Digitalization in Indonesia's Agrifood Sector in the Wake of the COVID-19 Pandemic

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ABSTRACT

COVID-19 has disrupted Indonesia's agricultural food supply chain, leading to the massive mintage and exertion of digitalization in the food and agriculture (agrifood) sector. This study systematically mapped the landscape of agrifood digital technology studies and startups in Indonesia and its relation to the COVID-19 pandemic. A systematic evidence evaluation was harnessed for this study to obtain data, which were translated into thematic and interactive maps. The study shows that COVID-19 has hampered some agrifood activities but has positively accelerated the development of digital technologies in the sector. The Government of Indonesia has issued national initiatives and policies that support implementing digital technologies in the agrifood sector. The digital technologies studied and utilized in Indonesia's agrifood industry are websites, the Internet of Things (IoT), global positioning system (GPS) and geographic information system (GIS) technology, artificial intelligence (AI), big data, and robotics. About 22.8 percent of the reviewed literature discusses the ripple effects of COVID-19 on the digitalized agrifood sector in the country. Most startups are in the form of farmers' advisory, mechanization platforms, digital marketplace, e-commerce, traceability, food delivery, and peer-to-peer lending. Both the studies and applications are primarily concentrated on Java island and have benefited from digital technologies, such as IoT, blockchain, AI, smartphone or Android, mobile apps, GPS/GIS, and drones. Startup companies have applied strategic measures to cope with the implications of the pandemic, such as suspending some of their activities.

Keywords: digital agrifood, digital technologies, interactive and thematic map, studies and application
JEL codes: Q, Q16

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INTRODUCTION

The WHO (2021) statistics on COVID-19 reported that as of 14 October 2021, a total of 4,231,046 individuals had been positive for COVID-19 in Indonesia, with 142,811 cumulative deaths. In 2019, the share of agriculture in its GDP decreased; since 2020, it has started to rise as a result of the Government of Indonesia's (GoI) post-COVID-19 recovery efforts.

To contain and control the transmission of the deadly virus, governments all over the world, including Indonesia, implemented measures to curb the pandemic. Human mobility was restricted as large-scale social restrictions were imposed among other strategic health measures. However, these measures have caused significant economic disruptions and setbacks, particularly in the agriculture subsectors (e.g., food supply chain). The pandemic has disrupted food and agriculture (agrifood) goods security, production processes, transportation, and logistics (Alam et al. 2021).

Accordingly, the GoI employed strategic measures to address these pandemic-induced disruptions in the agrifood supply chain, including digitalization. The implications of digitalizing the supply chain include (1) restructured supply chain flows to adjust to digitalization, (2) last-mile delivery becoming more important, and (3) closure or capacity descaling of physical stores (Pujawan and Bah 2021).

The digitalization of the food supply chain in Indonesia is in its infancy, and its adoption is incremental rather than radical due to its complexity and its time-consuming nature (Saryatmo and Sukhotu 2021). Aside from the agrifood supply chain, digital technologies have been harnessed to support micro, small, and medium enterprises (MSMEs) and the development of startups in Indonesia, such as business model, sustainability, policy design, and entrepreneurial ecosystem (Fitriasari 2020; Winarsih, Indriastuti, and Fuad 2021; Purbasari, Muttaqin, and Sari 2021; Widiyanto et al. 2021). The Indonesia Development Forum (IDF 2021) reported that about 24 percent of MSMEs in Indonesia had entered digital platforms during the pandemic, which increased from only 13 percent (around eight million businesses) pre-COVID-19. However, the number of startups decreased due to the pandemic from about 2,400 in 2019 to 2,311 in 2021; nevertheless, the country still ranked among the world's five biggest startup centers (Kasih 2021).

