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An Investigation Of Cost-Benefit Dimensions Of 5G Networks For Agricultural Applications

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Abstract

The agricultural industry is facing unprecedented challenges in meeting the growing demand for food while minimizing its impact on the environment. To address these challenges, the industry is embracing technological advancements such as 5G networks to improve efficiency and productivity. However, the benefits of 5G technology must be weighed against the costs of implementing a suitable network.

This paper presents cost-benefit dimensions that are needed to assess the economic feasibility of implementing 5G networks for several agricultural applications. The paper describes the costs of deploying and maintaining a 5G network and the benefits of several 5G-specific use cases, including precision agriculture, livestock monitoring, and swarm robotics.

Using industry reports and case studies, the model quantifies the benefits of 5G networks, such as enabling new digital agricultural processes, increased productivity, and improved sustainability. It also considers the costs associated with equipment and infrastructure, as well as the challenges of deploying a network in rural areas. The results demonstrate that 5G networks can provide significant benefits to agricultural businesses and provide an overview about the cost factors. Both benefit and cost dimensions are analyzed for the 5G-specific agricultural use cases.

Keywords

5G; Smart Farming; Communication Technology; Sustainability; Industry 4.0

1. Introduction

Since its launch, 5G technology has become increasingly important, as evidenced by the rising mobile radio standard subscription rates. By the end of last year there were almost 1 billion subscriptions reported, almost twice as many as in 2021 [1]. The consensus is that, if it hasn't already, 5G technology will have an impact on practically all industries. The consumer goods, manufacturing, logistics, and agricultural industries are predicted to see the most changes because of 5G. Higher speeds and lower latency, for instance, will enable the use of augmented reality and virtual reality in the business-to-consumer (B2C) sector, enhancing the customer experience. For instance, cities could use Augmented Reality (AR) or Virtual Reality (VR) at tourist attractions or museums to provide more information, or "points of information" (POI). In contrast, better analysis of the real-time data accessible in industry helps lower machine downtime and establish production standards [2]. 5G technology will also have an expanding impact on agriculture, with "smart farming" as the fundamental concept. The application of information and communication technologies in agriculture is referred to as "smart farming." Unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), and wireless sensor networks all have a significant technological impact on smart farming [3]. For instance, huge fields can be observed and monitored from the air using UAVs. With no need for a large

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workforce, various status information like weed growth, concealed animals, insect infestation, and water can be automatically gathered. Due to its low latency, fast connectivity, and high data throughput features, 5G technology has a lot of potential, especially when used in conjunction with (semi-)autonomous vehicles, a huge amount of simultaneously used end devices or data streams used in real time.

The adoption of 5G has the potential to influence the agricultural sector by enabling advanced applications and enhancing operational efficiency. However, the financial implications of implementing 5G networks in agricultural companies remain largely unexplored. Although the decision to invest in 5G infrastructure involves substantial financial considerations, a comprehensive financial assessment of the associated costs and benefits is noticeably lacking. Agricultural companies need to evaluate the potential financial implications, including the initial investment required for infrastructure deployment, ongoing maintenance costs, and potential revenue streams or cost savings that can be generated by implementing 5G-enabled use cases. By conducting a rigorous financial assessment, companies can make informed decisions regarding the adoption of 5G and allocate their resources efficiently. In addition to the cost factors, it is also important to consider the potential benefits of implementing a 5G network and compatible technologies. For a final evaluation, it is necessary to consider both sides.

The research presented in this paper addresses the aforementioned issue by showing the current state of an ongoing research project and providing cost and benefit dimensions. At the outset, our attention will be directed towards addressing the research gap related to this subject. Subsequently, the use cased and detailed dimension of both benefits and costs associated with the implementation and utilization of a 5G network will be described. Lastly, an overview of forthcoming developments will be provided.

2. Methodology

The development of the proposed 5G cost and benefit dimensions was grounded in the method described subsequently. Initially, extensive desk research was conducted to collect information pertaining to 5G-specific use cases within the agricultural sector. Furthermore, insights from the research project 5G.NATURAL and other related research endeavours were utilized to refine these dimensions. Drawing upon the desk research findings and insights gleaned from the research projects, a deductive approach was adopted to deduce relevant beneficial factors associated with 5G technologies in agriculture. These factors were clustered into three dimensions in terms of content to enhance clarity and structure. Subsequently, these dimensions were applied to the use cases to elucidate the specific benefits for each scenario.

