DIGITAL TRANSFORMATION IN THE AGRICULTURE SECTOR: EXPLORING THE SHIFTING ROLE OF EXTENSION WORKERS

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Abstract
The world's digitalization will continue. The exponentially increasing use of digital technology has caused disruption in a variety of industries, including agriculture. The purpose of this paper is to (1) examine how digital technologies are transforming the agricultural sector and (2) investigate the changing roles of agricultural extension workers in the digital era. This paper incorporated qualitative data (online observation) gathered via the World Wide Web via unobtrusive observation technique, as well as data from a literature review. The findings revealed that digital technology is altering the agricultural sector in two ways: the food system and the agricultural knowledge and innovation system. This paper tries to demonstrate how digitalization has changed the role of agricultural extension workers. The Extension worker's role is renewed to adjust to the digital ecosystem, such as informant, consultant, advisor, facilitator, mediator, and promoter. In addition, extension workers' roles as content creators and influencers, gatekeepers, big data analysts, artificial intelligence, and gamify creators will be expanded in the new field. Meanwhile, in response to these two major challenges, this research provides managerial implications for extension institutions and individual agricultural extension workers in Indonesia as they respond to the digital era.

Keywords: Transformation, digital technology, digital platform, agricultural extension workers

I. INTRODUCTION

Agriculture is an important sector for Indonesia, contributing around 12.6% of the country's GDP, employing almost a third (29.96%) of the Indonesian labour force, and being dominated (93%) by smallholder farmers. This sector makes the country depend on the agricultural sector during the COVID-19 pandemic. While another sector decreased, agriculture recorded a growth of 1.37% (BPS, 2022). Millions of Indonesians (275 million people) depend on the agricultural sector to supply their food consumption with diverse preferences as the middle-class economy grows. To supply these demands, it is important to maintain and improve the productivity, competitiveness, and sustainability of agricultural businesses.

Certainly, the agricultural sector still copes with recurring problems. Farmers have a low bargaining position and face difficulties accessing markets and price information (Anggraini et al., 2020), low production efficiency (Rachmawati, 2021), and unattainable to technology and financing for inclusive capitalization (Fitriani, 2018). Furthermore, there is still found information asymmetry between farmers and other agricultural value chain actors, resulting in a lack of transparency and effective communication to generate high productivity and prevent food loss due to untraceable supply chains (Goh, 2022).

Simultaneously, the world is becoming increasingly digitalized. The emergence of the COVID-19 pandemic, whether we like it or not, has encouraged and accelerated the process of digitalization in all areas of life. Technological development has accelerated with the growth of the internet in recent years. 73,7% *of* internet users were reported in the global digital report (https://www.hootsuite.com/resources/digital-trends). Actually, users of mobile connections (mobile phone/smartphone/tablet) reached 125.6% of Indonesia's total population. This means that one person has more than one device. Moreover, there are rapid advances in digital

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technology in the form of digital devices, automation, artificial intelligence, and machine learning. These innovative technologies are leading to what researchers call the 'fourth agricultural revolution', or 'Agriculture 4.0'. This revolution is shaping the agriculture of the future characterized by high-tech, radical, and potentially game-changing (Klerkx & Rose, 2020).

Agriculture 4.0 has disruptive and transformative properties. The adoption of innovative technologies has the potential to affect the way food is produced, processed, traded, and consumed (Klerkx & Rose, 2020). The most frequently cited impacts of digitization in agriculture tend to refer to precision agriculture technologies that are promoted as highly efficient, capable of reducing input costs while increasing yields, inclusiveness, transparency, and business sustainability (Eastwood et al., 2019; Ayoub Shaikh et al., 2022). Furthermore, the intervention of innovative technologies such as IoT, AI, block chain, augmented reality, remote sensing, and distributed computing, farmers have access to inputs, markets, finance, and decision-making services for good farming practices. Innovative technologies are predicted to enable new business models that can help increase farm yields and profitability efficiently and effectively (Goh, 2022).

This condition is also a new challenge for agricultural extension, and how to respond to changes in society. Some researchers call it a digital society, a society characterized by digitized and connected social life, with computers and algorithms mediating many daily activities. Digital technology has become part of everyday life. Things that were once considered science fiction are now taken for granted, such as smartphones, global information networks, and virtual reality. Society has become increasingly dependent on technology and digital infrastructure. The structure of this new society is quite abstract and difficult to understand (Dufva & Dufva, 2019). It is time for agriculture extension to change one of its old paradigms, namely the transfer of information and technology. Knowledge and information are no longer dominated by extension workers. Digitalization has the potential to increase democratization and change the relationship between extension workers and farmers to be more equal and inclusive.

Agricultural extension has evolved as an integral part of agricultural development over the past century. The extension became an instrument of government policy starting in the 1970s as an effort to deal with the world food crisis through the main food production increase program (Benson & Jafry, 2013), through Green Revolution efforts to expand new practices, varieties, knowledge, and techniques in anticipation of Malthus' prediction of famine due to unbalanced population growth and food production growth (Cook *et al*., 2021). Until now, the extension still plays a central role in agricultural development in Indonesia.

The advent of digital technology has changed the way people communicate, work, learn and interact. The results of the Informatics and Communication Ministry survey (Kominfo, 2020) report that WhatsApp is the most widely used social media (98.9%), then Facebook (89.8%) and YouTube (87.8%). This affects the sources of information obtained by the community, most of which (76%) come from social media. Even 55.2% stated that they trusted information from social media, especially WhatsApp. The digital era, where people's actions are often mediated by digital ICT, has forced the agricultural extension system to adjust. Digital-based ICT does not create social order, but unconsciously, when people adopt a technology, the characteristics, system, and order will indirectly change. Some countries are responding to digitalization by expanding the role of extension workers, not just transferring technology as has been done. Some of the new roles of extension workers that have emerged in the digital era require a new type of skill, namely digital literacy.

Thus this study aims to answer two questions: (1) To what extent are digital technologies transforming the agricultural sector? and (2) What should agricultural extension agencies do to remain relevant in the digital era? In the literature, these have been extensively investigated to review related to the topic of agriculture and digitalization. Discern the changes taking place, widely reported, and extensively explored in the literature used online observations. This paper starts by giving an overview of the types of digital technologies that can transform the agricultural sector. Additionally, outline the forms and landscapes of transformation that are occurring as digitalization develops in agriculture. From there discussed the shifting role of agricultural extension that needs to be anticipated. Finally, concluded by considering the implications for extension organizations and agricultural extension personnel.

II. METHODOLOGY

The data were collected using two methods: literature review and online observation with an Unobtrusive Observation technique on digital platform sites in the Indonesian agricultural sector.

The literature review was a review of all major studies related to digital transformation and agricultural extension to integrate or synthesize evidence related to the research questions. The literature review was sourced from Scopus and google scholar databases.

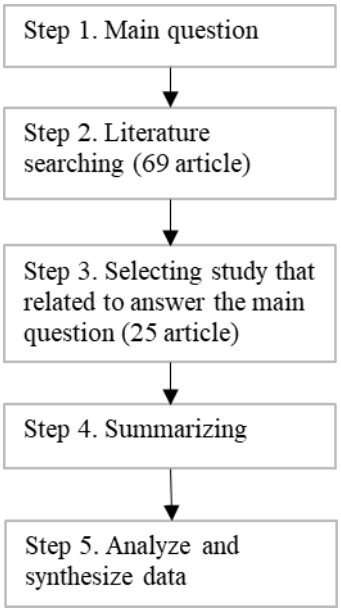

Fig. 1. The flow diagram of the literature review

Intending to identify studies that are suitable for achieving the key objectives of this research, we search in the literature database Scopus using the string "agriculture" AND "digital transformation" AND "digital technology" OR "digital farming" OR "mobile phone" OR "internet" OR "internet of things" OR "block chain" OR "Artificial intelligence" OR "Drone". 69 articles were found. Then selected those articles that are relevant and able to referee answer research questions. Sort in 25 articles related to the research topic. These articles were summarized and categorize, synthesize, and analyse the data. Accomplished research objective focused on the local Indonesian context, the articles were searched which has related to research questions on Google Scholar.

