INNODOCT 2022
Valencia, November 2nd-7th 2022
Doi: https://doi.org/10.4995/INN2022.2022.15746

Opportunities and Barriers of Smart Farming Adoption by Farmers Based on a Systematic Literature Review

[a]Leonardo H. Talero-Sarmiento, [b]Diana T. Parra-Sanchez, [c]Henry Lamos-Diaz
[a]Universidad Autónoma de Bucaramanga, docente del programa en Ingeniería Industrial, ltalero@unab.edu.co.; [b] Independiente, Colombia, dparra486@unab.edu.co.; [c]Universidad Industrial de Santander, docente del programa de Ingeniería Industrial hlamos@uis.edu.co.

How to cite: Talero Sarmiento, L. H.; Parra-Sánchez, D.T.; Lamos-Diaz, H. 2022 Opportunities and Barriers of Smart Farming Adoption by Farmers Based on a Systematic Literature Review. In the proceedings book: International conference on innovation, documentation and education. INNODOCT/22. Valencia, November 2nd-7th 2022. https://doi.org/10.4995/INN2022.2022.15746

Abstract
Smart Farming is a revolutionary paradigm in the agri-food sector that integrates real-time data collection through various sensors and sources (i.e., the Internet of Things technologies (IoT) such as automation systems, farm bots, drones, and technological computer infrastructure). These integrated solutions support more intelligent decisions in the agricultural sector, increasing competitiveness and productivity in rural areas. However, there are difficulties with interoperability, security, data governance, farming practices diversity, farmer capacitation, and technology diffusion. End-users are heterogeneous, from illiterate producers to farm enterprises, which involves a custom ICT adoption strategy for each potential customer. This paper presents a systematic literature review that identifies the opportunities and barriers to adopting Smart Farming solutions in rural areas, highlighting the need to implement centered-user design strategies to increase the technology adoption considering two different types of farmers.

Keywords: IoT *Adoption, DOI, Smart farming, TAM, UTAUT.*

Introduction

Smart Farming, Smart Agriculture, Digital Agriculture, e-Agriculture, Agriculture 4.0, or Agri-food 4.0 (Lezoche et al., 2020; Saiz-Rubio & Rovira-Más, 2020; Sott et al., 2020; van der Burg et al., 2019) It is a paradigm shift for the agri-food sector that focuses on optimal farm management cycle. (Lioutas & Charatsari, 2020). The decision-making across the value food chain implies a cyber-physical system, which means that smart devices connected to the Internet control the farm system (Wolfert et al., 2017). Hence, SF transforms traditional physical-social farming systems into cyber-physical-social systems. Smart Farming technologies indicate IoT-based solutions in Agrobusiness according to the cyclic system technologies of Precision Agriculture (PA) (Kolipaka, 2020; Lioutas et al., 2019): Data acquisition, Data analysis, and evaluation, and Precision application.

Taking into account the Food Agriculture Organization (FAO) recommendations related to Information and Communications Technology (ICT) adoption in agriculture; precisely, the e-Agriculture strategy to transform agriculture and food production based on ubiquity, portability, and mobility of digital technologies for optimal decision-making (FAO, 2018) and the International Telecommunication Union (ITU) strategies fostering ICT-centric innovation and smart and sustainable development (ITU, 2018b, 2018a). This work suggests a better understanding of farmers' opportunities and barriers to Smart Farming Adoption. With this aim in mind, in this paper, we explore a new unified approach for deploying IoT solutions in farms, considering technologies' perceived usefulness.

1.Aims and objectives

Some studies observed a relationship between Smart Farming Adoption and some critical variables: Firstly is the perception of economic and commercial barriers (Caffaro & Cavallo, 2019, 2020). Secondly is the farmers' education in technology (Pivoto et al., 2019; Suebsombut et al., 2020). Thirdly is smart technologies' perception of use and the potential for radical changes in farm management [6], [17]. Fourthly is the hard use and interpretation of data due to their volume and complexity (Van Es & Woodard, 2017). Fifthly is the farm assets, covering investment capability, land scale (size), and previous technology implementation (Eastwood & Renwick, 2020; Wolfert et al., 2017). Thus, Smart Farming Adoption as another technology requires prior diffusion. Hence, there is relevant to consider the Diffusion of Innovation theory (DOI) (Rogers, 1983). Then the variables that can influence technology adoption in the agricultural sector must be analyzed, considering the end-user. There is broad theoretical and experimental evidence in the literature to support two types of Farmers: Smallholder farmers and Business farmers. Depending on the end-user category, there are theoretical references that explain the adoption of technologies, such as The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and the Technology Acceptance Model (TAM) (Davis, 1989).