The identification of cost factors influencing the decision to implement 5G use cases was accomplished through a combination of desk research, practical research experience, and expert interviews. In the case of expert interviews, several professionals from the information and communication technology (ICT) industry, possessing practical expertise in implementing 5G networks, were interviewed. Leveraging these insights, we conducted an exemplary analysis of benefits and costs for the evaluation of 5G networks in the context of specific agricultural applications.

3. Research Results

In the following, the results of our research will be presented.

3.1 Research Gap

Despite the increasing interest in the integration of 5G technology within the agricultural sector, a significant research void exists concerning the comprehensive financial assessment of associated costs and benefits. While the potential advantages of 5G networks for advanced agricultural applications and operational efficiency are widely acknowledged, limited research has been conducted to run a rigorous financial evaluation. Specifically, there is a dearth of studies examining the initial investment required for infrastructure deployment, ongoing maintenance costs, and the potential revenue streams or cost savings that can be generated by implementing 5G-enabled use case in agricultural enterprise [4].

To date, only a small number of studies have addressed the issue of costs, and when they have, it has not been in the context of both 5G and agriculture. Existing research of 5G feasibility has focused on specify topics, such as an economic model for 5G drones in production, or another cost analysis for 5G drones in emergency situations [5,6]. Other research focused on an open source techno-economic assessment framework for 5G deployment but again there is no connection with agriculture [7]. Overall, there are a few sources that delve deeper into the costs, and even they do, the analysis is limited. Most studies merely acknowledge that 5G will incur higher costs compared to previous generations and emphasize the need to consider factors such as income levels, population density, and other socioeconomic influences [8–10]. Most surveys that focus specifically on 5G technologies in agriculture are mainly concerned with benefits and lack of cost aspects [11-16]. Table 1 shows the summary of surveys regarded in this research paper.

This research paper aims to fill this research gap by presenting the cost-benefit dimensions that evaluate the economic feasibility of implementing 5G networks for various agricultural applications. By describing both the costs and benefits of 5G networks, this study provides valuable insights for stakeholders in the agricultural industry. Furthermore, the dimensions serve as the basis for cost-benefit analysis models.

Table 1: Surveys to benefits and costs aspects of 5G applications in agriculture.

Survey	Kumar et al. [4]	Kiesel & Schmitt[6]	Hunukumbure & Tsoukaneri [5]	Oughton et al. [7]	Das & Damle [8]	Frank et al. [9]	Oughton et al. [10]	Aruubla-Hoyos et al. [11]	Bacco et al. [12]	Li & li[13]	Said Mohammed et al. [14]	Abbas et al. [15]	Irudaya Raj et al. [16]
Year	2022	2020	2019	2019	2023	2022	2019	2022	2018	2020	2021	2022	2021
5G Technology	●	●	●	●	●	◑	◑	●	◑	●	●	●	●
Benefits of 5G	●	◑	○	◑	◑	◑	○	●	●	◑	◑	○	●
Costs of 5G	○	◑	●	●	◑	●	●	○	○	○	○	○	○
Agriculture	●	○	○	○	○	○	○	●	●	●	●	●	●

●: Supported; ◑: Partially supported; ○: Unsupported.

3.2 Results

3.2.1 Benefit dimensions

In the following, general benefit factors from the application of a 5G network are discussed first. Three factors in particular stand out compared to existing 4G LTE technologies.

With speeds of up to 20 Gbit per second in the data rate, a significantly higher transmission rate is possible [13]. A lower latency of less than 1 millisecond makes real-time applications possible. The third factor is given by the higher density of the 5G network, with which significantly more devices can be networked in a physical area. It must be mentioned, that current 5G networks are not able to perform optimal in all three features at the same time. Optimizing a network for one feature weakens its ability for the others. The 5G network is to be understood to an end because it is only through the combined use with corresponding technologies that these advantages come to fruition. Examples include the use of autonomous machines, artificial intelligence or swarm logic [17].