The data from Online observation were collected from May to June 2022 on eleven websites related to this topic. The selection of this website was determined purposively based on the Compasslist report with the title Indonesia agritech report. From there, several start-ups were tabulated whose company valuations have increased exponentially. Searching by Google search engine regarding start-ups business practices was attained through their official website. Then the content analysis was conducted regarding business services, products, and business models. The validity of the websites was tested by the URL Checker https://www.emailveritas.com/url-checker using advanced artificial intelligence (AI) and machine learning techniques to quickly detect fraudulent websites and determine if legitimate.

Online observation is a research method that is widely used in the digital era through online observation on sites related to the research topic, in this case, sites related to digital platforms in the agricultural sector. The technique used is unobtrusive observation. An unobtrusive researcher is a bystander collecting data without interacting. This means that the researcher can collect data by downloading relevant materials for further analysis. In this form of observation, the researcher does not make posts, ask questions, respond, or involve themselves in interactions with the community on the online site. Considering that all the data collected in this study can be accessed by the public, the researcher feels that there will be no privacy of individuals or institutions will be disturbed by this research (Salmons, 2021).

This research finds the right context as a novelty where digital transformation needs to be addressed by changing the role of agricultural extension workers, especially in developing countries.

III. RESULTS AND DISCUSSION

A. Digital Technology as an Entrance to Digital Transformation

Digital technology refers to the use of digital-based information and communication technologies to collect, store, analyse and share information, providing essential technical support for innovation in various fields. In the agricultural sector, digital technologies are disruptive because they replace old technologies while making old ways of working irrelevant and modifying the attributes that users value (Christensen, 2013). Unexpectedly, Nieto Cubero et al., (2021) entitle it to a radical technology because of its ability to generate new market infrastructures and produce discontinuities at the macro and micro levels.

Humans have limited capacity to process complex agricultural big data, so they need the help of tools that facilitate analysis in making useful decisions. Based on observation, there are 6 categories of digital technologies that are the entry points for digital transformation in agricultural practices: mobile phones, internet-connected to various electronic devices, the Internet of Things

(IoT), Artificial Intelligence (AI), Drones, and Block chain (Table 1).

Table 1. Digital technology and its role in the agriculture sector

No	Digital technology	Capacity/ability	Roles in agriculture	Source
1	Mobile phone	Voice and text communication	Facilitate communication between actors regarding prices, markets, production facilities, cultivation consulting, and climate information	(Aker & Ksoll, 2016; (Khan et al., 2020); Beza et al., 2018)
2	Internet (connected to a laptop or smartphone)	Voice communication, text, images, video, social media, browsing, digital platforms (e-commerce, e-learning)	Facilitate access to information and communication of farmers globally, increase human resource capacity online, business networks, markets, economic transactions, and financing	(Emeana et al., 2020); (ZHENG et al., 2022); Subejo et al., 2019)
3	Internet of Things (IoT): Wireless Sensor Networks (WSNs) Cloud computing, big data analytics, Embedded systems, Communication protocols	Capture, process, filter, and store data locally and in the cloud, for the development of a user-friendly interface and various other utilities as needed.	Capture, process, filter, and store data locally and in the cloud, for the development of a user-friendly interface and various other utilities as needed.	(Boursianis et al., 2022); Hsu et al., 2020)
4	Artificial Intelligence (AI) and Machine learning	Observing, learning, and reasoning, and offering approximate solutions for complex functions.	Assist decision-making in precision agriculture cultivation	(Ayoub Shaikh et al., 2022); Elbeltagi et al., 2022)
5	Drone (Unmanned Aerial Vehicles)	Create high-resolution aerial imagery and perform AI-commanded actions	Supporting precision agriculture, detecting and mapping pests, diseases, and weeds, irrigating, fertilizing, and spraying pesticides.	(Rejeb et al., 2022); Tsouros et al., 2019)
6	Block chain	Combining cryptography and distributed computing to provide an algorithm for exchanging values securely	Providing data flow security into agricultural business models, assisting in product traceability, and financial technology (fintech) development.	(Ferrández-Pastor et al., 2022; Patel et al., 2022)

First, mobile phones are an early-generation digital technology, wireless handheld device that allows users to make and receive calls and send text messages. Mobile phones operate on cellular networks, which consist of cell sites scattered throughout cities, the countryside, and even mountainous areas. If the user happens to be in an area where there is no signal from any cell site belonging to the cellular network provider to which he/she subscribes, calls cannot be made or received at that location (Aker & Ksoll, 2016).

Second, the internet is a globally connected network system that facilitates worldwide communication and access to data resources through an enormous collection of private, public, business, academic, and government networks. In the agricultural sector, the Internet allows the exchange and sharing of knowledge, for example about market situations, climate predictions, and government programs. Therefore, thanks to the internet, a farmer can acquire knowledge and expand it, contact other actors, promote his

products and services, order the necessary means of production, and carry out administrative tasks (Emeana et al., 2020).

Third, the Internet of Things (IoT) is one of the most revolutionary technologies, as all objects, connected to the web, will be enabled to share, and process data through their sensors and communication devices autonomously. The basic concept is that the interaction between physical components using a specific scheme will be connected to the Internet. In an agricultural environment, IoT devices provide useful information about various physical parameters to improve cultivation practices. The goal is to identify how the information collected can be used smartly. Farmers can use smartphones and tablet devices, to access real-time agricultural data (soil and crop conditions, irrigation, fertilization, weeds, or climate). As a result, farmers can act and intervene when necessary, based on valid data, rather than relying on their traditional intuition (Boursianis et al., 2022).

Fourth, Artificial intelligence (AI) has revolutionized information technology and shaped the way of live. AI is a system with the ability to act intelligently, interpret external data correctly, and use this purpose to carry out specific tasks with flexible configurations, even capable of reproducing human behaviour with cognitive, social, and emotional intelligence (Di Vaio et al., 2020). Due to its flexibility and robustness, AI is also being applied in agriculture. It is reported that AI applications can act as a rapid decision-making tool during climate change with high accuracy and low statistical error (Elbeltagi et al., 2022).

Fifth, drones, known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UAS), are remote-controlled aircraft that have many advantages over other remote sensing technologies. Drones can provide high-resolution images and videos on cloudy days. In agriculture, the use of drones integrated with computing technology and on-board sensors can support agricultural management (e.g., mapping, monitoring, irrigation, crop diagnosis), crop growth monitoring yield estimation, drought stress assessment, and weed, pest, and disease detection. Drones are even capable of simultaneously spraying the right amount of water and pesticides based on environmental data (Rejeb et al., 2022).

Finally, block chain is a decentralized, replicable, distributed ledger technology that underlies many additional innovations and is secure, traceable, cost-effective, transparent, and fast. In the agricultural sector, some researchers are using block chain technology for supply chain digitization and traceability, linking it with Radio Frequency Identification or RFID devices (Ferrández-Pastor et al., 2022). Since block chain is a technology that relies on algorithmic blocks, containing transaction information, connected and validated in chronological order and forming a chain that contains permanent, immutable, transparent, and tamper-proof records, it is also widely used in the field of agricultural finance (Patel et al., 2022).

Digital technology can produce two types of disruptive innovations, namely digital farming, and smart farming, also known as precision farming.

First, digital agriculture is defined as the application of digital technologies along the agricultural value chain. Digital tools can be embodied in agricultural machinery (e.g., precision farming technologies using sensors, data analytics, and variable rate technologies) or intangible, e.g., extension applications, farm management software, and digital platforms that connect farmers to the value chain (Daum et al., 2022).

Second, smart agriculture or precision agriculture is a term defined as the application of modern information and communication technologies (IoT, GPS, big data) to improve the productivity and quality of agricultural products (De Clercq et al., 2018). IoT technology can manage temperature, light, and soil moisture data in a central control system by applying Artificial Intelligence (AI) algorithms to help farmers manage crop production systems (Wolfert et al., 2017). Smart agriculture provides practical solutions to solve several complex problems such as soil fertility, crop quality, pest and disease incidence, precision fertilization and irrigation, and various agronomic data recording.