This work considers a sustainable food value chain to context the stakeholder's relationship. Thus, FAO's structure is a helpful framework for reference due to its four main components (FAO, 2014). Therefore, this work proposes a comprehensive definition to describe this technology phenomenon: *Smart Farming Adoption is the design, development, and deployment of affordable, scalable, and easily accessible information and communication technologies to support intelligent decisions in the agricultural sector, which transforms the traditional physical-social farming systems into cyber-physical-social systems using IoT-based solutions in the cyclic system of Precision Agriculture*. to identify Opportunities and Barriers of Smart Farming Adoption.

2.Methodology

For the Systematic Literature Review process, this work has the following search protocol: guiding research questions, research strategy, selection criteria, classification, and synthesis of the selected studies. Hence, for the development of this study, the four guiding questions are: **Q1:** What are the primary studies on implementing Smart Farming solutions and their perception of use? **Q2:** How are the different actors in the agricultural value chain interrelated regarding Smart Farming solutions uses? **Q3:** What are the theoretical references for the Adoption of Smart Farming solutions in rural areas? **Q4:** What IoT technologies have been implemented in rural areas to support the work of farmers?

For this study, we extract the selected documents from the Scopus database. It allowed us to identify the technological trend and find papers published in prestigious databases such as *IEEE Xplore, ScienceDirect, Springer Link,* and other publishers such as MDPI that publish in Open Access. We manually reviewed the selected documents to obtain the information that would allow answering the guiding questions. To select these documents, we take into consideration scientific articles, or conference proceedings in English, published during the 2016-2021 period, belonging to the following disciplines: *Computer Science, Engineering, Agricultural and Biological Sciences, Social Sciences, Mathematics, Energy, Environmental Science, Business, Management and Accounting, Decision Sciences,* y *Economics, and Econometrics and Finance.* In this preliminary search, we only used the descriptor "Smart Farming" to explore the study subject. We selected 2016 as the initial year of the investigation due to the increasing number of published documents. Therefore, the final search equation was:

$$\begin{aligned}&\boldsymbol{TITLE-ABS-KEY\ (\text{"}Smart\ farming\text{"})\ AND\ (LIMIT}\\&\boldsymbol{-TO\ (PUBYEAR\ ,2021)\ OR\ LIMIT-TO\ (PUBYEAR\ ,2020)\ OR\ LIMIT}\\&\boldsymbol{-TO\ (PUBYEAR\ ,2019)\ OR\ LIMIT-TO\ (PUBYEAR\ ,2018)\ OR\ LIMIT}\\&\boldsymbol{-TO\ (PUBYEAR\ ,2017)\ OR\ LIMIT-TO\ (PUBYEAR\ ,2016))\ AND\ (LIMIT}\\&\boldsymbol{-TO\ (LANGUAGE\ ,\text{"}English\text{"}))\ AND\ (LIMIT-TO\ (SRCTYPE\ ,\text{"}j\text{"})\ OR\ LIMIT}\\&\boldsymbol{-TO\ (SRCTYPE\ ,\text{"}p\text{"}))\ AND\ (EXCLUDE\ (SUBJAREA\ ,\text{"}PHYS\text{"})\ OR\ EXCLUDE\ (SUBJAREA\ ,}\end{aligned} \quad \textbf{(1)}$$

Initially, we reviewed the title, abstract, and keywords of the 409 documents retrieved. Later, we reviewed the articles according to each abstract's scope and its relation to our study topic. We select the final works based on the following inclusion (i.e., Articles covering rigorous research methods focused on adopting Smart Farming solutions in rural areas, which consider TAM or UTAUT, implementing as a unit of analysis farmers as end-users) and exclusion criteria like (i) articles focused on the technical evaluation of technological deployments without highlighting the interaction with farmers nither, (ii) Survey-type literature review article without proposing (i) theoretical frameworks, (ii) behavioral or statistical perception models, or (iii) Letters to the editor, event summaries, or additional documents that do not match the search equation.

3.Results

This work draws the results accordingly to the research questions as follows:

3.1.Q1:What are the primary studies on implementing Smart Farming solutions and their perception of use?