The above factors, in combination with the deployment of 5G compatible technologies, enable a range of benefits that can be categorised into three dimensions. These are elaborated below in relation to the benefits for agriculture. The first dimension includes benefits in terms of **flexibility**. 5G technologies allow automated and autonomous machines due to the latency and transmission rate. As a result, farmers, for example during harvest, are less dependent on additional personnel, as fewer staff are needed, which counteracts the shortage of skilled workers and overall less physical effort is required [12,18]. In addition, machines can work autonomously due to real-time transmission and can thus be used in a target- and demand-oriented manner. In this way, optimal times for work can be chosen and the flexibility of farmers can be strengthened.

The second dimension concerns aspects of **security**. Since several devices can be connected over a 5G network and real-time transmission is possible, communication between the individual devices is increased, which can have a positive effect on various security aspects. The continuous ingestion and exchange of data provides greater resilience and increases the resilience of digital technologies in agricultural use [19]. Another security issue that can be improved with the use of 5G and related technologies are environment-related aspects by collecting weather or field data to detect arid lands or fire that can cause harm to fields or animals [11].

The third dimension covers the topic of **quality**. Due to the option to collect real-time data through sensors, these can be analysed and used as a basis for decisions or for predictions. Predictive analyses, for example, enable recommendations to be made regarding harvesting times, so that planning and the deployment of personnel and machinery can be optimised [16]. In addition, a 5G network can be used to implement technologies that ensure greater transparency through data analyses and thus make processes more sustainable and resource-efficient [20]. By the overall efficient use of 5G related technologies the operating costs, personnel costs and resource costs as well can be significantly reduced [14].

In chapter 3.2.4. the specific benefits related to the use cases are highlighted.

3.2.2 Cost dimensions of 5G network implementation and operation

The cost factors were collected as described in the methodology by specifying and implementing a rural 5G network and then validated through expert interviews. They and their dependencies are presented below.

Basically, 5G-specific costs can be divided into capital expenditures and operational expenditures. The former is subdivided into hardware, software, infrastructure, and service costs; the latter into service costs and licensing costs for the spectrum of bandwidth to be used. Most of the cost factors depend on the specific design of the network in terms of the area covered, the internal or external location of the network, the users involved, and the required performance and quality of the network.

In the experience of our research partners and other experts, it has been shown that use cases can be divided into small, medium, and large ones to estimate the costs. The classification is shown in Table 2. The actual costs incurred sometimes differ considerably by up to a factor of 4. An overview with the relative cost differences is shown in Table 3. They are derived from the practical experience of a research partner within 5G.NATURAL, who is from the ICT industry and has vast experience in implementing 5G networks. The network quality factor refers to whether the 5G network can use high-end features such as super low latency or high giga bit bandwidths. Correspondingly powerful hardware and software is currently expensive and not necessary for every application. However, it can be assumed that due to the technical further development of the products, a price relaxation can be expected in the next few years. It should be borne in mind that all prices are also a matter of negotiation and depend on the order quantity, the company, etc.

It should be noted that investment costs depend on whether a public or private 5G network is used. Since it cannot be guaranteed, especially in agricultural use cases, that the public networks will achieve sufficient coverage and quality everywhere in the field, in many cases it will have to be assumed that own private, possibly transportable 5G networks will be used. However, this entails higher investment costs.

Table 2: Criteria for determining the size of a 5G network.

Size of 5G network	Indoor area	Outdoor area	User
Small	1 acre / 4048 m^2	0.25 acre / 1012 m^2	20
Medium	5 acre / 20240 m^2	1.25 acre / 5060 m^2	50
Large	10 acre / 40480 m^2	2.50 acre / 10120 m^2	100

Table 3: Relative cost comparison of differently designed 5G networks

	Small		Medium		Large	
	Low/normal Features	High End Features	Low/normal Features	High End Features	Low/normal Features	High End Features
Indoor	1	2.0	1.3	2.9	1.9	3.9
Outdoor	1.1	2.4	1.4	3.2	1.9	4.1

Table 4 shows the individual cost factors identified for implementing a 5G network. Costs marked with an * are independent of the size of the network, the indoor and outdoor location, and the number of integrated end devices. Factors in brackets () are optional depending on the use case and are not mandatory. For a better overview, the factors were clustered into capital expenditures (CAPEX) and operational expenditures (OPEX). Note that service and license factors are divided between the two categories.