B. Digital Transformation in Agriculture

The development of digital technology has resulted in digital transformation in the agricultural sector. There is no universal definition of digital transformation in academic circles. According to Peng & Tao (2022), that digital transformation is a change in the core business model and creates a new business model due to the use of digital technology. Digital transformation is synonymous with the transformation of business practices characterized by business model innovation, value creation, and new economic forms.

The digital transformation of agriculture has gone beyond the use of tools and software, as it impacts the knowledge and skills of its users, both main actors (farmers), business actors, and other supporting actors such as extension workers,

researchers, and consumers. Information fusion plays a vital role in digital extension transformation. The aspect of information fusion is the integration of various heterogeneous information sources. Information fusion serves as an improvement in the estimation and prediction of circumstances based on the combination process of data or information (Steinberg & Bowman, 2001). In agricultural extension, information fusion is useful for predicting information-seeking behaviour. The development of internet users in the search for agricultural innovations needs to be studied further through the Internet of Behaviours.

Internet of Behaviours (IoB) is the aggregation and analysis of data based on user behaviour and preferences. IoB serves as a link between the digital world and human behaviour, characteristics, goals, and interactions and provides the desired adjustment or exchange between the quality of experience (QoE) and quality of service (QoS). IoB can observe human behaviour, adjust itself, and continuously influence human decisions implicitly and explicitly (Moghaddam et al., 2022). The development of IoB initiated the research and development of personal digital twin and cognitive digital twin (De Kerckhove & Saracco, 2021; Javaid et al., 2021; Stary, 2021). Extension IoB activities can have implications for the creation of Knowledge as a Service software (De Kerckhove & Saracco, 2021) in the field of agricultural extension.

The digital transformation of agriculture can be detected in the emergence of digital platforms. A digital platform is a kind of platform that functions as a standardized digital interface by utilizing digital technology to facilitate interactions between various parties (Chen et al., 2022). Appertain to digital platforms as a way to develop information technology infrastructure, and they include social media, mobile computing, and e-commerce platforms (Ahmed et al., 2022). Digital platforms sometimes utilize location data and previous usage information to predict behaviour. It thus goes beyond the traditional market mechanism of one-way interaction to make it more interactive. Digital platforms have three main characteristics, which are technology-mediated, enable interaction between groups of users, and allow groups of users to perform specified tasks (Ratten, 2022).

Based on online observations, digital platforms have penetrated the agricultural sector not only to change the old business model into a new one but also to overcome the problems of farmers that have not been facilitated. These problems include five aspects, namely access to information (related to good agricultural practices /GAP, prices, pests and diseases, climate), access to financing and farm insurance, access to quality production inputs (such as seeds, fertilizers, and pesticides), market access, and access to mechanization and precision farming technology services. The presence of the platform seems to consolidate the prerequisites for agricultural development as formulated by Mosher that there are five basic conditions and facilitating conditions. The basic conditions include markets, technology, means of production, production stimulation, and smooth and continuous transportation. The facilitating conditions consist of education (extension), financing, "*gotong royong" (*cooperation), improvement and expansion of agricultural land, and agricultural development planning (Mosher, 1965)

Departing from these problems, digital platforms have emerged to change two major systems, namely the food system and the agricultural knowledge and innovation system. The transformation of the food system is marked by the emergence of digital marketplaces, traceable supply chain systems, fintech-based financing (peer-to-peer lending), and mechanization and precision agriculture platforms. The transformation of agricultural knowledge and innovation systems is characterized by the emergence of new forms of agricultural information services, new sources of knowledge, and new actors in agricultural innovation. This paper only provides the broad perspective design to enable future transformative processes. Meanwhile, further research and implementation are needed to explore the real evolving digital extension in Indonesia.

(1) Transformation of the Food System

The food system starts from upstream, on a farm, off-farm, and distribution chain. The upstream aspect is the stage before planting in the field, including plant and livestock breeding, biotechnology, seed/seedling production, and farmland history. The on-farm aspect is the second stage of the agricultural production chain, which is carried out on the land. The off-farm aspect refers to the process chain of agricultural products developed off-farm, covering post-harvest, processing, and storage. The distribution aspect is the last stage where food products are transported for consumption by the public.

The transformation of the food system due to the use of digital technology is characterized by the development of new business models, namely the digital marketplace model, the financial technology (fintech)-based peer-to-peer financing

model with crowdfunding pattern, the supply chain traceable network model, and the precision farming model (Table 2). Each of these business models is starting to displace the old business model. The transformation seeks to provide an end-to-end solution to agricultural problems by cutting the supply and demand information gap and traceability of agricultural products

Table 2. The changing landscape of food systems due to digitization in the agriculture sector

No	Area of change	Description of changes
1	Market	Facilitating farmers and buyers (off-takers) and consumers, breaking the long marketing chain
2	Agricultural finance	Provision of financial services through the intermediation of creditors (lenders) with farmers (borrowers) peer-to-peer (P2P) lending with low-interest rates to increase agricultural productivity or profitability
3	Supply chain	Manage supply chain to increase profitability through certification and traceability
4	Farming practices and mechanization services	Producing precision agricultural technology to increase productivity and yield quality based on Internet of Things (IoT) solutions, providing crop maintenance services (fertilization & IPM) using drones

The first change is the commodity market. Up to a point, the market is defined as a physical meeting place between sellers and buyers. The length of the marketing chain from farmers to consumers is often the cause of the high disparity in prices received by farmers and prices that must be paid by consumers. Many actors are involved in the marketing chain of agricultural products. As an initial bridge, there are agribusiness terminals and sub-terminals (STA) that facilitate transactions and the formation of commodity prices. The emergence of digital platforms such as “Sayurbox” (https://www.sayurbox.com/), The farm-to-table concept allows consumers to buy fresh vegetables and fruits directly from farmers, and vice versa, allowing farmers to gain direct access to urban consumers.

Similarly, the platform “TaniHub” (https://foodsolutions.tanihub.com/) provides market solutions and farmer support applications that help simplify agricultural supply chains, increase farmer income, and stabilize product prices. These solutions address the challenges of not having up-to-date marketing or pricing information, as well as food supply and demand mismatches.

From a network theory perspective, the emergence of "hubs" is a consequence of the length of the agri-food chain, which consists of many actors who directly and/or indirectly operate along the journey of a product, from the initial stage of production to the final stage of use. Direct actors are those who work directly along the supply chain, from upstream to downstream, from farmers, traders, and retailers, to consumers. Indirect actors are those who contribute to supporting the smooth running of the supply chain, such as providers of seeds, seedlings, fertilizers, agricultural machinery, and pesticides. The role of digital "hubs" is replacing the classic "hubs" that used to be played by agribusiness terminals and sub-terminals. The ability of digital "hubs" to aggregate small suppliers and create a single point of transaction for consumers brings about changes for more efficient business processes. In addition, digital technology makes commercial transactions easier, faster, and cheaper than ever before. The application of communication technology, which is capable of sharing data, also supports the fulfilment of certain food needs (Sgroi & Marino, 2022).

The second change is in the aspect of agricultural financing. Hitherto, farmers have had difficulty accessing financing for farm capital. As a result, farmers have fallen into debt with intermediary traders and perpetuated the *Ijon* system. Bank credit has had difficulty penetrating because the risk of agricultural credit is quite high, and the procedures are quite strict and cannot be fulfilled by farmers. The emergence of digital-based financing platforms offers access to credit and facilitates the role of debtors in crowdfunding. Such as the “TaniFund” and “Crowde” platforms (https://crowde.co/) attempt to create a service ecosystem for farmers by providing access to financing (sharia contract/*murabahah*/buying and selling) and supply of production facilities or high-quality inputs such as seeds, fertilizers, and pesticides and access to markets at prices that are transparent to farmers. They work with off-takers to buy farmer's produce.

Digital agricultural finance platforms with crowdfunding patterns are emerging as a means of enabling professionals or financiers in urban areas to lend to farmers in rural areas. Besides being attractive due to higher returns and interest rates. There are also philanthropic reasons to help farmers succeed. The loan pattern is usually made at the start of the growing season and repaid a few months later. Short-cycle crops that generate

strong returns are ideal such as chili peppers, vegetables, and corn.