Some works emphasize that farm technology usability improves facilities and agricultural technology implementation. Smart Farming Technologies must simultaneously solve multiple management and planning tasks.(Caffaro et al., 2020; Kampker et al., 2019; Pivoto et al., 2019; Zhai et al., 2020). Hence, it is essential to address an initial requirement analysis to avoid cumbersome user experiences. Suakanto et al. (2016) For Decision Support Systems in Data sensor networks, the tech solution must be easy to implement and configure. A good requirement analysis can improve the user experience. Thus, the: Ease of use and user experience are key for end-users to adopt Smart Farming.(Xin & Zazueta, 2016). Some end-users consider Smart Farming Adoption's benefits, especially its usability. Smart Farming could be: Farming-friendly, Increase productivity due to reduced input costs, helps make better management decisions because correct data gathering provides better information, improves farm impact on nature while increasing crop yield, and improves farmers' work comfort, work processes, and workload. (Kernecker et al., 2020; Knierim et al., 2019). Despite farm distance from cities, lack of information, and farmers' mental barriers, SFA has clear benefits (Sarri et al., 2020).

Xin and Zazueta (2016) suggest a relation between User experience and Smart Farming Adoption backed up by evidence to develop a knowledge-based hybrid cloud architecture. The authors conclude: "A customized solution is key so that farmers can select apps they need and use their farm-specific data, citizen forums, workshops, surveys, internet forums, interest group representation on steering committees, and user-centered design." Accordingly, the design must go through a unique and holistic co-creation process to tune up the User Experience by adopting a Smart Farming Solution. For this, the sustainable stakeholders of the food value chain framework must select the most appropriate set of tools, devices, components, and data sources (Makinde et al., 2019; Roussaki et al., 2019). Besides the stakeholder integration process to improve User Experience, there are some essential guidelines to improve the Ease of Use of Online Knowledge Sharing systems. The following lessons are fundamental: Provide content that the users find relevant and valuable, Have a user-friendly interface, Make information meaningful, Tackle the research – user gap and specify Smart Farming Technology added value, Provide local contextualization – tackle spatial/temporal variation, and Provide up to date information (Bruce, 2016; Kernecker et al., 2020). A brief conclusion to the advantages and challenges described above indicates successful cases of applying Smart Farming Technologies and their perception of ease of use and User experience as a strategy to improve Smart Farming Adoption.

3.2.Q2:How are the different actors in the agricultural value chain interrelated regarding Smart Farming solutions uses?

The available evidence of retrieved works points to most actors in the sustainable food value chain belonging to the Production Link considering the FAO's framework (FAO, 2014). Those stakeholders are diverse in roles, from internal farmworkers to external institutions. One aspect of farmer-stakeholder relationships is the technology used for data and information sharing.(Bruce, 2016; Kruize et al., 2016; Roussaki et al., 2019). This idea implies the existence of Technology suppliers, which can own farming software or develop a technical platform, the Application Components, and the Devices/ Nodes (Barreto & Amaral, 2018; Braun et al., 2018; Kruize et al., 2016; Wolfert et al., 2017). Technology suppliers must create custom, efficient hardware and software. A single, precise description from stakeholders can optimize functionality, implementation, and piece partitioning. Based on the above, centered-user design or co-design, it is necessary to capture the whole set of tools, devices, components, and data sources needed by farmers and agronomists.(Andrieu et al., 2019; Ayre et al., 2019; Barreto & Amaral, 2018; Braun et al., 2018; Bruce, 2016; Jakku et al., 2019; Kernecker et al., 2020; Knierim et al., 2019; Makinde et al., 2019; Rose & Chilvers, 2018; Roussaki et al., 2019). More, to ensure the best practices during the requirements analysis phase, it is essential to desegregate the different Farmer types.

Even if the growers aim to increase the agricultural ecosystem in efficiency and production sustainability, at least there are two different grower profiles: Farmer and Farm enterprises. The first profile includes synonymies as small-scale farmers, conventional production farmers, family farmers, and family units (Andrieu et al., 2019; Braun et al., 2018; Eastwood & Renwick, 2020; Jakku et al., 2019; Sarri et al., 2020). This profile is critical to improving farm management. According to FAO, about 90 percent of the world's 570 million farms are owned and operated by families. Moreover, many smallholder family farmers are poor and food insecure, having limited access to markets and services (2020). Therefore, Smart Farming Adoption's ultimate challenge is considering this unique profile during the SFT design process, making technologies accessible and usable.