The transformation of conventional agriculture into more digitalized features has been supported by initiatives like the 2018 Making Indonesia 4.0 Roadmap, the 2019 E-Commerce Roadmap, and the 2020 Go Digital Vision. These initiatives have supported the development of the country's agrifood sector as a powerhouse for digital industries, e-commerce, financial technologies, on-demand services, and digital SMEs. Accordingly, several policies that focus on agriculture were adopted to support these initiatives, including Presidential Regulation No. 74 of 2017 on E-commerce Roadmap 2017–19 (GoI 2017), Regulation of Ministry of Agriculture No. 4 of 2019 on the Guidelines for the Movement of Agricultural Human Resources Development Towards the World's Food Barn (GoI 2019), and Law No. 11 of 2021 on Job Creation (GoI 2020). Likewise, many digital agriculture-based MSMEs and startups can support the development of precision farming, smart farming, and digital farming such as e-commerce, online marketplace, advisory platform, farm mechanization, and fintech (market aggregator, crowdfunding, digital banking, peer-to-peer lending, investment, and insure-tech).

Aside from initiatives and policies, many studies on the potential use of digital technologies for Indonesia's agrifood sector have been conducted to help transform digital technologies in the sector. For instance, digital repositories or libraries, websites, and geographic information systems (GIS) were developed for agricultural purposes in 2011 and 2013 (Kurniawati 2011; Nugroho and Akbar 2013). In recent years, smart farming, precision farming, and digital farming have been studied for their potential in Indonesia, and the studies on these areas have intensified during the pandemic (Rachmawati 2020; Hartono et al. 2021;

Wulandari et al. 2021). However, many studies on the potential of digitalization for the sector are still siloed due to the geographical distribution of Indonesia. Most studies still need to be aggregated on certain islands, leading to the slow application of the potential of digital agriculture technologies in Indonesia.

Research on Indonesia's digital mapping technologies for agrifood purposes has yet to be fully developed. Accordingly, this paper aims to map the existing literature on digital technology used in Indonesia's agrifood industry and analyze the implications of the COVID-19 pandemic on the research and development of digital technology in the sector. This paper used a systematic evidence evaluation to examine digital agriculture policies, status, and application and to map the digital agriculture initiatives that have been applied in Indonesia's startups.

METHODS

Extraction of Data

Various kinds of literature were obtained from Google Scholar by designating population, exposure/intervention, counterfactual, and outcome (PICO/PECO) framework as keywords in searching for related literature. In this paper, the populations include Indonesia's agrifood sector; interventions comprise use of digital technologies studies, types, potential, and application. The exposure analyzed was the COVID-19 pandemic. The counterfactuals consist of non-use of digital technologies, studies, and potential; and the outcomes consist of several digital technology studies in Indonesia's agrifood industry, types of digital technologies used in the sector, and the implications of the COVID-19 pandemic on digital technology studies.

The keywords were constructed and put in academic databases and through a search engine from the framework, namely Google Scholar. The set of criteria used to include and exclude the published literature for studies mapping is based on the PECO/PICO framework. The keywords *digital agriculture, Indonesia,* and the year of publication (2006–22) were used as criteria. Specific parameters were designed to acquire data, including digital technology-related higher education and its program study, digital literacy index, research/application types, digital technology types, COVID-19-related digital technology studies and application, study content, digital technology use for agrifood, literature language, literature publication, study place, and reference. The parameters were documented in MS Excel Office 2019, including the name of digital agriculture studies and initiatives (i.e., companies, MSMEs, startups); initiatives profile (i.e., place, year of establishment, type of agriculture subsector, brief information, and global positioning system [GPS] altitude); use of digital technologies; type of digital technologies; policies; and COVID-19 relations. Afterward, the acquired data were analyzed, presented, and interpreted.

Research Mapping and Application

Two maps were used in this study to depict research and application, namely, an interactive GIS map and a thematic GIS map. The thematic map was created using ArcMap version 10.5 published in 2016 and featured in ArcGIS (Esri Indonesia, Indonesia). The parameters used to develop the thematic map were *study place and digital technologies type.* Meanwhile, the interactive GIS maps were produced from the 2019 Excel data after they were processed using Google Earth Pro version 7.3.4.8248 (Google Inc., USA). The data were then inserted into the GIS website.[1] The parameters used to develop the online interactive maps were *research and startup's location, research/startups types, digital technology types, COVID-19-related digital technology studies, study content, digital technology use for food and agriculture, literature language, literature publication,* and *reference.*

1 https://gis.co.id, Indonesia

RESULTS AND DISCUSSION

Types of Digital Technologies in the Agriculture Sector

Based on the literature reviewed, several types of digital technologies are considered to have disrupted the global agriculture sector: artificial intelligence (AI), the Internet of Things (IoT), blockchain, big data, smartphones, uncrewed aerial vehicles, digital employees or workspace, virtual reality, augmented reality, robotics, automation, and 3D printing (Appendix Table 1). These technologies help increase yield and productivity of agricultural activities by managing and controlling certain parts of or the whole food supply chain. For instance, AI that is sometimes integrated with IoT, remote sensors, and drones can be used for plantation management, pesticide control use, fertilizer intake, and crop irrigation.

