how 5G's high-speed connectivity and low latency facilitate real time data collection and decision-making in farming operations. Similarly, Zhang et al. [12] delve into the role of 5G in enabling autonomous agricultural machinery and its impact on labour efficiency. Several international studies have examined the challenges and applications of 5G in agriculture [5], [13], [14].

Tang et al. [1] conducted "A survey on the 5G network and its impact on agriculture: Challenges and opportunities." Their aim was to systematically review how 5G technologies can transform agriculture through improved connectivity, precision farming, and enabling of IoT/sensor networks, and to identify both challenges (technical, economic, deployment) and opportunities. Their results show that 5G promises much in terms of bandwidth, latency, support for massive device connectivity, which could help real-time monitoring, autonomous machinery, etc., but that practical barriers remain cost of infrastructure, uneven coverage (especially in rural areas), regulatory issues, and that many studies are still conceptual rather than empirical.

Zhivkov et al. [13] in "5G on the Farm: Evaluating Wireless Network Capabilities and Needs for Agricultural Robotics" went beyond conceptual and did empirical and simulated experiments. They tested private 5G Standalone (5G-SA), public 4G, and private WiFi6 in agricultural robotics use cases (robot streaming video, detecting weeds/crops, etc.). They compared throughput, latency, reliability. Their results: public 4G is inadequate for operations requiring high throughput and low latency; 5G-SA greatly outperforms 4G in all metrics; WiFi6 can often outperform 5G-SA in latency and throughput in certain conditions, though it has range limitations. They conclude that no single wireless technology is sufficient; hybrid/combined solutions may be required.

Although these studies provide strong foundations, several gaps remain. However, many studies do not sufficiently address issues such as affordability for smallholder farmers, regulatory / policy constraints in specific regions, smart farming technology readiness, and scaling are less well explored. Therefore, this study will address these by systematically reviewing the trends over time 10 years (2015-2025), quantifying geographic and thematic gaps. The study seeks to advance strategies that telecommunication sectors and agricultural stakeholders in underdeveloped countries can adopt to establish a resilient digital infrastructure capable of supporting 5G-enabled smart farming systems.

C. Systematic Research Methodology

This study adopts a systematic literature review (SLR) approach guided by the PRISMA 2020 framework to ensure rigor, transparency, and reproducibility [15]. Relevant peer-reviewed articles were extracted from the Scopus database, covering the period 2015–2025. The search string combined keywords on 5G, precision agriculture, smart farming, and IoT. VOSviewer was used to conduct the bibliometric analysis of the selected articles by mapping the publication trend [15].

TITLE-ABS-KEY (("5G" OR "fifth generation network") AND ("precision agriculture" OR "smart farming" OR "agricultural technologies")) AND PUBYEAR > 2015 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final"))

Articles were screened in four stages: identification, screening, eligibility, and inclusion. The dataset was refined by limiting results to English-language journal articles and conference papers, published in final stage. This methodological approach enabled a structured mapping of publication trends, challenges, and opportunities of 5G in agriculture, highlighting gaps and guiding future research.

D. Presentation and Discussion Results

The dataset spans 2015–2025 as shown in table 1, covering 96 sources and 274 documents with a high annual growth rate of 34.93%. Documents are relatively recent (average age 2.7 years) and well-cited (14.28 citations per document), supported by 2,374 references. Content is keyword-rich, with 2,366 Keywords Plus and 2,786 author keywords. Authorship is highly collaborative: 2,079 authors contributed, with no single-authored documents, averaging 13.1 co-authors per paper, and 28.47% involving international collaboration. In terms of publication type, conference papers dominate (177), followed by journal articles (97), indicating a strong focus on rapid dissemination and scholarly engagement in emerging research areas.