In contrast, the second grower profile is Farm enterprises or Agribusiness. It can be an arable farm, livestock farm, horticultural farm, wild fauna, and flora (Kruize et al., 2016). Snapp and Pound say production models are crucial (2017) "Diversifying farm enterprises will boost mixed-enterprise farming systems' output." (Snapp & Pound, 2017). Then, some studies and reviews leave smart farming technology readiness implicit.(Barreto & Amaral, 2018; Braun et al., 2018; Caffaro et al., 2020; Ingram & Maye, 2020; Jakku et al., 2019; Kernecker et al., 2020; Kruize et al., 2016; Lioutas & Charatsari, 2020; Rose & Chilvers, 2018; Wiseman et al., 2019). Developing SFT for Farm enterprises could improve farming systems quickly; however, based on global farm composition, SFT for smallholder farmers is required to achieve Sustainable Development Goals.

In summary, to facilitate the Smart Farming Adoption process, it is necessary to develop technology center-user designed or co-designed, particularly considering the educational, social, economic, and technological challenges in smallholder farming. This participatory design requires collaboration between actors across the food value chain. Innovative agri-tech (Bacco et al., 2018; Braun et al., 2018; Jakku et al., 2019; Rose & Chilvers, 2018; Roussaki et al., 2019), Corporate Venture Firms (Braun et al., 2018; Jakku et al., 2019; Knierim et al., 2019; Rose & Chilvers, 2018; Wolfert et al., 2017), Incubators (Braun et al., 2018; Jakku et al., 2019; Rose & Chilvers, 2018; Roussaki et al., 2019; Wolfert et al., 2017), University (Barreto & Amaral, 2018; Braun et al., 2018; Ingram & Maye, 2020; Jakku et al., 2019; Kernecker et al., 2020; Knierim et al., 2019), Venture Capital Firms (Braun et al., 2018; Jakku et al., 2019; Knierim et al., 2019; Rose & Chilvers, 2018; Wolfert et al., 2017), and Business accelerators (Braun et al., 2018; Jakku et al., 2019; Rose & Chilvers, 2018; Roussaki et al., 2019; Wolfert et al., 2017). A holistic vision can help develop affordable, scalable, and easily accessible solutions for Smart Farming.

3.3.Q3:What are the theoretical references for the Adoption of Smart Farming solutions in rural areas?

Once we selected the retrieved papers related to technology adoption, this research identifies theoretical references applying the snowball methodology (Lewis-Beck et al., 2004). Considering the idea of compatibility as a decisive factor for the innovation adoption process (Lioutas & Charatsari, 2020), We can go back to the theoretical framework of diffusion of innovations proposed by Rogers (Rogers, 1983). This theory explains how new ideas and technologies spread and why. This theory is essential due to current tools or procedures for improving technology adoption. (Balafoutis et al., 2020). Smart Farming Adoption also involves adopting, using, and adapting digital technologies on-farm. (Klerkx et al., 2019). Last, these are the main theoretical and methodological perspectives. Last, these are the main theoretical and methodological perspectives. (Klerkx et al., 2019): (i) adoption and diffusion theory. (ii) Behavioral psychology. (iii) Practice theory. (iv) Assemblage theory. (v) Cost and benefit modeling. (vi) Econometrics, Evolutionary economics. And (vii) Innovation systems (Klerkx et al., 2019). Based on the snowball method and early adoption on smallholder farms, we highlight internet penetration and training as essential for SFA and a knowledge source in transitional agriculture.(Janc et al., 2019; Knierim et al., 2019).

It then discusses internet penetration and its benefits. Michels et al. results were comparable (Michels et al., 2020) because co-design must consider Internet penetration due to age, farm size, location, and Internet familiarity are risks associated with mobile internet adoption in agriculture. Indeed, "Identifying factors influencing mobile internet adoption can help policymakers and businesses develop marketing strategies for mobile farm equipment (Michels et al., 2020). To close this question, we return to the idea of Klerkx et al. (2012) (Klerkx et al., 2012). The authors researched methods of Agricultural Innovation Systems (AIS). This work presents an in-depth analysis of the main elements: The evolution in thinking on systems approaches as a co-evolutionary process (i.e., combined technological, social, economic, and institutional change). The AIS' differences in conceptualization and operationalization and the interactions between multi-actor, infrastructures, policies, and institutions. Key enablers and disablers of AIS. Methods for researching AIS. Moreover, Interventions at different levels stimulate AIS. This viewpoint provides a comprehensive and extensive view of actors and factors that co-determine innovation because of potential adopters' values, experiences, and need to improve Smart Farming Adoption (Lioutas & Charatsari, 2020).