Table 4: Cost factors for implementing 5G networks.

	Cost Components	Line Items
CAPEX	Network Element	Core Hardware* (e.g., server, switch)
		Core Software & supporting Software*
		RAN Hardware (e.g., RAN, antenna, server, switch)
		RAN software & supporting software
		(Savings potential with split indoor and outdoor network)
		Fiber / Connectivity (passive component)
		5G end device (incl. SIM card)
	Network Element Redundancy	Core Hardware (e.g., server, switch)
		Core software & supporting software
	Infrastructure	Power Supply, cable layout, rack, tower installation, etc.
		(Cell on wheel / mobile antennas)
		(Internet / external network connectivity)

		(Remote connectivity infrastructure)
	Services and licenses	Requirement Capturing and solution design
		Procurement and delivery
		RF planning and optimization
		Deployment, Integration & testing
		Device onboarding and use case integration
OPEX		RAN software license renewal
		Core software license renewal
		Spectrum license
		Spectrum license renewal
		(Maintenance)
		(Additional infrastructure, rentals, energy costs etc.)

3.2.3 5G-specific use cases in agriculture

In the following, three 5G-specific use cases in agriculture are presented. A use case is considered 5G specific if it exploits the unique features and capabilities of 5G networks not provided by other mobile technologies equally. In particular, the three characteristics of low latency, high transmittable data rates, and high network capacity will be considered below for this purpose. [21]

Swarm robotics for harvesters: The first use case was elaborated within the 5G.NATURAL research project. Multiple harvesting and logistic machines manoeuvre over the field as a swarm, while harvesting or transporting crops from the harvesters to a collection station. All machines move autonomously, but can be controlled, if necessary, via a central unit installed at the edge of the field. The machines are connected to a platform and retrieve relevant data, such as a navigation map of the field including starting point, end point, rows of fields to be harvested, the position of the harvesting machines and a route. The use case is 5G-specific, as the real-time transmission of the waypoints and sensor data requires a high transmittable data rate and short latency times to be able to securely control the harvesting machines via 5G.

Condition monitoring using drones: In the second use case condition monitoring is conducted using drones, for example to monitor crop health or locate weeds [22]. Precision farming enables agricultural management decisions to be tailored locally and to treat a field as a heterogeneous instead of a homogeneous unit [23]. Waypoints are communicated to the drone to fly over the field by an edge server via 5G. A camera is attached to the drone that transmits large amounts of image data during flight to the edge server, which uses machine learning to analyse the crop health and detect weeds [24]. Outsourcing weed detection will save energy for computing power and weight for the same resulting in cheaper drones that have longer flight times. The use case is 5G-specific, as real-time transmission of image data requires a high transmittable data rate and short latency to control the drone over 5G [25].

Precision Livestock Farming (PLF): PLF involves the use of various sensors and actuators to improve management capacity for large groups of animals and relies on the collection and analysis of real-time. [26] In the third use case information on physiological conditions of animals is collected in real time. Cameras and on-animal sensors are used to collect information, e.g., on movement, heart rate and temperature, and transmit it via 5G to an edge computing device. Furthermore, information on grazing and resting behaviors as well as feed intake can be collected. On the edge device, the information is analyzed and abnormalities are transmitted to the farmers. [27] The use case is 5G-specific due to the large number of sensors using the 5G network, the high network capacity, and the high data rates to be transmitted.

3.2.4 Benefits and costs of use cases

In the following, the three use cases are each considered from the perspective of the benefit dimensions and cost specific aspects.