Only a few studies on digital employees or workspace and 3D printing for the agricultural sector were identified in this study. In Indonesia, digital technologies, including smartphones, drones, robotics and automation, AI, IoT, blockchain, and big data, are mainly studied for their application in the sector.

Digital Agriculture Strategies

Mainstreaming digital agriculture in a national agrifood policy agenda and plan was one of the best strategies to create opportunities for sustainable development and inclusive growth during the pandemic.

Appendix shows the agrifood strategies in Indonesia that mainstream the COVID-19 concern in the agrifood industry. The GoI has been implementing strategies for digital transformation with and without mainstreaming in the sector. These strategies are in the form of national initiative, policy, vision, or plan to establish the fourth industrial revolution (4IR) in specific economic development sectors, especially in agrifood. All these strategies include the sector in their strategic activities or policy agenda; only one digital strategy did not include the sector, namely, Presidential Regulation No. 95 of 2018 on Electronic-Based Government System (SPBE). In addition, not all strategies have integrated digital technologies into the agrifood sector or directly interlinked with it, such as the National Industrial Development Master Plan 2015–35; National Research Master Plan 2017–45; Indonesia 2045: Berdaulat, Maju, Adil, dan Makmur (Sovereign, Progressive, Fair, and Prosperous); National Medium-Term Development Plan (RPJMN IV) 2020–24; and Law of the Republic of Indonesia No. 11 of 2020 on Job Creation (Omnibus Law on Job Creation).

Some strategies have embodied digital agriculture technologies such as:

1. National Movement of 1000 Digital Startups: The Digital Energy of Asia
2. Presidential Regulation No. 74 of 2017 on Road Map of the National Electronic-Based Trading System (e-Commerce Road Map) 2017–19
3. Making Indonesia 4.0 (Toward 2030)
4. President Regulation No. 39 of 2019 on One Data Initiative (Satu Data Indonesia)
5. STRANAS KA: National Strategy for Artificial Intelligence 2020–45
6. Ministry of Agriculture Regulation No. 4 of 2019 on Guidelines for Agricultural Human Resources Development Movement Towards World Food Barns 2045
7. Ministry of Agriculture Regulation No. 16 of 2013 on Guidelines for Agricultural Extension Information Management System in Ministry of Agriculture
8. Decree of Ministry of Agriculture No. 259 of 2020 on Ministry of Agriculture Strategic Plan 2020–24

In these strategies, the transformation identified in digital agriculture are digital agriculture startups, industry, and e-commerce development; online data platform for agriculture

information; digital technologies (AI, IoT, big data) integration; cyber extension and agriculture exchange platform; and millennials empowerment for agriculture development. These are mainly implemented by the Ministry of Agriculture and the Ministry of Industry. Interministerial and multistakeholder coordination are likewise needed to implement the strategy. Thus, the Ministry of National Development Planning, Coordinating Minister for Economy, Minister of Home Affairs, Minister of Commerce, Minister of Cooperatives and Small and Medium Enterprises, and Minister of Transportation are also involved in the implementation. In the agriculture sector, note that Regulation No. 16 of 2013 on the Guidelines for Agricultural Extension Information Management System in the Ministry of Agriculture was issued by the Indonesian Ministry of Agriculture to guide stakeholders on the use of online platforms, such as cyber extension, Simluh, and Simpoktan. Afterward, two national policies and a national plan were adopted to apply digital agriculture technologies on the ground.