3.4.Q4:What IoT technologies have been implemented in rural areas to support the work of farmers

This work investigates and explores Smart Farming Technologies available on retrieved documents. As a first approximation, all technologies applied to Smart Farming can be nested with the Agriculture Internet of things Domain (J. Doshi et al., 2019; Kamilaris et al., 2016; Talavera et al., 2017). However, a more detailed analysis is required to determine SFT. We present the main groups of technologies considering their application to research work or their highlighted importance: (i) Wireless Sensor Networks (Bacco et al., 2018; Choi & Jie, 2016; Roussaki et al., 2019; Suakanto et al., 2016). App (Alves et al., 2019; Bruce, 2016; Caffaro et al., 2020; Marimuthu et al., 2017; Roussaki et al., 2019). (ii) Big Data (Caffaro et al., 2020; Wolfert et al., 2017). (iii) Cloud computing (Alves et al., 2019; Caffaro et al., 2020; Roussaki et al., 2019; Suakanto et al., 2016). (iv) Databases and terminals (Alves et al., 2019; Barreto & Amaral, 2018; Choi & Jie, 2016; Wiseman et al., 2019). (v) Digital Twins (Alves et al., 2019). (vi) Decision Support systems (Alves et al., 2019; Caffaro et al., 2020; Z. Doshi et al., 2018; Roussaki et al., 2019; Suakanto et al., 2016; Zhai et al., 2020). (vii) Embedded system (Caffaro et al., 2020; Choi & Jie, 2016). (viii) Internet, website, and Social networks (Braun et al., 2018; Bruce, 2016; Janc et al., 2019; Knierim et al., 2019; Marimuthu et al., 2017; Michels et al., 2020; Musat et al., 2018). (ix) IoT (Bacco et al., 2018; Braun et al., 2018; Caffaro et al., 2020; Lioutas & Charatsari, 2020). (x) Sensors (Choi & Jie, 2016; Roussaki et al., 2019). (xi) Software as a service (Caffaro et al., 2020; Kruize et al., 2016; Roussaki et al., 2019). (xii) UAV and UGV (Bacco et al., 2018; Caffaro et al., 2020)

Conclusions

Based on the findings, the main conclusion for this work is that developing Smart Farming Technologies to fulfill sustainable development goals requires a change of focus to smallholder farm requirements. This transition is necessary to apply methodologies such as co-design, user-centered design, and participatory design, considering the whole perspectives of sustainable food value chain stakeholders. Furthermore, Smart Farming solutions will not include only the engineer perspective but also integrate social science to facilitate technology adoption in an on-site context. The overcoming challenges include: (i) Adopting knowledge from experienced experts. (ii) Enhance accessibility, Improve usability. (iii) Enriching Decision Supports Systems. (iv) Reduce technology acquisition costs and improve Resource efficiency. (v) Guarantee Cyber-security. (vi) Improve Business Continuity, Crisis Management, Leadership, and Governance.

References

ALVES, R. G., SOUZA, G., MAIA, R. F., TRAN, A. L. H., KAMIENSKI, C., SOININEN, J.-P., AQUINO, P. T., & LIMA, F. (2019). A digital twin for smart farming. *2019 IEEE Global Humanitarian Technology Conference (GHTC)*, 1–4. https://doi.org/10.1109/GHTC46095.2019.9033075

ANDRIEU, N., HOWLAND, F., ACOSTA-ALBA, I., LE COQ, J.-F., OSORIO-GARCIA, A. M., MARTINEZ-BARON, D., GAMBA-TRIMIÑO, C., LOBOGUERRERO, A. M., & CHIA, E. (2019). Co-designing Climate-Smart Farming Systems With Local Stakeholders: A Methodological Framework for Achieving Large-Scale Change. *Frontiers in Sustainable Food Systems*, *3*. https://doi.org/10.3389/fsufs.2019.00037

AYRE, M., MC COLLUM, V., WATERS, W., SAMSON, P., CURRO, A., NETTLE, R., PASCHEN, J.-A., KING, B., & REICHELT, N. (2019). Supporting and practising digital innovation with advisers in smart farming. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100302. https://doi.org/10.1016/j.njas.2019.05.001

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. *2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany)*, 1–6. https://doi.org/10.1109/IOT-TUSCANY.2018.8373043

BALAFOUTIS, A. T., EVERT, F. K. VAN, & FOUNTAS, S. (2020). Smart Farming Technology Trends: Economic and Environmental Effects, Labor Impact, and Adoption Readiness. *Agronomy*, *10*(5), 743. https://doi.org/10.3390/agronomy10050743

BARRETO, L., & AMARAL, A. (2018). Smart Farming: Cyber Security Challenges. *2018 International Conference on Intelligent Systems (IS)*, 870–876. https://doi.org/10.1109/IS.2018.8710531