The third change is the supply chain system. Supply chain here is a term related to the concept of traceability in food production, as traceability is associated with recording the flow of food products. In the complexity of the supply chain, there is potential for deliberate fraud, i.e., by substituting ingredients or failing to meet quality or microbiological safety standards leading to food adulteration. Hitherto, the supply chain of food products has been exceedingly difficult to trace its origin. Digital platforms are emerging to address consumer concerns about quality and halal food products. Traceability, transparency, and integrity of food products have become global issues that need to be attain the agricultural producers. Transparency here is defined as the openness of where the food is produced, processed, and transported. Integrity relates to food safety, authenticity, and quality of food products. Block chain technology is widely used by start-up companies in Indonesia to build digital platforms that can make food products easily traceable in the supply chain. Currently, consumers, especially for export products, want food products that are clear where they come from, are grown on land with clear certification, the production process (organic or not), and are monitored in real-time at every step along the value chain by different parties. Platforms such as "TaniSupply" or "Koltiva" (https://www.koltiva.com/) offer digital solutions that enable supply chain traceability.

The fourth change is precision agriculture and mechanization. Precision agriculture is a digital-based smart farming technology to increase efficiency, effectiveness, productivity, and profitability. This technology is also a solution to anticipate the reduction of agricultural labor. Platforms such as "Habibi Garden" (www.habibigarden.com) offer integrated precision farming devices that promise efficiency in automatic irrigation systems, plant watering, and fertilization decisions based on actual sensor data, plant growth can be monitored and controlled via Smartphone. Likewise, the E-fishery platform (https://efishery.com/en/) provides auto feeders for fish and shrimp. This allows farmers to schedule feedings using a smartphone. The device has an Internet of Things (IoT)-based sensor to know when the fish or shrimp are full, so it stops dispensing feed. The "Aria" platform (https://www.hiaria.id/) offers drone services at a low cost of service per hectare so that it can be affordable, considering that small farmers are unlikely to buy drones because they are expensive.

By providing integrated services, digital platforms are also working with pesticide companies to provide chemicals for agriculture. Here, a new profession emerged: drone pilots, individuals who can operate drones for agricultural activities (mapping, spraying fertilizers and pesticides, and observation). Advanced technologies such as sensors, artificial intelligence, and robotics are increasingly being promoted as a means to increase food production as well as efficiency by minimizing the use of resources (Rotz et al., 2019).

(2) Transformation of Agricultural Knowledge and Innovation System

Agricultural knowledge and innovation systems (AKIS) are a network of research, education, extension, and support subsystems that aim to provide agricultural knowledge and innovations to farmers (Rijswijk et al., 2019). The observation shows that the development of digitalization in the agricultural sector more broadly provides opportunities for inexperienced players to enter the AKIS that provide new services through digital technology facilities.

The areas of research, education, and extension which have been dominated by the role of the public/government have begun to adjust with the role of the private sector and farmers through the process of social learning. The fluidity of the public and private roles of knowledge providers in digital agriculture continues to move towards a more data-driven and open innovation model. The development of social media technology such as Facebook, YouTube, Instagram, TikTok, and WhatsApp as well as a network of websites has become a centre for the dissemination and interaction of new knowledge. Three areas are transforming, namely the area of information services, information sources, and innovation producers (Table 3).

Table 3. The changing landscape of agricultural knowledge and innovation systems due to digitalization

No	Areas of change	Description of changes	New business model
1	Information services	The emergence of digital platforms that provide information to farmers on prices, harvest planning, climate, and potential pest & disease attacks online, and in real-time	Digital platforms: Apps and websites on agronomy, market information (prices), farm management tools

No	Areas of change	Description of changes	New business model
2	Source of knowledge	The development of a virtual community of farmers facilitated by social media platforms that enable knowledge exchange	Crowdsourcing
3	Innovation actors	The emergence of active participation of farmers as non-scientists in scientific research and being able to produce new products (seeds, fertilizers, pesticides, agricultural machinery) and disseminate them through the internet.	Citizen science

The first change is in the realm of information services. Hitherto, agricultural information has been provided by the state through the organization of agricultural counselling. The development of digital technology and public demand for speed and accuracy of services has led to new online service provisions business models such as the cultivation information website "Paktani Digital" (https://paktanidigital.com/) and the agricultural consultation application "Dokter Tania" (https://www.neurafarm.com/), the information service "integrated cropping calendar" (http://katam.info/), and "cyber extension" (http://cybex.pertanian.go.id/). Some of these platforms are one-way communication but some are two-way communication, for example, the "Dokter Tania" consultation platform. This change has caused the spatial role of extension workers in some aspects such as in consultation services to be replaced by digital devices.

The second change is in the source of knowledge. In the Agricultural Knowledge and Information System (AKIS), knowledge is the domain of research, education, and extension institutions. Along with the development of digital technology, a concept called Crowdsourcing emerged. This idea was first coined in 2006 by J. Howe, editor of Wired magazine. Crowdsourcing is a new way of working and exchanging information that is digitally mediated (Nevo & Kotlarsky, 2020). Crowdsourcing allows farmers, farmer groups, and even agricultural companies to exchange ideas, information, experiences, and knowledge in a virtual community. This situation leads to connections among actors in the agricultural system. The result is increased social interaction between key actors and businesses mediated by digital technology online. Social interaction can be an essential element of social learning.

Social learning theory was introduced by Albert Bandura who stated that the learning process can occur by observing, storing information (retention), imitating (reproducing), and finally, farmers are motivated to imitate the behaviour, attitudes, and emotional reactions of other farmers (Bandura & Walters, 1977). For this farmer, the virtual interaction space has the advantage of not being limited to spatial or temporal dimensions, which allows him to meet other farmers in areas he has never known before. Virtual space not only provides a place for introduction but also a space for existence and collaboration. Hitherto, the social learning process has been facilitated by extension workers through physical group meetings. Meanwhile, nowadays, learning is mediated by digital platforms such as WhatsApp groups (WAG), YouTube, Instagram (Suratini et al., 2021), and Facebook groups (Aulifia et al., 2016). The extension worker is no longer the authority on knowledge, as group members have the same position. Only members who have strong social capital and social ties gain the trust of other members (Fielke et al., 2020).

The development of digital technology and crowdsourcing has led to a potentially bleak future for the extension profession. As Yuval Noah Harari predicted, as digital technology gets smarter, more and more professions will be eliminated from the job market. The idea of a profession for life becomes obsolete. Only the idea of lifelong learning will continue to be relevant (Harari, 2017). This means that if extension workers want to survive in the digital era. There is no other choice, except to continue learning to adapt to the dynamics of the times, and upgrade their capacity with new skills, new literacy, and a new mind set.

The third change occurs in the realm of innovation actors. The presence of digital technology has intensified citizen science. The term citizen science developed in the mid-1990s. Some researchers refer to it as amateur science or "popular science" or some say community science is used to designate non-professionals involved in science without the aim of producing new scientific knowledge (Ebitu et al., 2021). Citizen science gives rise to the active participation of non-scientists (laypeople/amateurs/volunteers) in scientific research activities, including data collection, interpretation, and analysis.

In recent years, there have been farmers who can breed and produce many superior varieties of rice, and there are also those who produce hybrid corn seeds on the island of Java (Antons et al.,

2020). In addition, in the digital market, there are many sales of superior plant seeds from farmer research, and sales of farmer-produced agricultural machinery, pesticides, and fertilizers made by farmers. These changes need to be anticipated and responded to by public research institutions to determine the positioning of the research domain.

C. The Shifting Role of Agricultural Extension Workers

The digital agriculture ecosystem through the start-up model in Indonesia is experiencing rapid growth, and according to the Compass List Indonesia Agritech Report 2020 (www.compasslist.com), the valuation of agricultural start-up companies is increasing exponentially. The digitalization of agriculture in the private sector can be seen in agricultural companies and the birth of the digital agricultural start-up trend, as well as the Internet of Things system for cultivation, monitoring, harvesting, distribution, marketing, and extension. There are potential agri-start-ups for instance Chilibeli, Kedai Sayur, eFishery, TaniGroup, EdenFarm, Tunas Farm, Habibie Garden, 8villages, Aruna, Jala, MSMB, Eragano, iGrow, Limakilo, Biotech, Crowde, Inagi, Magalarva, and Warung Pintar. The agri-start-ups received funding from East Ventures, Salim Group, UMG Idealab Indonesia, Alpha JWC Ventures, Mandiri Capital Indonesia, Telkomsel, Sinar Mas Digital Ventures, Triputra Group, Hatch, 500 Startups, and Brinc (Tang & Putera, 2020).