Table 1. Description of dataset results

Timespan	**2015-2025**
Sources (Journals, Books, etc)	96
Documents	274
Annual Growth Rate %	34.93
Document Average Age	2.7
Average citations per doc	14.28

References	2374
DOCUMENT CONTENTS	
Keywords Plus (ID)	2366
Author's Keywords (DE)	2786
AUTHORS	
Authors	2079
Authors of single-authored docs	0
AUTHORS COLLABORATION	
Single-authored docs	0
Co-Authors per Doc	13.1
International co-authorships %	28.47
DOCUMENT TYPES	
Article	97
Conference Paper	177

Figure 2 shows a steady increase in publications on 5G in agriculture from 2015 to 2020, followed by a sharp increase between 2021 and 2022, peaking in 2024. This reflects growing global interest in leveraging 5G for smart farming, IoT-based monitoring, and precision agriculture. However, the apparent decline in 2025 publications should be interpreted with caution, as Scopus indexing for the year 2025 was still ongoing. Consequently, the substantive trend analysis in this study focuses primarily on the period 2015–2024, where data completeness is assured.

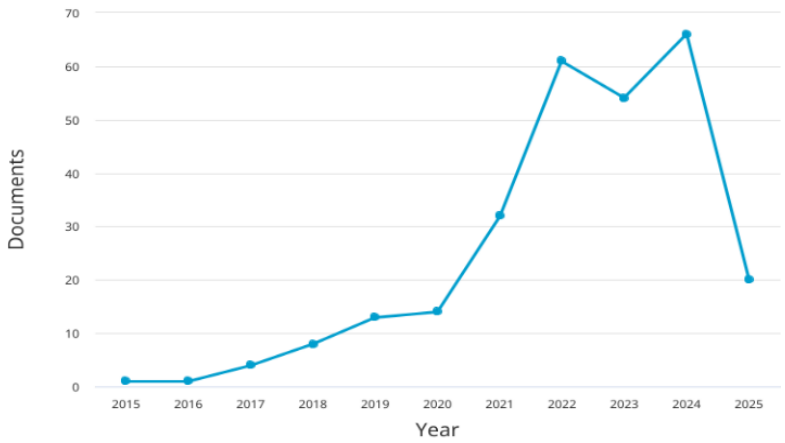

Figure 2. Publication Trends by Years

D.1. Publications by top 20 countries

Figure 3 illustrate the frequency distribution of publications or contributions by country in the field of 5G-enabled smart agriculture and related technologies. India leads significantly with 193 contributions, followed by China (149) and the USA (122). This dominance reflects the strong research investment and strategic prioritization of digital transformation in agriculture within these regions. China and India's leadership is also linked to their large agricultural sectors and

government-driven initiatives promoting smart farming technologies. The USA, while slightly behind, continues to demonstrate robust contributions due to its advanced technological infrastructure and integration of IoT and AI in farming.

European countries such as Germany (63), Italy (56), and Greece (47) also show strong involvement, reflecting the EU's emphasis on precision agriculture and sustainability goals. The UK (34) maintains a visible presence, though smaller compared to continental Europe. Contributions from Brazil and Malaysia (27 each) highlight growing interest in emerging economies, particularly in adapting 5G to local agricultural contexts.

Other contributors such as Saudi Arabia, South Korea, South Africa, and Pakistan reflect regional efforts to integrate smart farming solutions despite infrastructure challenges. Countries with lower frequencies, such as Algeria (16) and Denmark (16), still indicate meaningful but niche participation. As shown in figure 3, India's dominance is not only quantitative but reflects strategic national investments in 5G-enabled agriculture, which contrasts with lower but emerging contributions from African countries such as South Africa. Overall, the distribution underscores global momentum while emphasizing regional disparities in research intensity and capacity.