The GoI has also opened opportunities to put Agriculture 4.0 into practice through the National Movement of 1000 Digital Startups, Making Indonesia 4.0, and One Data Initiatives. Accordingly, the policies have provided millennials with the opportunity to develop their own business, be entrepreneurs, or start their own companies. The WEF (2019) reported that 35.5 percent of the youth in Indonesia aspire to be entrepreneurs. In implementing digital agriculture, however, the GoI still needs to consider the following challenges: labor alteration, data protection and cybersecurity, digital divide issues, digital education and capacity building development, integration of digital technologies research and practices, sustainability mechanism for digital actualization, and public and private partnership (WEF 2019). Soeparna (2018) also identified a number of barriers to applying digital agriculture, stating the following factors as hurdles in implementing IoT for e-agribusiness: security issues, data privacy, device complexity, costly devices, and skilled human resources.

The digital divide is still considered a significant issue in using digital technologies in Indonesia. This is mainly due to the country's demography, having more than 18,000 islands with unequal access to and use of the technologies. About 50 percent of forest farmers in Gunungkidul Yogyakarta, for example, have a high level of digital divide; only farmers with high educational level and income could utilize digital devices optimally to meet their lifestyle needs (Dewinta, Harsoyo, and Wati 2019).

Digital Agriculture Studies

Figure 1 shows a map of the research areas where the digital technology studies focused on. This study identified some parameters, including digital technology distribution and study language used.[2] The map also details some parameters that can become a reference for the users or readers. The figure shows that most of the study sites of the digital agriculture-related studies are on Java island; on the other hand, studies that focused on Sumatera island, Sulawesi island, and Kalimantan island are evenly scattered. However, Papua island has few agriculture-related studies.

Most of the studies published in journals, scientific articles, working papers, and other gray literature are produced by universities and research-based institutions. Note that these institutions are highly active in conducting research on the use and progress of digital technologies for Indonesia's agrifood sector. The level of activity of these institutions presumably depends on the following factors:

1. the topic as one of the leading research topics;
2. availability of support (i.e., government policy/mandate, finance, technical support, and other assistance) from internal and external institutions;
3. up-to-date and novel research concern;
4. the tremendous benefits of digital technologies for agriculture; and

2 An online interactive map of this study is also available at https://agriculture40studies.gis.co.id/

Figure 1. Map of the research areas

5. unpredictable and urgent situations especially during the COVID-19 pandemic.

The studies examined in this paper can primarily serve as a baseline in the application of digital technologies in the agriculture subsectors (e.g., crops, fishery, forestry, and livestock). In addition, the studies analyzed can serve as a reference on how to improve the digital technologies that have already been applied. For instance, Go-Tani apps-based Android was developed as an agriculture extension platform in Bulango Timur district and is used to provide credible and factual information to address farmers' problems (Yasin, Hermawanto, and Aldiansya 2019). The Purwakarta government has also applied an automated teller machine rice (E-perelek) to provide the public with effective and efficient access to perelek rice (Fitriah et al. 2020). A study reported by Hasdar, Ferra, and Syaifulloh (2019) targeted beneficiaries from the Agrofood Technopreneur Programme, which succeeded in providing online training for smallholder farmers to promote their agriculture products in Bukalapak, Shopee, Tokopedia, and Google My Business.

The languages predominantly used in the articles are written in Bahasa Indonesia, with only a few publications in English. Figure 2 shows the maps of the language types used in the studies related to digital agriculture technology. Similar to the studies' distribution, based on the languages, most of them were conducted on Java island. The reason the digital agriculture studies are published in Bahasa Indonesia may be due to the following:

1. ease of communication among Indonesian researchers in different geographical conditions;
2. limited access to studies in English and lack of proficiency of researchers in the language; and
3. many national journals publish digital agriculture technology studies.

Figure 2. Maps of the language types used in the studies related to digital agriculture technology