In case community like it or not, these digital agriculture actors are helping to advance many aspects of traditional agriculture and are making important contributions to the transformation. The agriculture sector needs from production, supply chain, market access, and transactions to financing solutions. Stakeholders in the agriculture sector must be aware of and ready for the changes brought about by the digital transformation

The Indonesian government tried to respond to the dynamics of technological development at the global level by launching an advanced, independent, and modern agriculture program. One of the breakthroughs made by publishing Presidential Regulation (Perpres No 35/2022) concerning Strengthening the Function of Agricultural Extension, which includes strengthening working relationships, institutions, human resource capacity, extension materials, utilization of information and communication technology (ICT), and infrastructure facilities.

An extension is still expected to play a central role in guarding and mitigating social changes in society to ensure that all farmers are not left behind in the pace of change. Not only Indonesia, but from our literature review were founded that several countries are responding to digitalization by expanding the role of extension workers, not just transferring technology as has been done so far. Some of the new roles of extension workers have emerged in the digital era (Table 4).

Table 4. The shifting role of extension workers in the era of digital society

The role of extension agents	Descriptions	Source
Informant	Provide information, recommendations, and hybrid knowledge	(Rose *et al*., 2018)
Consultant	Serving consultation via video call	(Zournazis & Marlow, 2015)
Advisor	Accompanying farmers' learning in understanding the nature of digital data and its interpretation.	(Klerkx, 2021).
Facilitator	Facilitate virtual meetings	(Klerkx, 2021).
Mediator	Intermediating farmers, advanced software, and farming system actors	(Bryant *et al*., 2010)
Promotor	Promote and encourage farmer involvement in the use of digital platforms	(Eastwood *et al*., 2019)
Content creator dan influencer	Creating content on social media, posting statuses for influence, interaction, engagement, and celebrity roles	(Klerkx, 2020)
Translator	Translating knowledge at the interface of technology and agricultural management	(Eastwood *et al*., 2019)
Sense maker	help farmers explore the meaning and added value of digital tools and technologies	(Eastwood *et al*., 2019)
Expert users	As an expert user of a particular digital platform	(Eastwood *et al*., 2019); (Hughes et al., 2021) (Kummer et al., 2021)

The role of extension agents	Descriptions	Source
Data analyst	Analysing the database of farmers who access web-based extension sites and combining hybrid knowledge	(Rose *et al*., 2018); (Juniarti et al., 2022)
Artificial Intelligence scientist	Internet of behaviour analysis represents actual conditions, analyses historical activities, and simulates future behaviour.	(Verdouw et al., 2021)
Decision maker based on socio-cyber-physical system	Decision-making and making rules (policy) based on a data-driven socio-cyber-physical system	(Rijswijk et al., 2021)
Software Developer	Creating an agricultural extension recommendation system based on Semantic Web knowledge representation: ontology, web services, software agents; user personalization; and knowledge-based system.	(Pryima et al., 2020); (Jahanshiri & Walker, 2015)
Gamify creator	Designing and creating an agricultural extension with a gamification approach that prioritizes playfulness	(Klerkx, 2021)

Based on Table 4, digitalization has shifted some of the roles of agricultural extension workers to follow the needs of a digital society. The use of smartphones has changed the way extension workers practice and interact with farmers. The informant role, which used to be done physically and is limited, is now starting to be done through multichannel.

According to Rose *et al*., (2018), the role of extension workers in delivering information has evolved into delivering hybrid knowledge, which farmers have not yet obtained in cyberspace. The next differentiator is that extension workers also play a role in analysing big data. The abundance of data and information in cyberspace is a wonderful opportunity for extension workers to develop themselves and produce and process the information needed by farmers. This analytic capability characterizes the knowledge produced by extension workers compared to that produced by farmers themselves.

The same applies to the role of consultant. In the past, extension workers only provided face-to-face consultations, but now, in addition to face-to-face meetings, they also receive consultation services in the form of video calls (Zournazis & Marlow, 2015). In the Netherlands, in playing the role of advisor, extension workers assist farmers in understanding the nature of digital data and its interpretation.

Extension workers have started to reduce the intensity of face-to-face meetings, and play the role of facilitator in virtual meetings. This pattern is considered more efficient and minimizes costs. To influence farmers to be interested in new practices, extension workers also play the role of content creators, by posting statuses or interesting things on social media, interacting, building engagement, and increasing the number of followers (Klerkx, 2021).

In New Zealand, Eastwood *et al*., (2019) reported that extension workers proactively lead farmer engagement with software in dairy farming. They act as promoters, promote, and encourage farmer involvement in the use of digital platforms. Then also as a sense maker, helping farmers increase added value using digital devices, and acting as a translator, which is translating digital language into the farmer's language.

Bryant *et al*., (2010) also reported the role of extension workers as mediators, bridging the interests of farmers with stakeholders. For example, in mediation with financing institutions, extension workers need to understand the procedures and risks of farm credit as well as fintech, e-wallet, and digital-based licensing procedures (Klerkx, 2022). This mediation is increasingly facilitated by digital technology.

IV. PRACTICAL IMPLICATIONS

The digital age, where people's actions are often mediated by technology, has forced agricultural extension systems in some countries to adjust. Technology does not create social order, but unconsciously, when people adopt a technology, the characteristics, system, and order will indirectly change. The adjustment is not just about organizing extensions in cyberspace such as developing Cybex websites, virtual meetings, and online technical guidance, but focusing on physical spaces that are increasingly digital. Thus, digitalization is the process of supporting clients and partners who are moving their operations in the context of digital agriculture. This has the consequence of the need to build new capacities,

in this case, we borrow the term popularized by Professor Robert Duncan (1976), namely ambidexterity in terms of extension organizations and terms of human resources (agricultural extension workers).

For extension organizations, it is important to maintain the tension between the potential benefits of digital transformation and its potential negative impacts. Extension organizations must be able to explore and adapt to the evolving waves of transformation while exploiting the potential and resources available to ensure that no farmer is left behind. In contrast, the relationship between digital transformation and farmer welfare is not always linear. Technology always has ambivalence. It can improve the efficiency and effectiveness of processes, enhance collective action, and democratize knowledge, but on the other hand, the technology always leaves behind those who do not meet the standard requirements due to knowledge and skills gaps. In this case, small and marginalized farmers will find it difficult to follow the trends of Agriculture 4.0.

Extension organizations must be able to ensure that extension services reach all social layers. Exploration efforts are realized through the development of innovation in every line of extension (organizational innovation, service innovation, infrastructure innovation, human resource management innovation, and financing innovation) to respond and accompany the pace of digital transformation which is quite disruptive and so fast. Without innovation, extension organizations will lose their relevance. Extension organizations will only become administrative agents of government projects.

From the exploitation aspect, it is necessary to improve the structure to be more agile to quickly adapt to potential opportunities and threats due to digitalization. Current extension organizations have a large, highly hierarchical, bureaucratic structure, from the central to the village level, with work instructions that seem top-down. This situation makes it quite difficult to respond to environmental changes. Therefore, the organization needs to think about how to make the bureaucratic structure simpler, its resources (both human, financial, and facilities) have high flexibility to be shifted, and focus on action.

For individual agricultural extension workers, amid challenging situations full of uncertainty and complexity, it is necessary to foster three new things, namely a new mind set, new literacy, and new soft skills. First of all, the new mind set in question is a growth mind set (Dweck, 2006), namely the belief in being willing and able to change for the better. This needs to be pursued because most agricultural extension workers are generation X and baby boomers who tend to have resistance to change.

Secondly, new literacy or digital literacy is the ability of agricultural extension workers to operate digital technology to support agricultural development. Digital literacy needs to be fostered and cultivated to be able to communicate with the digital society. Most of the current extension workers are digital immigrants, somewhat stuttering in technology, As a consequence, all extension agriculture actor endeavour adaptability the digitalization.