Swarm robotics for harvesters: In terms of safety, the use of 5G and related technologies has the benefit of collision avoidance. Through the networking of the machines via a 5G network and the real-time transmission of data, the location can be determined continuously. This prevents the machines from colliding with each other. Camera recordings and their transmission can detect people or animals in front of the machine. Due to the low latency, the direct transmission of a stop signal is possible, so that collisions can also be avoided here. In terms of quality, the swarm logic allows the use of many small harvesters instead of fewer harvesters that put less pressure on the soil. Due to the much higher accuracy with which autonomous robots operate, they can also harvest more precisely. Generally, the use of smaller and resource saving, autonomous harvesting robots enables new agricultural use cases with new potentials, e.g., sustainable, and economic mixed cropping farming. The consideration of the flexibility dimension shows a clear benefit from the possibility to use harvesting machines autonomously via a 5G network. Here, farmers are less dependent on the use of harvest workers.

For this use case, the outdoor area size is particularly relevant to dimension the 5G network and derive the costs. As it is a safety-critical application, since the harvesters are controlled via the 5G network, high data transmission rates, low latency and high reliability are essential. For this reason, the choice results in a more powerful and thus costly 5G network with high-end features. Beyond the essential components of a 5G network, the seasonality of harvests requires a mobile network and that may require infrastructure building costs, if necessary.

Condition monitoring using drones: The greatest benefit lay in the quality dimension. The use of drones, high-resolution camera images and the analysis of these enables the precise detection of weeds. Pesticides and herbicides can be sprayed precisely in this case, which saves resources on the one hand and protects the environment on the other. The precise detection is also a benefit for the safety dimension, as any diseases, which in the worst case mean crop failure, can be detected, and treated at an early stage. The amount of work and the associated deployment of personnel can also be reduced, as in the first use case. As the data is not processed on the drone itself, additional weight on it is saved, prolonging its range for each charge cycle.

High data transmission rates and low latency times are relevant to be able to transmit the image recordings and operate the drone via the 5G network. For this reason, the choice of a more powerful 5G network results in a more costly 5G network with high-end features. Beyond the essential components of a 5G network, it must be considered that the network could be mobile and may require infrastructure costs.

Precision Livestock Farming (PLF): This use case largely touches on the benefit dimensions of security and flexibility. The condition data transmitted gives farmers an overview of any diseased animals so that they can react quickly and take appropriate action. In this way, an extension to the entire herd can ideally be prevented and costs can be saved. Likewise, female animals that are about to give birth can be digitally monitored so that appropriate measures can be taken here as well. Determining the appropriate data eliminates the need for on-site visual monitoring, reducing labour costs.

This use case involves many animals, which means the amount of end user devices is large, albeit numerous sensors transmit a rather small amount of data over the 5G network, except for certain devices as cameras. Thus, the network capacity is crucial for a 5G networks design. In contrast, the indoor area of a barn is relatively small when compared to the first two outdoor use cases. Due to the required network capacity and the high data rates to be transmitted, a more powerful 5G network will be needed. If adjacent outdoor areas also need to be covered for the third use case, the area to be covered increases, but on the other hand, synergies and overlaps arising can be considered, which make the network expansion more cost-effective.

4. Conclusion and Outlook

This paper described the costs and benefits of implementing and using 5G networks in agricultural applications. These provide initial indications for both research and practice. As already pointed out in the research gap, many research papers deal with the costs and benefits of 5G in the agricultural context, but in isolation from each other. However, in order to understand both aspects and, above all, their interplay, it is necessary to bring the two factors into a common context. This paper offers a first approach that can serve as a basis for further research. This could, for example, be the quantification of the benefit dimensions to enable a more in-depth cost-benefit analysis. On this basis, precise cost-benefit models can be created that allow for a more in-depth analysis. By the end of 2023 a software based business case calculator is planned to be developed and published within the project 5G.NATURAL. The identified factors and use cases will be used as the basis for the software. For practical purposes, the dimensions provide reference points for farmers to create an initial awareness of a cost framework. In addition, concrete benefits in agricultural terms are shown that can drive the use of 5G technologies in agriculture.

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References

[1] Möller, R., 2023. Ericsson Mobility Report. Ericsson.

[2] Humayun, M., Hamid, B., Jhanjhi, N.Z., Suseendran, G., Talib, M.N., 2021. 5G Network Security Issues, Challenges, Opportunities and Future Directions: A Survey. J. Phys.: Conf. Ser. 1979 (1), 1–10.