BRAUN, A.-T., COLANGELO, E., & STECKEL, T. (2018). Farming in the Era of Industrie 4.0. *Procedia CIRP*, *72*, 979–984. https://doi.org/10.1016/j.procir.2018.03.176

BRUCE, T. J. A. (2016). The CROPROTECT project and wider opportunities to improve farm productivity through web-based knowledge exchange. *Food and Energy Security*, *5*(2), 89–96. https://doi.org/10.1002/fes3.80

CAFFARO, F., & CAVALLO, E. (2019). The Effects of Individual Variables, Farming System Characteristics and Perceived Barriers on Actual Use of Smart Farming Technologies: Evidence from the Piedmont Region, Northwestern Italy. *Agriculture*, *9*(5), 111. https://doi.org/10.3390/agriculture9050111

CAFFARO, F., & CAVALLO, E. (2020). Perceived Barriers to the Adoption of Smart Farming Technologies in Piedmont Region, Northwestern Italy: The Role of User and Farm Variables. In *International Mid-Term Conference of the Italian Association of Agricultural Engineering* (pp. 681–689). https://doi.org/10.1007/978-3-030-39299-4_74

CAFFARO, F., MICHELETTI CREMASCO, M., ROCCATO, M., & CAVALLO, E. (2020). Drivers of farmers' intention to adopt technological innovations in Italy: The role of information sources, perceived usefulness, and perceived ease of use. *Journal of Rural Studies*, *76*, 264–271. https://doi.org/10.1016/j.jrurstud.2020.04.028

CHOI, W.-H., & JIE, M.-S. (2016). Auto Plants Growing Embedded System Design Using Wireless Sensor Networks. *International Journal of Multimedia and Ubiquitous Engineering*, *11*(4), 147–156. https://doi.org/10.14257/ijmue.2016.11.4.15

DAVIS, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319–340.

DOSHI, J., PATEL, T., & BHARTI, S. KUMAR. (2019). Smart Farming using IoT, a solution for optimally monitoring farming conditions. *Procedia Computer Science*, *160*, 746–751. https://doi.org/10.1016/j.procs.2019.11.016

DOSHI, Z., NADKARNI, S., AGRAWAL, R., & SHAH, N. (2018). AgroConsultant: Intelligent Crop Recommendation System Using Machine Learning Algorithms. *2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, 1–6. https://doi.org/10.1109/ICCUBEA.2018.8697349

EASTWOOD, C. R., & RENWICK, A. (2020). Innovation Uncertainty Impacts the Adoption of Smarter Farming Approaches. *Frontiers in Sustainable Food Systems*, *4*. https://doi.org/10.3389/fsufs.2020.00024

FAO. (2014). Developing sustainable food value chains: guilding principles. In *Fao* (1st ed.). FAO Publications.

FAO. (2018). *e-Agriculture Newsletter No.1*.

FOOD AND AGRICULTURE ORGANIZATION - FAO. (2020). *Family Farming Knowledge Platform*. Theme. http://www.fao.org/family-farming/themes/small-family-farmers/en/

INGRAM, J., & MAYE, D. (2020). What Are the Implications of Digitalisation for Agricultural Knowledge? *Frontiers in Sustainable Food Systems*, *4*. https://doi.org/10.3389/fsufs.2020.00066

ITU. (2018a). *Resolution 71: Strategic plan for the Union for 2020-2023*.

ITU. (2018b). *Resolution 200: Connect 2030 Agenda for global telecommunication/information and communication technology, including broadband, for sustainable development*.

JAKKU, E., TAYLOR, B., FLEMING, A., MASON, C., FIELKE, S., SOUNNESS, C., & THORBURN, P. (2019). "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100285. https://doi.org/10.1016/j.njas.2018.11.002

JANC, K., CZAPIEWSKI, K., & WÓJCIK, M. (2019). In the starting blocks for smart agriculture: The internet as a source of knowledge in transitional agriculture. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100309. https://doi.org/10.1016/j.njas.2019.100309

KAMILARIS, A., GAO, F., PRENAFETA-BOLDU, F. X., & ALI, M. I. (2016). Agri-IoT: A semantic framework for Internet of Things-enabled smart farming applications. *2016 IEEE 3rd World Forum on Internet of Things (WF-IoT)*, 442–447. https://doi.org/10.1109/WF-IoT.2016.7845467