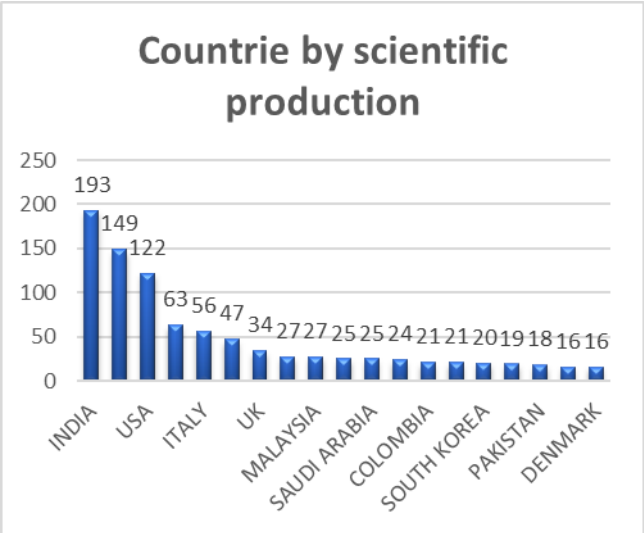

Figure 3. Publication Trends by Country

D.2. Trending key themes

There are several themes that are highlighted which are associated with the role of 5G in agricultural network setups. Motor themes such as edge computing, artificial intelligence, and queuing networks demonstrate high relevance and development, reflecting their role in enabling real-time decision-making and automation. Basic themes like 5G mobile communication systems, IoT, and UAVs form the backbone of smart farming, supporting connectivity and data-driven operations. Niche themes (e.g., low-latency communication, beyond 5G) show strong development but limited agricultural integration, suggesting future research opportunities. Emerging/declining themes, including greenhouses and propagation

models, indicate underdeveloped or specialized areas. Overall, the analysis suggests that while IoT and UAVs dominate as foundational technologies, future progress relies on merging AI, edge computing, and advanced wireless models for robust precision agriculture.

D.3. Indicated challenges associated with integrating 5G into precision agriculture

Integrating 5G into precision agriculture offers significant opportunities but also presents challenges. Opportunities include ultra-reliable low-latency connectivity that enables real-time data transfer from IoT devices, drones, and autonomous machinery, improving efficiency in planting, irrigation, and livestock monitoring [16-19]. 5G enhances machine learning and automation, supporting smart robotics and predictive analytics for crop health and yield optimization [21-23]. Additionally, seamless connectivity strengthens supply chain management and traceability [14].

However, challenges remain. Infrastructure deployment in rural farming areas requires substantial investment, with high costs for base stations, sensors, and equipment upgrades [5], [22]. Connectivity limitations, such as weak coverage and spectrum constraints, hinder large-scale adoption [18]. Farmers also face affordability issues and the need for technical training to effectively use 5G-enabled solutions. Balancing these challenges with opportunities, 5G holds transformative potential for precision agriculture, enabling smarter, data-driven, and more sustainable farming practices.

D.4. Strategies for Establishing a Resilient 5G-Enabled Agricultural Network

To foster a robust digital infrastructure that supports 5G-enabled smart farming systems in underdeveloped regions, both telecommunication sectors and agricultural stakeholders must adopt collaborative and multi-level strategies as shown in figure 4.