[3] Moysiadis, V., Sarigiannidis, P., Vitsas, V., Khelifi, A., 2021. Smart Farming in Europe. Computer Science Review (39), 1–22.

[4] Kumar, R., Sinwar, D., Pandey, A., Tadele, T., Singh, V., Raghuwanshi, G., 2022. IoT Enabled Technologies in Smart Farming and Challenges for Adoption, in: , Internet of Things and Analytics for Agriculture, Volume 3. Springer, Singapore, pp. 141–164.

[5] Hunukumbure, M., Tsoukaneri, G., 2019. Cost Analysis for Drone Based 5G eMBB Provision to Emergency Services, in: 2019 IEEE Globecom workshops (GC wkshps). Proceedings : Waikoloa, HI, USA, 9-13 December 2019. 2019 IEEE Globecom Workshops (GC Wkshps), Waikoloa, HI, USA. 12/9/2019 - 12/13/2019. IEEE, Piscataway, NJ, pp. 1–5.

[6] Kiesel, R., Schmitt, R.H., 2020. Requirements for Economic Analysis of 5G Technology Implementation in Smart Factories from End-User Perspective. Personal, Indoor and Mobile Radio Communications, 1–7.

[7] Oughton, E.J., Katsaros, K., Entezami, F., Kaleshi, D., Crowcroft, J., 2019. An Open-Source Techno-Economic Assessment Framework for 5G Deployment. IEEE Access 7, 155930–155940.

[8] Das, S., Damle, M., 2023. Implementation Challenges & Applications of 5G and Ecosystems, in: "2023 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS)". 2023 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS), Erode, India. 3/23/2023 - 3/25/2023. IEEE, pp. 1492–1499.

[9] Frank, H., Colman-Meixner, C., Assis, K.D.R., Yan, S., Simeonidou, D., 2022. Techno-Economic Analysis of 5G Non-Public Network Architectures. IEEE Access 10, 70204–70218.

[10] Oughton, E.J., Frias, Z., van der Gaast, S., van der Berg, R., 2019. Assessing the capacity, coverage and cost of 5G infrastructure strategies: Analysis of the Netherlands. Telematics and Informatics 37, 50–69.

[11] Arrubla-Hoyos, W., Ojeda-Beltrán, A., Solano-Barliza, A., Rambauth-Ibarra, G., Barrios-Ulloa, A., Cama-Pinto, D., Arrabal-Campos, F.M., Martínez-Lao, J.A., Cama-Pinto, A., Manzano-Agugliaro, F., 2022. Precision

Agriculture and Sensor Systems Applications in Colombia through 5G Networks. Sensors (Basel, Switzerland) 22 (19).

[12] Bacco, M., Berton, A., Ferro, E., Gennaro, C., Gotta, A., Matteoli, S., Paonessa, F., Ruggeri, M., Virone, G., Zanella, A., 2018. Smart farming: Opportunities, challenges and technology enablers, in: 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany). 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), Tuscany. 08.05.2018 - 09.05.2018. IEEE, pp. 1–6.

[13] Li, T., Li, D., 2020. Prospects for the Application of 5G Technology in Agriculture and Rural Areas, in: 2020 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE). 2020 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE), Harbin, China. 25.12.2020 - 27.12.2020. IEEE, pp. 2176–2179.

[14] Said Mohamed, E., Belal, A., Kotb Abd-Elmabod, S., El-Shirbeny, M.A., Gad, A., Zahran, M.B., 2021. Smart farming for improving agricultural management. The Egyptian Journal of Remote Sensing and Space Science 24 (3), 971–981.

[15] Syed Muhammad Zaigham Abbas Naqvi, Shoaib Rashid Saleem, Muhammad Naveed Tahir, Shixin Li, Saddam Hussain, Syed Ijaz Ul Haq and Muhammad Awais, 2022. Role of 5G and 6G Technology in Precision Agriculture. environmental science proceedings 23 (3), 1–5.