Finally, there are new soft skills. Today's extension workers are mostly concerned with technical perspectives but do not think enough about how to deal with farmers as multifaceted human beings. The new soft skills in question are the ability to collaborate, communicate, complex problem-solving that is not only technical but also non-technical, able to understand the digital ecosystem, and creative, and critical thinking. As mentioned above, digital transformation produces progressive and regressive tensions. Extension workers must be able to bridge the digital divide, especially farmers who are identified as powerless hence that they are not uprooted and separated from the new generation of farmers or commonly called millennials (Setiawan et al., 2020).

Synthesizing relevant literature to the research objectives, the literature review, and online observation related to digital transformation and agricultural extension have several implications. The broad themes with practical implications are digital technology transformation system in Indonesia agriculture. Additionally, it seems there are not many socio agriculture scholars in Indonesia who are involved the global trend, in particular Agriculture Knowledge and Innovation System, with in Web 2.0 and Web 3.0. era. The majority implication of the research area applies for those development actors:

a. Government

- As preliminary studies for policy instruments in the development agenda digitalization extension agriculture.
- Supporting the research referee in the implementation of strategic planning Ministry of Agriculture, specifically Agricultural extension based on information and communication technology and improve the quality of agricultural human resources.

b. Research and Academic Institutions

- Propose the priority research agenda in the agriculture advisory system based on web 2.0 and web 3.0 development.

- Collaborate the research work among multidiscipline expertise social science, computer science, and government research agency.
- Identify the real phenomenon of transformation digitalization on research work. Observe the main problem and case in the Indonesia agriculture human resources.

c. Private Sector

- Evaluate the mobile application, digital and smart farming technology to know and fulfil the needs of end users.
- Enlarge the adoption innovation digitalization agriculture based on the database users and the characteristic of adopter.

V. LIMITATION

This study nevertheless has several limitations that can be corrected in further research. First, websites we have observed is very limited, they may present something that is ideal business services and does not reflect existing facts. This situation needs to be clarified. Second, this research focuses on one actor, namely agricultural extension workers. Digital transformation in the agricultural sector involves many actors: farmers, the private sector, and the government. Third, this study did not investigate virtual networks that farmers may have such as social media, which can also be considered an increasingly important source of information.

Based on these limitations, the suggestion for the further research could explore the role of other actors involved in digital transformation in both the food and knowledge systems. How do other actors in the farmer network, such as extension workers, and traders, see the different network configurations? These issues may also be included in future studies. Second, the business models identified here need to be verified. These studies could use a more systematic empirical observation approach. How the user experience can be explored. For example, whether the involvement of farmers in using digital technology can increase productivity and farmer income. Third, it would be interesting to examine to what extent the level of digital literacy of agricultural extension workers. Thus the extension worker have sufficient digital literacy level to be able to adapt and adjust work patterns in the digital era? What are the challenges and obstacles experienced in carrying out extension work?

VI. CONCLUSION

Disruptive digital technology has transformed the agricultural sector through changes in the food system and agricultural innovation knowledge systems. This change has a duality, on the one hand, it benefits farmers because it increases production and supply chain efficiency, but on the other hand it creates a digital divide as well as the commercialization and commodification of agricultural information data. Extension institutions and individual agricultural extension workers must overcome and sustain these two tensions through repositioning and changing roles. Extension workers as content creators and influencers, gatekeepers, translators, sense makers, expert users, big data analysts, artificial intelligence and digital twin data scientists, decision-makers, software developers, and gamify creators.

Digitization is not just equipping extension organizations with ICT tools, but more than that, a new mind set, new literacy, and new soft skills must be built. Given that this study is exploratory and has a limited sample size of observations, the business models identified here need to be verified in future research. These studies could use a more systematic approach to empirical observation.

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Appendix 1. Selected studies that answer research questions about digital transformation in the agricultural sector

No	Research question	Study
1	To what extent are digital technologies transforming the agricultural sector?	Aker & Ksoll, 2016
		Ayoub Shaikh et al., 2022
		Beza et al., 2018
		Boursianis et al., 2022
		De Clercq et al., 2018
		Emeana et al., 2020
		Ferrández-Pastor et al., 2022
		Hsu et al., 2020
		Khan et al., 2020
		Patel et al., 2022
		Rejeb et al., 2022
		Rose *et al*., 2018
		Subejo et al., 2019
		Tsouros et al., 2019
		Wolfert et al., 2017
		ZHENG et al., 2022
		Zournazis & Marlow, 2015
2	What should agricultural extension agencies do to remain relevant in the digital era	Bryant *et al*., 2010
		Eastwood *et al*., 2019
		Hughes et al., 2021
		Jahanshiri & Walker, 2015
		Juniarti et al., 2022
		Klerkx, 2020
		Klerkx, 2021.
		Kummer et al., 2021
		Pryima et al., 2020;
		Rijswijk et al., 2021
		Rose *et al*., 2018;
		Verdouw et al., 2021

Appendix 2. List of websites

No	**Organization**	**Focus**	**Data**	**Web address**
1	PT Sayurbox	e-grocery platforms	Qualitative	https://www.sayurbox.com
2	PT Tanihub Indonesia	Bridging farmers with the market	Qualitative	https://foodsolutions.tanihub.com/
3	PT. Crowde Membangun Bangsa	Agricultural funding ecosystem	Qualitative	https://crowde.co/
4	PT Koltiva	Tailoring IT solutions and agri-tech services.	Qualitative	https://www.koltiva.com/
5	PT. Habibi Digital Nusantara	Agricultural technology.	Qualitative	www.habibigarden.com
6	PT Multidaya Teknologi Nusantara	Aquaculture ecosystem by offering an end-to-end platform that provides access to feed, financing, and market to fish and shrimp farmers	Qualitative	https://efishery.com/en/
7	Aria Agriculture Indonesia	Service of logistic and precision farming	Qualitative	https://www.hiaria.id/
8	Paktani digital	Connecting farmers with various other stakeholders in one digital application device.	Qualitative	https://paktanidigital.com/
9	PT. Neura Cipta Nusantara	Precision agriculture	Qualitative	https://www.neurafarm.com/
10	Ministry of Agriculture	Spatial and tabular information about cropping calendar, season predictions etc	Qualitative	http://katam.info/

No	Organization	Focus	Data	Web address
11	Ministry of Agriculture	Web-based information system provides exchange of agricultural information through the cyber area	Qualitative	http://cybex.pertanian.go.id/
12	Compasslist	Information about innovative technology startups	Quantitative	www.compasslist.com
13	Hootsuite	Global digital report such as internet user, social media user	Quantitative	https://www.hootsuite.com/resources/digital-trends

REFERENCES

Ahmed, A., Bhatti, S. H., Gölgeci, I., & Arslan, A. (2022). Digital platform capability and organizational agility of emerging market manufacturing SMEs: The mediating role of intellectual capital and the moderating role of environmental dynamism. *Technological Forecasting and Social Change*, *177*, 121513.

Aker, J. C., & Ksoll, C. (2016a). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy*, *60*, 44–51. https://doi.org/https://doi.org/10.1016/j.foodpol.2015.03.006

Aker, J. C., & Ksoll, C. (2016b). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy*, *60*, 44–51. https://doi.org/https://doi.org/10.1016/j.foodpol.2015.03.006

Anggraini, N., Sutarni, S., Fatih, C., Zaini, M., Analianasari, A., & Humaidi, E. (2020). Digital marketing produk pertanian di desa sukawaringin Kecamatan Bangunrejo Kabupaten Lampung Tengah [Digital marketing of agricultural products in sukawaringin village, Bangunrejo, Lampung Tengah]. *Jurnal Pengabdian Nasional*, *1*(1).

Antons, C., Winarto, Y. T., & Prihandiani, A. F. (2020). Farmer-plant-breeders and the law on Java, Indonesia. *Critical Asian Studies*, *52*(4), 589–609.