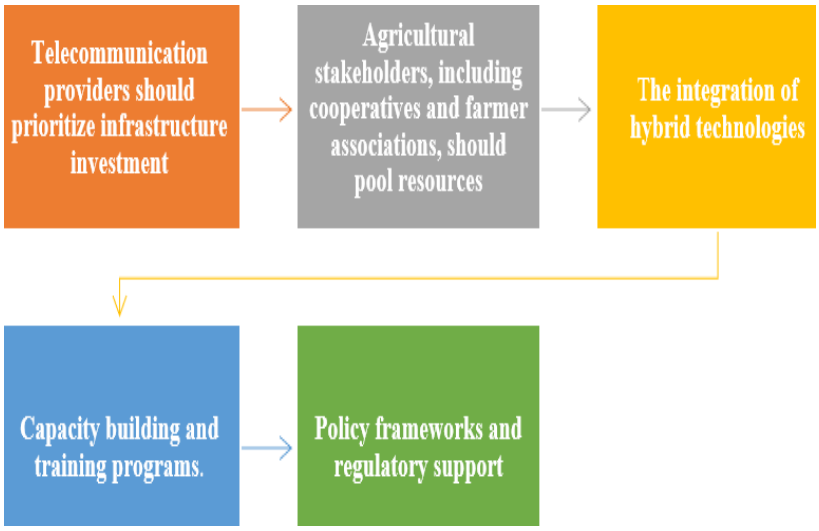

Figure 4. Strategies for Improving 5G-Enabled Agricultural Network

First, telecommunication providers should prioritize infrastructure investment by extending base stations, small cells, and low-power wide-area networks into rural areas, ensuring seamless coverage and reduced latency. These efforts can be supported through public–private partnerships, where governments offer subsidies or incentives to lower the financial burden of deploying advanced networks in remote farming landscapes.

Second, agricultural stakeholders, including cooperatives and farmer associations, should pool resources to establish community-shared connectivity hubs that leverage 5G edge computing nodes for real-time data processing, thus reducing reliance on centralized servers.

Third, the integration of hybrid technologies such as combining 5G with satellite communications, WiFi6, and IoT gateways can provide redundancy and enhance coverage in areas where continuous 5G availability is not feasible.

Fourth, capacity building and training programs are vital to equip farmers with the technical knowledge required to use 5G-enabled IoT devices, drones, and autonomous machinery effectively.

Lastly, policy frameworks and regulatory support must encourage spectrum allocation for agricultural use, affordable data tariffs, and interoperability standards, ensuring that small-scale farmers can access these technologies without prohibitive costs. Together, these strategies will create a resilient, inclusive, and sustainable 5G-driven agricultural ecosystem.

E. Recommendations

The following figure 5 it is a proposed framework as a stepwise process that links policy, infrastructure, implementation mechanisms, capacity building, and farming outcomes to establish a resilient 5G-enabled agricultural ecosystem. The proposed conceptual framework recommends a multi-level approach for establishing resilient 5G-enabled agriculture. At the macro level, governments and telecom providers should collaborate on infrastructure expansion, spectrum allocation, and cost reduction. At the meso level, hybrid connectivity and edge computing hubs should be deployed to support IoT integration for precision farming [25]. At the micro level, farmer training and digital platforms must enhance adoption and literacy. Collectively, these strategies ensure sustainable smart farming, improved productivity, and long-term food security in underdeveloped regions.

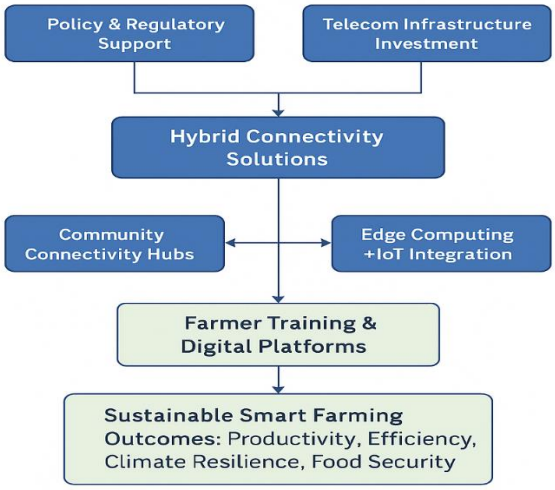

Figure 5. Proposed Conceptual Framework

E.1. Enabling Environment (Policy and Telecom Investment)

At the foundation, government policy and regulatory support are essential to ensure spectrum allocation, affordability of services, and rural connectivity expansion. Tang et al. [1] emphasize that while 5G offers unmatched speed and low latency, its effectiveness in agriculture depends on addressing infrastructure costs and rural coverage challenges. Similarly, Naqvi et al. [14] highlight the role of 5G and upcoming 6G networks in bridging connectivity gaps, but stress that supportive regulations and funding are needed for rural deployment.