KAMPKER, A., STICH, V., JUSSEN, P., MOSER, B., & KUNTZ, J. (2019). Business Models for Industrial Smart Services – The Example of a Digital Twin for a Product-Service-System for Potato Harvesting. *Procedia CIRP*, *83*, 534–540. https://doi.org/10.1016/j.procir.2019.04.114

KERNECKER, M., KNIERIM, A., WURBS, A., KRAUS, T., & BORGES, F. (2020). Experience versus expectation: farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precision Agriculture*, *21*(1), 34–50. https://doi.org/10.1007/s11119-019-09651-z

KLERKX, L., JAKKU, E., & LABARTHE, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100315. https://doi.org/10.1016/j.njas.2019.100315

KLERKX, L., VAN MIERLO, B., & LEEUWIS, C. (2012). Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In *Farming Systems Research into the 21st Century: The New Dynamic* (pp. 457–483). Springer Netherlands. https://doi.org/10.1007/978-94-007-4503-2_20

KNIERIM, A., KERNECKER, M., ERDLE, K., KRAUS, T., BORGES, F., & WURBS, A. (2019). Smart farming technology innovations – Insights and reflections from the German Smart-AKIS hub. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100314. https://doi.org/10.1016/j.njas.2019.100314

KOLIPAKA, V. R. R. (2020). Predictive analytics using cross media features in precision farming. *International Journal of Speech Technology*, *23*(1), 57–69. https://doi.org/10.1007/s10772-020-09669-z

KRUIZE, J. W., WOLFERT, J., SCHOLTEN, H., VERDOUW, C. N., KASSAHUN, A., & BEULENS, A. J. M. (2016). A reference architecture for Farm Software Ecosystems. *Computers and Electronics in Agriculture*, *125*, 12–28. https://doi.org/10.1016/j.compag.2016.04.011

LEWIS-BECK, M. S., BRYMAN, A., & LIAO, T. F. (EDS.). (2004). Snowball Sampling. In *The SAGE Encyclopedia of Social Science Research Methods*. Sage Publications, Inc. https://doi.org/10.4135/9781412950589.n931

LEZOCHE, M., HERNANDEZ, J. E., ALEMANY DÍAZ, M. DEL M. E., PANETTO, H., & KACPRZYK, J. (2020). Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture. *Computers in Industry*, *117*, 103187. https://doi.org/10.1016/j.compind.2020.103187

LIOUTAS, E. D., & CHARATSARI, C. (2020). Smart farming and short food supply chains: Are they compatible? *Land Use Policy*, *94*, 104541. https://doi.org/10.1016/j.landusepol.2020.104541

LIOUTAS, E. D., CHARATSARI, C., LA ROCCA, G., & DE ROSA, M. (2019). Key questions on the use of big data in farming: An activity theory approach. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100297. https://doi.org/10.1016/j.njas.2019.04.003

MAKINDE, A., ISLAM, M. M., & SCOTT, S. D. (2019). Opportunities for ACI in PLF. *Proceedings of the Sixth International Conference on Animal-Computer Interaction*, 1–6. https://doi.org/10.1145/3371049.3371055

MARIMUTHU, R., ALAMELU, M., SURESH, A., & KANAGARAJ, S. (2017). Design and development of a persuasive technology method to encourage smart farming. *2017 IEEE Region 10*

Humanitarian Technology Conference (R10-HTC), 165–169. https://doi.org/10.1109/R10-HTC.2017.8288930

MICHELS, M., FECKE, W., FEIL, J., MUSSHOFF, O., LÜLFS-BADEN, F., & KRONE, S. (2020). "Anytime, anyplace, anywhere"—A sample selection model of mobile internet adoption in german agriculture. *Agribusiness*, *36*(2), 192–207. https://doi.org/10.1002/agr.21635

MUSAT, G.-A., COLEZEA, M., POP, F., NEGRU, C., MOCANU, M., ESPOSITO, C., & CASTIGLIONE, A. (2018). Advanced services for efficient management of smart farms. *Journal of Parallel and Distributed Computing*, *116*, 3–17. https://doi.org/10.1016/j.jpdc.2017.10.017

PIVOTO, D., BARHAM, B., WAQUIL, P. D., FOGUESATTO, C. R., CORTE, V. F. D., ZHANG, D., & TALAMINI, E. (2019). Factors influencing the adoption of smart farming by Brazilian grain farmers. *International Food and Agribusiness Management Review*, *22*(4), 571–588. https://doi.org/10.22434/IFAMR2018.0086

ROGERS, E. M. (1983). *Diffusion of Innovations* (Third Edit). The Free Press.