[16] Fantin Irudaya Raj, E., Appadurai, M., Athiappan, K., 2021. Precision Farmin in Modern Agriculture, in: Choudhury, A., Biswas, A., Singh, T.P., Ghosh, S.K. (Eds.), Smart Agriculture Automation Using Advanced Technologies. Data Analytics and Machine Learning, Cloud Architecture, Automation and IoT, 1st ed. 2021 ed. Springer Singapore; Imprint Springer, Singapore, pp. 61–88.

[17] Seelmann, V., Abbas, M., Stratmann, L., 2020. 5G - eine Mobilfunkrevolution verändert die Industrie. UdZ Praxis.

[18] Horstmann, J., 2020. Digitalisierung und Vernetzung - Landwirtschaft im Wandel, in: Frerichs, L. (Ed.), Jahrbuch Agrartechnik 2019. Institut für mobile Maschinen und Nutzfahrzeuge, Braunschweig, pp. 1–8.

[19] Eberz-Eder, D., Kuntke, F., Schneider Wolfgang, Reuter, C., 2021. Technologische Umsetzung des Resilient Smart Farming (RSF) durch Einsatz von Edge Computing, in: Informatik in der Land-, Forst- und Ernährungswirtschaft. Informations-und Kommunikationstechnologie in kritischens Zeiten. 41. GIL-Jahrestagung, Potsdam. Gesellschaft für Informatik e.V., pp. 79–84.

[20] Bosse, S., Berns, K., Bosch, J., Dörr, J., Eichhorn, F.C., Eisert, P., Fischer, C., Gassen, E., Gerstenberger, M., Geringhausen, H., Heil, J., Hilsmann, A., Hirth, J., Huber, C., Hussaini, M., Kasparick, M., Kloke, P., Krause-Edler, H., Mackle, L., Magnusson, J., Möhrle, F., Möller, M., Pickel, P., Rautenberg, C., Schotten, H.D., Stanczak, S., Thiele, L., Ücdemir, H., Wania, A., Stein, A., 2021. Nachhaltige Landwirtschaft mittels Künstlicher Intelligenz - ein plattformbasierter Ansatz für Forschung und Industrie, in: Informatik in der Land-, Forst- und Ernährungswirtschaft. Informations-und Kommunikationstechnologie in kritischens Zeiten. 41. GIL-Jahrestagung, Potsdam. Gesellschaft für Informatik e.V., pp. 41–52.

[21] Ramraj Dangi, Praveen Lalwani, Gaurav Choudhary, Ilsun You and Giovanni Pau, 2022. Study and Investigation on 5G Technology: A Systematic Review. Sensors 22 (26), 1–32.

[22] Hafeez, A., Husain, M.A., Singh, S.P., Chauhan, A., Khan, M.T., Kumar, N., Chauhan, A., Soni, S.K., 2023. Implementation of drone technology for farm monitoring & pesticide spraying: A review. Information Processing in Agriculture 10 (2), 192–203.

[23] Finger, R., Swinton, S.M., El Benni, N., Walter, A., 2019. Precision Farming at the Nexus of Agricultural Production and the Environment. Annu. Rev. Resour. Econ. 11 (1), 313–335.

[24] Mario Vento, Gennaro Percannella, Sara Colantonio, Daniela Giorgi, Bogdan J. Matuszewski, Hamideh Kerdegari, Manzoor Razaak, Simone Diniz Junqueira Barbosa, Joaquim Filipe, Ashish Ghosh, Igor Kotenko, Junsong Yuan, Lizhu Zhou (Eds.), 2019. Computer Analysis of Images and Patterns, 140 pp.

[25] GSMA, KPN. Smart Farming: Weed Elimination with 5G Autonomous Robots, 12 pp.

[26] Cadero, A., Aubry, A., Dourmad, J.Y., Salaün, Y., Garcia-Launay, F., 2018. Towards a decision support tool with an individual-based model of a pig fattening unit. Computers and Electronics in Agriculture 147, 44–50.

[27] Odintsov Vaintrub, M., Levit, H., Chincarini, M., Fusaro, I., Giammarco, M., Vignola, G., 2021. Review: Precision livestock farming, automats and new technologies: possible applications in extensive dairy sheep farming. Animal: an international journal of animal bioscience 15 (3), 1–10.

Biography

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