E.2. Implementation Mechanisms (Hybrid Connectivity and Edge Computing)

Telecom operators, supported by public–private partnerships, deploy hybrid connectivity solutions that combine 5G with satellite, WiFi6, and IoT gateways to overcome weak signal zones in remote farmlands. According to Liu et al. [2], 5G-enabled IoT architectures enable seamless integration of smart irrigation systems, drones, and livestock sensors, while edge computing reduces latency by processing data locally. Marchese et al. [24] add that the combination of 5G and beyond networks offers precision agriculture unprecedented scalability and flexibility.

E.3. Community Hubs and Farmer Digital Platforms

Community-based connectivity hubs allow shared access to network infrastructure, making it cost-effective for small-scale farmers. Edge computing nodes, integrated at these hubs, ensure local AI-driven analytics for crop monitoring, irrigation control, and predictive decision-making [19]. Farmers then interact with digital platforms for training, apps, and market access, thereby reducing the digital divide.

E.4. Capacity Building (Farmer Training and Literacy)

The success of 5G-enabled agriculture depends not only on infrastructure but also on the digital literacy of end-users. Training programs enhance farmers' ability

to manage IoT devices, interpret data, and apply precision farming tools effectively. Moloudian et al. [22] show that technologies like agricultural robotics demand reliable connectivity, but without adequate user competence, their benefits remain underutilized.

E.4. Sustainable Farming Outcomes

Ultimately, the framework contributes to smart and sustainable farming outcomes, including higher productivity, reduced resource wastage, climate resilience, and food security. Mistry et al. [16] argue that 5G-powered Agriculture 4.0 integrates AI, drones, and IoT into a sustainable ecosystem, while Alsamhi et al. [21] confirm that such integration leads to long-term efficiency and profitability in farming operations.

F. Limitations of the Study

This study is limited to English-language publications indexed in the Scopus database between 2015 and 2025. As a bibliometric and systematic literature review, it does not include empirical field deployments or performance benchmarking of 5G technologies in live agricultural environments. Additionally, publication data for 2025 may be incomplete due to indexing delays. These limitations should be considered when interpreting the findings and citing the study.

G. Conclusions

This review underscores the transformative role of 5G in advancing modern agriculture through improved connectivity, automation, and real-time data-driven decision-making. By enabling integration with IoT, artificial intelligence, and robotics, 5G provides opportunities for optimizing crop yields, reducing resource wastage, and strengthening supply chain traceability. The bibliometric analysis demonstrates a clear upward trend in scholarly contributions, particularly between 2021 and 2024, reflecting the growing global commitment to smart farming solutions. However, findings also reveal persistent challenges that limit widespread adoption, especially in rural and underdeveloped regions. High infrastructural costs, weak network coverage, and affordability barriers for smallholder farmers remain critical constraints. Furthermore, the need for farmer training and digital literacy is vital to ensure effective utilization of 5G-enabled technologies.

Strategic solutions include infrastructure expansion through public–private partnerships, deployment of hybrid connectivity (5G, WiFi6, and satellite), and community-based digital hubs. Equally important are supportive policy frameworks for spectrum allocation, affordable tariffs, and interoperability standards. Together, these measures can create a resilient digital ecosystem that empowers farmers, enhances agricultural sustainability, and secures long-term food security. Ultimately, 5G represents not just a technological upgrade but a catalyst for achieving smart, inclusive, and sustainable agricultural transformation worldwide. The key contribution of this review lies not only in its bibliometric mapping, but in translating research trends into actionable infrastructure, policy, and capacity-building strategies for sustainable smart agriculture.