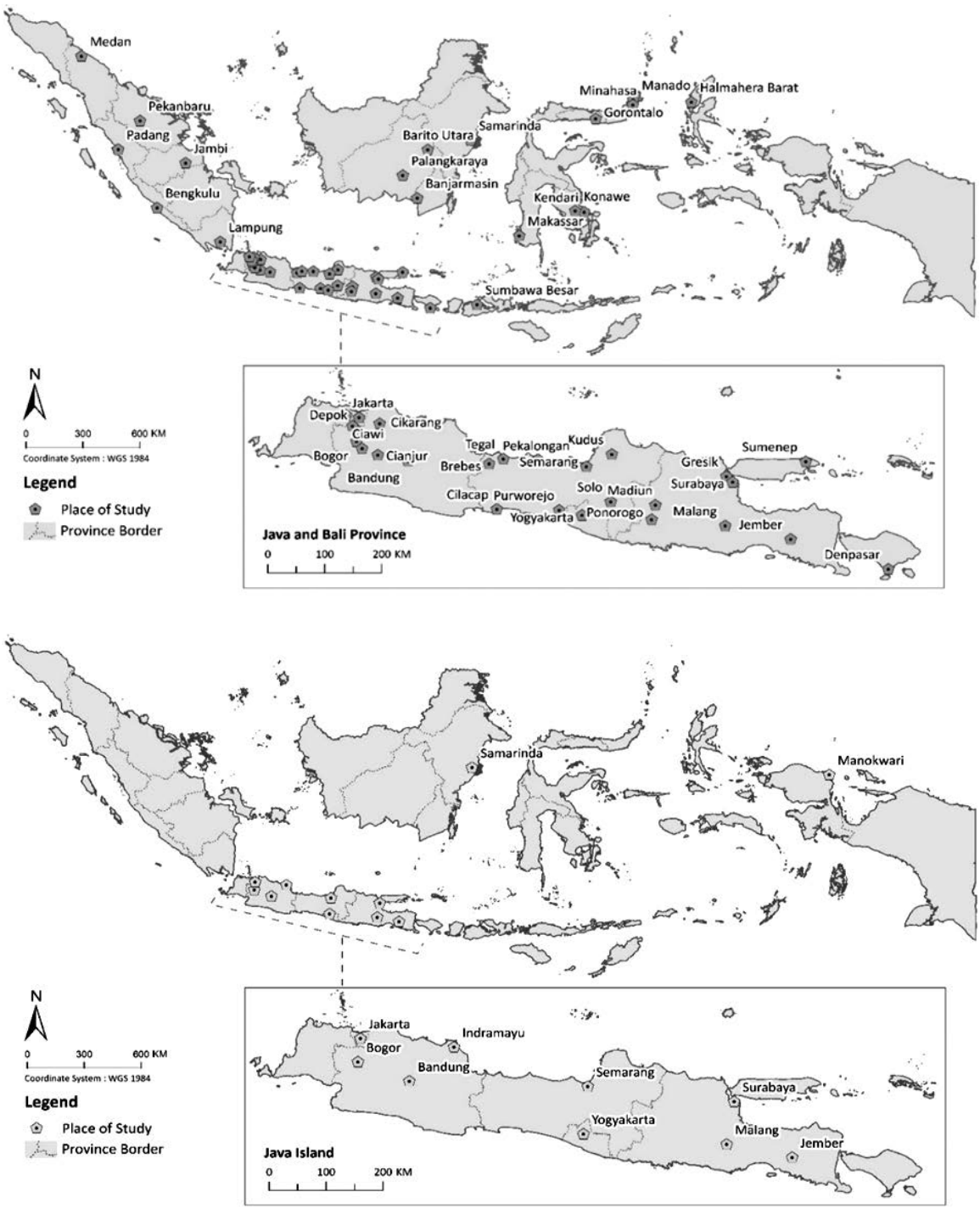
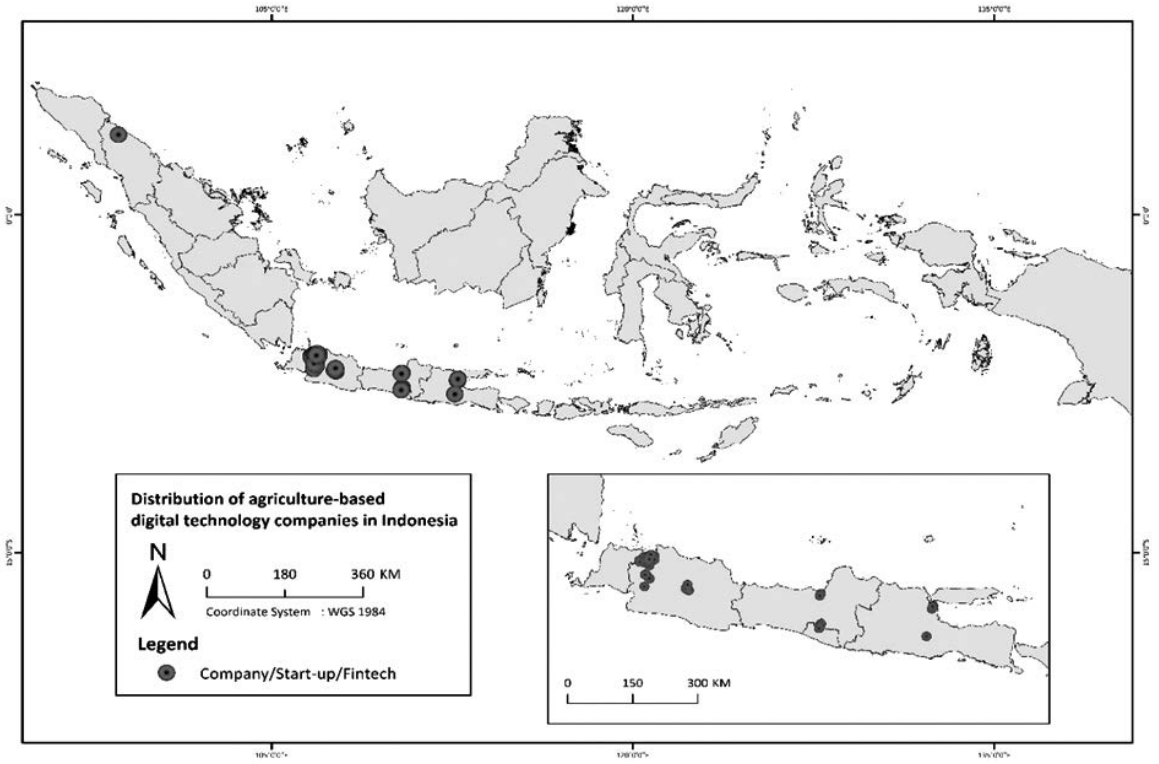