Aulifia, A., Subejo, S., & Harsoyo, H. (2017). Persepsi anggota grup facebook "Komunitas Hidroponik Jogja (Hi-Jo)" terhadap pengembangan hidroponik [Perception group members of "Komunitas Hidroponik Jogja (Hi-Jo)" toward hydroponic development]. *Agro Ekonomi*, *27*(2), 165. https://doi.org/10.22146/jae.22691

Ayoub Shaikh, T., Rasool, T., & Rasheed Lone, F. (2022). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. *Computers and Electronics in Agriculture*, *198*, 107119. https://doi.org/https://doi.org/10.1016/j.compag.2022.107119

Bandura, A., & Walters, R. H. (1977). *Social learning theory* (Vol. 1). Englewood cliffs Prentice Hall.

Benson, A., & Jafry, T. (2013). The State of Agricultural Extension: An Overview and New Caveats for the Future. *The Journal of Agricultural Education and Extension*, *19*(4), 381–393. https://doi.org/10.1080/1389224X.2013.808502

Beza, E., Reidsma, P., Poortvliet, P. M., Belay, M. M., Bijen, B. S., & Kooistra, L. (2018). Exploring farmers' intentions to adopt mobile Short Message Service (SMS) for citizen science in agriculture. *Computers and Electronics in Agriculture*, *151*, 295–310. https://doi.org/https://doi.org/10.1016/j.compag.2018.06.015

Boursianis, A. D., Papadopoulou, M. S., Diamantoulakis, P., Liopa-Tsakalidi, A., Barouchas, P., Salahas, G., Karagiannidis, G., Wan, S., & Goudos, S. K. (2022). Internet of things (IoT) and agricultural unmanned aerial vehicles (UAVs) in smart farming: a comprehensive review. *Internet of Things*, *18*, 100187.

BPS. (2022). *Berita Resmi Statistik: Pertumbuhan Ekonomi Produk Domestik Bruto [Official News Statistics: Gross Domestic Product Economic Growth]*.

Bryant, J. R., Ogle, G., Marshall, P. R., Glassey, C. B., Lancaster, J. A. S., Garcia, S. C., & Holmes, C. W. (2010). Description and evaluation of the Farmax Dairy Pro decision support model. *New Zealand Journal of Agricultural Research*, *53*(1), 13–28.

Chen, L., Tong, T. W., Tang, S., & Han, N. (2022). Governance and Design of Digital Platforms: A Review and Future Research Directions on a Meta-Organization. In *Journal of Management* (Vol. 48, Issue 1).

https://doi.org/10.1177/0149206321104502 3

Christensen, C. M. (2013). *The innovator's dilemma: when new technologies cause great firms to fail*. Harvard Business Review Press.

Cook, B. R., Satizábal, P., & Curnow, J. (2021). Humanising agricultural extension: A review. *World Development*, *140*, 105337. https://doi.org/https://doi.org/10.1016/j.worlddev.2020.105337

Daum, T., Adegbola, P. Y., Adegbola, C., Daudu, C., Issa, F., Kamau, G., Kergna, A. O., Mose, L., Ndirpaya, Y., Fatunbi, O., Zossou, R., Kirui, O., & Birner, R. (2022). Mechanization, digitalization, and rural youth - Stakeholder perceptions on three mega-topics for agricultural transformation in four African countries. *Global Food Security*, *32*, 100616. https://doi.org/https://doi.org/10.1016/j.gfs.2022.100616

De Clercq, M., Vats, A., & Biel, A. (2018). Agriculture 4.0: The future of farming technology. *Proceedings of the World Government Summit, Dubai, UAE*, 11–13.

De Kerckhove, D., & Saracco, R. (2021). *The Future of Digital Twins*. Digital Reality, an IEEE Future Directions.

Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research*, *121*, 283–314.

Dufva, T., & Dufva, M. (2019). Grasping the future of the digital society. *Futures*, *107*, 17–28. https://doi.org/https://doi.org/10.1016/j.futures.2018.11.001

Duncan, R. B. (1976). The ambidextrous organization: Designing dual structures for innovation. *The Management of Organization*, *1*(1), 167–188.

Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House.

Eastwood, C., Ayre, M., Nettle, R., & Rue, B. (2019). Making sense in the cloud: Farm advisory services in a smart farming future. *NJAS - Wageningen Journal of Life Sciences*, *90–91*(December 2018), 100298. https://doi.org/10.1016/j.njas.2019.04.004

Ebitu, L., Avery, H., Mourad, K. A., & Enyetu, J. (2021). Citizen science for sustainable agriculture – A systematic literature review. *Land Use Policy*, *103*, 105326. https://doi.org/https://doi.org/10.1016/j.landusepol.2021.105326

Elbeltagi, A., Kushwaha, N. L., Srivastava, A., & Zoof, A. T. (2022). Chapter 5 - Artificial intelligent-based water and soil management. In R. C. Poonia, V. Singh, & S. R. Nayak (Eds.), *Deep Learning for Sustainable Agriculture* (pp. 129–142). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-323-85214-2.00008-2

Emeana, E. M., Trenchard, L., & Dehnen-Schmutz, K. (2020). The revolution of mobile phone-enabled services for agricultural development (m-Agri services) in Africa: The challenges for sustainability. *Sustainability (Switzerland)*, *12*(2). https://doi.org/10.3390/su12020485

Ferrández-Pastor, F.-J., Mora-Pascual, J., & Díaz-Lajara, D. (2022). Agricultural traceability model based on IoT and Blockchain: Application in industrial hemp production. *Journal of Industrial Information Integration*, *29*, 100381. https://doi.org/https://doi.org/10.1016/j.jii.2022.100381

Fielke, S., Taylor, B., & Jakku, E. (2020). Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. *Agricultural Systems*, *180*(August 2019), 102763. https://doi.org/10.1016/j.agsy.2019.102763

Fitriani, H. (2018). Kontribusi fintech dalam meningkatkan keuangan inklusif pada pertanian (Studi analisis melalui pendekatan keuangan syariah dengan situs peer to peer lending pada pertanian di Indonesia [Fintech's contribution in increasing inclusive finance on agriculture. *El-Barka: Journal of Islamic Economics and Business*, *1*(1), 1–26.

Goh, L. (2022). How AgriTech Is Transforming Traditional Agriculture in Emerging Markets. *Breakthrough: The Promise of Frontier Technologies for Sustainable Development*, 125.

Harari, Y. N. (2017). Reboot for the AI revolution. *Nature*, *550*(7676), 324–327.

Hsu, T.-C., Yang, H., Chung, Y.-C., & Hsu, C.-H. (2020). A Creative IoT agriculture platform for cloud fog computing. *Sustainable Computing: Informatics and Systems*, *28*, 100285. https://doi.org/https://doi.org/10.1016/j.suscom.2018.10.006

Hughes, D., Kehs, A., & McClosey, P. (2021). PlantVillage Nuru: smallholder farmers in Kenya see income boosts with their personal artificial intelligence assistant. In A. Elbehri

& R. Chestnov (Eds.), *Artificial Intelligence for Agriculture* (pp. 34–40). FAO and ITU. https://doi.org/10.4060/cb7142en

Jahanshiri, E., & Walker, S. (2015). Agricultural Knowledge-Based Systems at the Age of Semantic Technologies. *International Journal of Knowledge Engineering-IACSIT*, *1*(1), 64–67. https://doi.org/10.7763/IJKE.2015.V1.11

Javaid, M., Haleem, A., Singh, R. P., Rab, S., & Suman, R. (2021). Internet of Behaviours (IoB) and its role in customer services. *Sensors International*, *2*, 100122. https://doi.org/10.1016/J.SINTL.2021.100122

Juniarti, H. A., Sari, Y., Salim, I., & Wulandari, N. T. (2022). Analisis Time Series Adopsi Pengguna Desa Apps berdasarkan Dataset dan Prediksi Adopter Menggunakan Model ARIMA [Time series analysis of Desa Apps User adoption based on dataset and adopter predictions using the ARIMA Model]. *Seminar Nasional Hasil Penelitian Sosial Ekonomi Pertanian*.

Khan, N. A., Qijie, G., Sertse, S. F., Nabi, M. N., & Khan, P. (2020). Farmers' use of mobile phone-based farm advisory services in Punjab, Pakistan. *Information Development*, *36*(3), 390–402.