H. References

[1]. Y. Tang, S. Dananjayan, C. Hou, Q. Guo, S. Luo, and Y. He, "A survey on the 5G network and its impact on agriculture: Challenges and opportunities," Computers and Electronics in Agriculture, vol. 180, p. 105895, 2021. https://doi.org/10.1016/j.compag.2020.105895

[2]. J. Liu, L. Shu, X. Lu, and Y. Liu, "Survey of intelligent agricultural IoT based on 5G," Electronics, vol. 12, no. 10, p. 2336, 2023. https://doi.org/10.3390/electronics12102336

[3]. M. van Hilten and S. Wolfert, "5G in agri-food: A review on current status, opportunities and challenges," Computers and Electronics in Agriculture, vol. 201, p. 107291, 2022. https://doi.org/10.1016/j.compag.2022.107291

[4]. P. Majumdar, S. Mitra, D. Bhattacharya, and B. Bhushan, "Enhancing sustainable 5G-powered agriculture 4.0: Summary of low-power connectivity, internet of UAV things, AI solutions and research trends," Multimedia Tools and Applications, vol. 84, no. 17, pp. 17389–17433, 2025. https://doi.org/10.1007/s11042-024-19728-1

[5]. S. B. Damsgaard, N. J. H. Marcano, M. Nørremark, R. H. Jacobsen, I. Rodriguez, and P. Mogensen, "Wireless communications for internet of farming: An early 5G measurement study," IEEE Access, vol. 10, pp. 105263–105277, 2022. doi: 10.1109/ACCESS.2022.3211096

[6]. K. E. Khujamatov, T. K. Toshtemirov, A. P. Lazarev, and Q. T. Raximjonov, "IoT and 5G technology in agriculture," in Proc. 2021 Int. Conf. Information Science and Communications Technologies (ICISCT), Nov. 2021, pp. 1–6. https://doi.org/10.1109/ICISCT52966.2021.9670037

[7]. L. Tomaszewski, R. Kołakowski, and M. Zagórda, "Application of mobile networks (5G and beyond) in precision agriculture," in Proc. IFIP Int. Conf. Artificial Intelligence Applications and Innovations, Cham, Switzerland: Springer, Jun. 2022, pp. 71–86. https://doi.org/10.1007/978-3-031-08341-9_7

[8]. C. Murugamani, S. Shitharth, S. Hemalatha, P. R. Kshirsagar, K. Riyazuddin, Q. N. Naveed, S. Islam, S. P. Mazher Ali, and A. Batu, "Machine learning technique for precision agriculture applications in 5G-based Internet of Things," Wireless Communications and Mobile Computing, vol. 2022, Art. no. 6534238, 2022. https://doi.org/10.1155/2022/6534238

[9]. S. R. Raja, B. Subashini, and R. S. Prabu, "5G technology in smart farming and its applications," in Intelligent Robots and Drones for Precision Agriculture, Cham, Switzerland: Springer Nature, 2024, pp. 241–264. https://doi.org/10.1007/978-3-031-51195-0_12

[10]. K. Mukherjee, S. Mukhopadhyay, S. Roy, and A. Biswas, "Application of IoT-enabled 5G network in the agricultural sector," in Smart Agriculture Automation Using Advanced Technologies, Singapore: Springer, 2022, pp. 151–164. https://doi.org/10.1007/978-981-16-6124-2_9

[11]. Y. Li, H. Lin, Z. Li, Y. Liu, F. Qian, L. Gong, X. Xin, and T. Xu, "A nationwide study on cellular reliability: Measurement, analysis, and enhancements," in Proc. ACM SIGCOMM 2021 Conf., Aug. 2021, pp. 597–609. https://doi.org/10.1145/3452296.3472908

[12]. X. Zhang, P. Ciais, X. Jian, X. Liu, R. Wang, K. Chen, Y. Huang, T. Huang, H. Gao, Y. Zhao, and J. Ma, "The carbon footprint response to projected base stations

of China's 5G mobile network," Science of the Total Environment, vol. 870, p. 161906, 2023. https://doi.org/10.1016/j.scitotenv.2023.161906

[13]. T. Zhivkov, E. I. Sklar, D. Botting, and S. Pearson, "5G on the farm: Evaluating wireless network capabilities and needs for agricultural robotics," Machines, vol. 11, no. 12, p. 1064, 2023. https://doi.org/10.3390/machines11121064