ROSE, D. C., & CHILVERS, J. (2018). Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming. *Frontiers in Sustainable Food Systems*, *2*(87), 1–7. https://doi.org/10.3389/fsufs.2018.00087

ROUSSAKI, I., KOSMIDES, P., ROUTIS, G., DOOLIN, K., PEVTSCHIN, V., & MARGUGLIO, A. (2019). A Multi-Actor Approach to promote the employment of IoT in Agriculture. *2019 Global IoT Summit (GIoTS)*, 1–6. https://doi.org/10.1109/GIOTS.2019.8766416

SAIZ-RUBIO, V., & ROVIRA-MÁS, F. (2020). From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy*, *10*(2), 207. https://doi.org/10.3390/agronomy10020207

SARRI, D., LOMBARDO, S., PAGLIAI, A., PERNA, C., LISCI, R., DE PASCALE, V., RIMEDIOTTI, M., CENCINI, G., & VIERI, M. (2020). Smart Farming Introduction in Wine Farms: A Systematic Review and a New Proposal. *Sustainability*, *12*(17), 7191. https://doi.org/10.3390/su12177191

SNAPP, S., & POUND, B. (2017). Farming Systems for Sustainable Intensification. In *Agricultural Systems* (pp. 93–122). Elsevier. https://doi.org/10.1016/B978-0-12-802070-8.00004-9

SOTT, M. K., FURSTENAU, L. B., KIPPER, L. M., GIRALDO, F. D., LOPEZ-ROBLES, J. R., COBO, M. J., ZAHID, A., ABBASI, Q. H., & IMRAN, M. A. (2020). Precision Techniques and Agriculture 4.0 Technologies to Promote Sustainability in the Coffee Sector: State of the Art, Challenges and Future Trends. *IEEE Access*, *8*, 149854–149867. https://doi.org/10.1109/ACCESS.2020.3016325

SUAKANTO, S., ENGEL, V. J. L., HUTAGALUNG, M., & ANGELA, D. (2016). Sensor networks data acquisition and task management for decision support of smart farming. *2016 International Conference on Information Technology Systems and Innovation (ICITSI)*, 1–5. https://doi.org/10.1109/ICITSI.2016.7858233

SUEBSOMBUT, P., CHERNBUMROONG, S., SUREEPHONG, P., JAROENWANIT, P., PHUENSANE, P., & SEKHARI, A. (2020). Comparison of Smart Agriculture Literacy of Farmers in Thailand. *2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON)*, 242–245. https://doi.org/10.1109/ECTIDAMTNCON48261.2020.9090695

TALAVERA, J. M., TOBÓN, L. E., GÓMEZ, J. A., CULMAN, M. A., ARANDA, J. M., PARRA, D. T., QUIROZ, L. A., HOYOS, A., & GARRETA, L. E. (2017). Review of IoT applications in agro-industrial and environmental fields. *Computers and Electronics in Agriculture*, *142*, 283–297. https://doi.org/10.1016/j.compag.2017.09.015

VAN DER BURG, S., BOGAARDT, M.-J., & WOLFERT, S. (2019). Ethics of smart farming: Current questions and directions for responsible innovation towards the future. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100289. https://doi.org/10.1016/j.njas.2019.01.001

VAN ES, H., & WOODARD, J. (2017). Innovation in Agriculture and Food Systems in the Digital Age. In *THE GLOBAL INNOVATION INDEX 2017* (1st ed., pp. 97–104).

VENKATESH, MORRIS, DAVIS, & DAVIS. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425. https://doi.org/10.2307/30036540

WISEMAN, L., SANDERSON, J., ZHANG, A., & JAKKU, E. (2019). Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming. *NJAS - Wageningen Journal of Life Sciences*, *90–91*, 100301. https://doi.org/10.1016/j.njas.2019.04.007

WOLFERT, S., GE, L., VERDOUW, C., & BOGAARDT, M.-J. (2017). Big Data in Smart Farming – A review. *Agricultural Systems*, *153*, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

XIN, J., & ZAZUETA, F. (2016). Technology trends in ICT - towards data-driven, farmer-centered and knowledge-based hybrid cloud architectures for smart farming. *Agricultural Engineering International: CIGR Journal*, *18*(4), 275–279.

ZHAI, Z., MARTÍNEZ, J. F., BELTRAN, V., & MARTÍNEZ, N. L. (2020). Decision support systems for agriculture 4.0: Survey and challenges. *Computers and Electronics in Agriculture*, *170*, 105256. https://doi.org/10.1016/j.compag.2020.105256