Klerkx, L. (2020). Advisory services and transformation, plurality and disruption of agriculture and food systems: towards a new research agenda for agricultural education and extension studies. *Journal of Agricultural Education and Extension*, *26*(2), 131–140. https://doi.org/10.1080/1389224X.2020.1738046

Klerkx, L. (2021). Digital and virtual spaces as sites of extension and advisory services research: social media, gaming, and digitally integrated and augmented advice. *Journal of Agricultural Education and Extension*, *27*(3), 277–286. https://doi.org/10.1080/1389224X.2021.1934998

Klerkx, L. (2022). Advisory support and learning on non-technical aspects of farming: a key topic for extension and education research. *The Journal of Agricultural Education and Extension*, *28*(3), 251–253. https://doi.org/10.1080/1389224X.2022.2073112

Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security*, *24*, 100347.

Kominfo. (2020). Status Literasi Digital Indonesia 2020: Hasil Survei di 34 Provinsi [Indonesia's digital literacy status 2020: survey results in 34 provinces]. 90.

Kummer, B., Karan, R., & Rupavathara, S. (2021). Plantix - your crop doctor: every month around one million smallholder farmers use the Plantix app to grow healthier crops. In A. Elbehri & R. Chestnov (Eds.), *Artificial Intelligence for Agriculture* (pp. 19–28). FAO and ITU. https://doi.org/10.4060/cb7142en

Moghaddam, M. T., Muccini, H., Dugdale, J., & Kjaergaard, M. B. (2022). Designing Internet of Behaviors Systems. *2022 IEEE 19th International Conference on Software Architecture (ICSA)*.

Mosher, A. T. (1965). Getting agriculture moving. Essentials for development and modernization. *Getting Agriculture Moving. Essentials for Development and Modernization.*

Nevo, D., & Kotlarsky, J. (2020). Crowdsourcing as a strategic IS sourcing phenomenon: Critical review and insights for future research. *The Journal of Strategic Information Systems*, *29*(4), 101593. https://doi.org/https://doi.org/10.1016/j.jsis.2020.101593

Nieto Cubero, J., Gbadegeshin, S. A., & Consolación, C. (2021). Commercialization of disruptive innovations: Literature review and proposal for a process framework. *International Journal of Innovation Studies*, *5*(3), 127–144. https://doi.org/https://doi.org/10.1016/j.ijis.2021.07.001

Patel, R., Migliavacca, M., & Oriani, M. E. (2022). Blockchain in banking and finance: A bibliometric review. *Research in International Business and Finance*, *62*, 101718. https://doi.org/https://doi.org/10.1016/j.ribaf.2022.101718

Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance? —From the perspective of public policy and innovation. *Journal of Innovation & Knowledge*, *7*(3), 100198. https://doi.org/https://doi.org/10.1016/j.jik.2022.100198

Pryima, S. M., Strokan, O. V., Rogushina, J. V., Gladun, A. Y., Lubko, D. V., & Malkina, V. M. (2020). Ontological Analysis of Outcomes of Non-formal and Informal

Learning for Agro-Advisory System AdvisOnt. *International Conference on Technologies and Innovation*, 3–17. https://bunker2.zlibcdn.com/dtoken/09307aa2729ea51c872931e1b3912be4/Technologies and Innovation 6th International Conference%2C CITI 2020%2C Guayaquil%2C Ecuador%2C November 30 – December 3%2C 2020%2C... %28Rafael Valencia-García%2C Gema Alcaraz-Marmol et

Rachmawati, R. R. (2021). Smart farming 4.0 untuk mewujudkan pertanian indonesia maju, mandiri, dan modern [Smart farming 4.0 to build advanced, independent, and modern Indonesian agriculture]. *Forum Penelitian Agro Ekonomi*, *38*(2), 137. https://doi.org/10.21082/fae.v38n2.2020.137-154

Ratten, V. (2022). Digital platforms and transformational entrepreneurship during the COVID-19 crisis. *International Journal of Information Management*, 102534. https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2022.102534

Rejeb, A., Abdollahi, A., Rejeb, K., & Treiblmaier, H. (2022). Drones in agriculture: A review and bibliometric analysis. *Computers and Electronics in Agriculture*, *198*, 107017. https://doi.org/https://doi.org/10.1016/j.compag.2022.107017

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies*, *85*, 79–90. https://doi.org/10.1016/J.JRURSTUD.2021.05.003

Rijswijk, K., Klerkx, L., & Turner, J. A. (2019). Digitalisation in the New Zealand Agricultural Knowledge and Innovation System: Initial understandings and emerging organisational responses to digital agriculture. *NJAS - Wageningen Journal of Life Sciences*, *90–91*(November), 100313. https://doi.org/10.1016/j.njas.2019.100313

Rose, D. C., Morris, C., Lobley, M., Winter, M., Sutherland, W. J., & Dicks, L. V. (2018). Exploring the spatialities of technological and user re-scripting: the case of decision support tools in UK agriculture. *Geoforum*, *89*, 11–18.

Rotz, S., Gravely, E., Mosby, I., Duncan, E., Finnis, E., Horgan, M., LeBlanc, J., Martin, R., Neufeld, H. T., Nixon, A., Pant, L., Shalla, V., & Fraser, E. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, *68*, 112–122. https://doi.org/https://doi.org/10.1016/j.jrurstud.2019.01.023

Salmons, J. E. (2021). *Doing qualitative research online* (2nd ed.). Sage.

Setiawan, I., Rasiska, S., & Supyandi, D. (2020). Korban "tuhan-tuhan" digital: garapan masa depan penyuluhan pembangunan 4.0 [digital victims "Gods": future form of development extension 4.0]. *Indonesian Journal of Socio Economics*, *1*(2), 115–128.

Sgroi, F., & Marino, G. (2022). Environmental and digital innovation in food: The role of digital food hubs in the creation of sustainable local agri-food systems. *Science of The Total Environment*, *810*, 152257. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.152257

Stary, C. (2021). Digital Twin Generation: Re-Conceptualizing Agent Systems for Behavior-Centered Cyber-Physical System Development. *Sensors*, *21*, 1096. https://doi.org/10.3390/s21041096

Steinberg, A., & Bowman, C. (2001). *Revisions to the JDL Data Fusion Model*. https://doi.org/10.1201/9781420038545.ch2

Subejo, Untari, D., Wati, R., & Mewasdinta, G. (2019). Modernization of agriculture and use of information and communication technologies by farmers in coastal Yogyakarta. *Indonesia Journal of Geography*, *51*(3), 332–345. https://doi.org/http://dx.doi.org/10.22146/ijg.41706

Suratini, S., Muljono, P., & Wibowo, C. T. (2021). Pemanfaatan media sosial untuk mendukung kegiatan penyuluhan pertanian di kabupaten minahasa Provinsi Sulawesi Utara [Utilization of social media to support agricultural extension activities in Minahasa Regency, North Sulawesi Province]. *Jurnal Penyuluhan*, *17*(1), 12–24.

Tang, B., & Putera, P. A. W. (2020). *Indonesia Agritech Report 2020, a CompassList Research Publication*. https://www.compasslist.com/CompassList_Indonesia_Agritech_Report_2020.pdf

Tsouros, D. C., Bibi, S., & Sarigiannidis, P. G. (2019). A review on UAV-based applications for precision agriculture. *Information*, *10*(11), 349.

Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021). Digital twins in smart

farming. *Agricultural Systems*, *189*, 103046. https://doi.org/https://doi.org/10.1016/j.agsy.2020.103046

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big data in smart farming–a review. *Agricultural Systems*, *153*, 69–80.

ZHENG, Y., ZHU, T., & JIA, W. (2022). Does Internet use promote the adoption of agricultural technology? Evidence from 1 449 farm households in 14 Chinese provinces. *Journal of Integrative Agriculture*, *21*(1), 282–292. https://doi.org/https://doi.org/10.1016/S2095-3119(21)63750-4

Zournazis, H. E., & Marlow, A. H. (2015). The use of video conferencing to develop a community of practice for preceptors located in rural and non traditional placement settings: An evaluation study. *Nurse Education in Practice*, *15*(2), 119–125.

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