[14]. S. M. Z. A. Naqvi, S. R. Saleem, M. N. Tahir, S. Li, S. Hussain, S. I. Ul Haq, and M. Awais, "Role of 5G and 6G technology in precision agriculture," Environmental Sciences Proceedings, vol. 23, no. 1, p. 3, 2022. https://doi.org/10.3390/environsciproc2022023003

[15]. J. Nyulas, Ș. Dezsi, A. F. Niță, Z. Magyari-Sáska, M. L. Frey, and A. Horváth, "Twenty-five years of scientific production on geoparks from the perspective of bibliometric analysis using PRISMA," Sustainability, vol. 17, no. 5, p. 2218, 2025. https://doi.org/10.3390/su17052218

[16]. U. Hariharan and K. Rajkumar, "Background and research challenges for blockchain-driven 5G IoT-enabled industrial automation," in *Blockchain for 5G-Enabled IoT*, S. Tanwar, Ed. Cham: Springer, 2021. doi: 10.1007/978-3-030-67490-8_2.

[17]. M. Bacco, P. Barsocchi, E. Ferro, A. Gotta, and M. Ruggeri, "The digitisation of agriculture: A survey of research activities on smart farming," Array, vol. 3, p. 100009, 2019. https://doi.org/10.1016/j.array.2019.100009

[18]. M. A. Ferrag, L. Shu, H. Djallel, and K. K. R. Choo, "Deep learning-based intrusion detection for distributed denial of service attack in agriculture 4.0," Electronics, vol. 10, no. 11, p. 1257, 2021. https://doi.org/10.3390/electronics10111257

[19]. K. Walia, M. Kumar, and S. S. Gill, "AI-empowered fog/edge resource management for IoT applications: A comprehensive review, research challenges, and future perspectives," IEEE Communications Surveys & Tutorials, vol. 26, no. 1, pp. 619–669, 2023. https://doi.org/10.1109/COMST.2023.3338015

[20]. Q. V. Khanh, N. V. Hoai, L. D. Manh, A. N. Le, and G. Jeon, "Wireless communication technologies for IoT in 5G: Vision, applications, and challenges," Wireless Communications and Mobile Computing, vol. 2022, Art. no. 3229294, 2022. https://doi.org/10.1155/2022/3229294

[21]. S. H. Alsamhi, F. Afghah, R. Sahal, A. Hawbani, M. A. Al-qaness, B. Lee, and M. Guizani, "Green internet of things using UAVs in B5G networks: A review of applications and strategies," Ad Hoc Networks, vol. 117, p. 102505, 2021. https://doi.org/10.1016/j.adhoc.2021.102505

[22]. Moloudian, M. Hosseinifard, S. Kumar, R. B. Simorangkir, J. L. Buckley, C. Song, G. Fantoni, and B. O'Flynn, "RF energy harvesting techniques for battery-less wireless sensing, Industry 4.0, and Internet of Things: A review," IEEE Sensors Journal, vol. 24, no. 5, pp. 5732–5745, 2024. https://doi.org/10.1109/JSEN.2024.3352402

[23]. M. R. Mahmood, M. A. Matin, P. Sarigiannidis, and S. K. Goudos, "A comprehensive review on artificial intelligence/machine learning algorithms for empowering the future IoT toward the 6G era," IEEE Access, vol. 10, pp. 87535–87562, 2022. https://doi.org/10.1109/ACCESS.2022.3199689

[24]. M. Marchese, A. Moheddine, and F. Patrone, "IoT and UAV integration in 5G hybrid terrestrial-satellite networks," Sensors, vol. 19, no. 17, p. 3704, 2019. https://doi.org/10.3390/s19173704

[25]. J. Song, Q. Zhong, W. Wang, C. Su, Z. Tan, and Y. Liu, "FPDP: Flexible privacy-preserving data publishing scheme for smart agriculture," IEEE Sensors Journal, vol. 21, no. 16, pp. 17430–17438, 2020. https://doi.org/10.1109/JSEN.2020.3017695