Figure 3. Concentration of digital agriculture companies



Digital Agriculture Practices

Research and innovation in digital agriculture need to be applied in the sector through the support from the GoI strategies (initiatives, national plans, and policies) as highlighted in Appendix Table 2. In Indonesia, digital agriculture-based companies (startups, businesses, industries, and SMEs) have been established to support the development of agriculture 4.0. Accordingly, an interactive map has been developed in this study to provide information on the distribution of digital agriculture companies, their names, locations, some brief information, types of digital technologies used, year of establishment, and references.[3] The map shows how far digital technologies (types and utilization) have been developed and applied in the food and agricultural sector in Indonesia.

Aside from the interactive map, a thematic map has also been developed. Figure 3 shows that most digital agriculture companies are concentrated on Java island, followed by Sumatera island. Such companies are not found on other islands (i.e., Kalimantan, Sulawesi, and Papua), although they can reach the other islands through the internet to market their products and services. For instance, food delivery services from Gojek (GoFood) and Grab (GrabFood) have been widely used in Kalimantan, Sulawesi, and Papua. Even during the pandemic, these apps were used as means for online food delivery service for MSMEs players and consumers. The apps could be used to enhance MSMEs' performance and to serve as alternative media for transactions to maintain and improve business continuity during the pandemic (Nurlinda et al. 2021). Furthermore, the demand for the food delivery services of these startup unicorns increased by about 10 percent (Candra, Ayudina, and Arashi 2021). During the

3 https://agriculture40companies.gis.co.id/

implementation of social restrictions, TaniHub and Sayurbox increased their transactions by three-fold. To maintain the availability of food products marketed during the pandemic, these startups developed several methods, such as a planting program, 1000 farmers' cooperation, and farmers' support (i.e., funding, technical assistance, and profit and loss calculation).

The companies harness digital technologies for e-commerce, farmers' advisory, mechanization platforms, digital marketplace, traceability, food delivery, and/or peer-to-peer lending. Some examples of digital technology used in certain companies are summarized in Table 1. These companies are located on Java island, although some digital technology features (e.g., mobile apps, iOS platforms, and smartphones) can be accessed on other Indonesian islands.

These startup companies also use one or more integrated digital technologies, such as big data, AI, GIS, GPS, drones, IoT, cloud computing, blockchain, mobile apps, smartphones, and satellites. In addition, the digital marketplace is the most dominant field for startup companies in

Table 1. Examples of digital agrifood companies in Indonesia

Name of Company	Digital Technology Used	Types of Company	Brief Information of Company
Gojek (GoFood), Grab (GrabFood), Traveloka (Traveloka Eats) and Shopee (ShopeeFood)	Artificial intelligence, and IoT-enabled GPS, smartphone (apps)	Food delivery services	Food delivery online platform allows consumers to order, choose, and deliver food from certain restaurants/shops/ markets through a smartphone without the direct presence of the consumers
Warung Pangan and Shopify (Food and Beverages E-commerce)	Mobile apps, website, and cloud	E-commerce	Facilitate suppliers, farmers, millennial farmers, entrepreneurs, and individuals who work for food and agriculture sector to market their agriculture commodities and produces through website or other electronic platforms
TaniHub, Chilibeli, Agromaret, Rarali. com, and Eden Farm	Artificial intelligence, cloud computing, mobile apps and android, iOS platform, and website	Digital marketplace/ e-marketplace	Provide an easy transaction process through digital technology features for trading agricultural commodities (e.g., fruit, vegetables, machines/ infrastructures, and services) with connecting farmers and producers to retailers, wholesalers, and individual customers
eFishery, KARSA, NeuraFarm, and Biops Agrotekno (Encomotion)	IoT, smartphone, mobile apps, artificial intelligence, drone, and satellite	Farmer advisory	Provide solutions and services for farmers and farming companies based on smart and precision agriculture intended to increase agriculture productivity and efficiency, and to provide recommendations for policy-decision makers (at governmental level).
TaniFund, Crowde, iGrow, Tanijoy, Mekar, iTernak, and Eragano	Website, smartphone, mobile apps, IoT, and blockchain	Peer-to-peer lending	A lending platform that provides financial support for Indonesia's farmers by connecting them with investors
HARA, Koltiva, and MSMB Indonesia	Big data, artificial intelligence, blockchain, GIS, IoT, mobile software apps, and cloud-based website	Traceability	Provide valuable data and services for farmers or related stakeholders for making decisions and for guiding agriculture development
PanenID, AgroDrone, and Agrito	GIS, drone, and IoT	Mechanization and automation services	Provide products and or service for agriculture mechanization and automation

Note: GIS = geographic information system

Indonesia, followed by peer-to-peer lending and farm advisory. In relation to this, the Financial Services Authority (OJK) issued Regulation No. 77/POJK.01/2016 on information-technology-based money-lending services to boost the growth of lending services and to create a new financing alternative for the public. As of 10 June 2021, a total of 125 peer-to-peer lending companies have registered under OJK; in the agrifood sector, TaniFund, Crowde, iGrow, Mekar, and iTernak have already registered with the OJK.

Other countries have likewise adopted digital agriculture, according to the literature reviewed in this paper. In Japan, scholars have conducted massive studies on digital agriculture. One of the innovations, NoshoNavi1000' that was developed for many years, involves major technological components of smart agriculture (Li et al. 2022). According to FAO and WB (2021a), digital infrastructure is well-established in Turkey, but the primary constraints include data collection and access, financial literacy, digital literacy, and the digital workforce. FAO and WB (2021b) also reported the profile of digital agriculture in Argentina, where the role of digital solutions in the agriculture sector has increased in recent years. At least 54 digital agriculture startups are currently operating and gaining traction in Argentina's agritech sector.

Relation of Digital Agriculture Technologies and the COVID-19 Pandemic

Figure 4 shows the map developed in this study on the digital agriculture technologies related to COVID-19. It highlights that the studies relevant to the pandemic are distributed on Java, Sumatra, Sulawesi, and Kalimantan islands. While most published studies are concentrated on Java island, none is on Papua island.

The COVID-19 pandemic disrupted Indonesia's agrifood value chain, and the disruption has generated both positive and negative impacts on the practices of digital agriculture technologies. For example, the social restriction measure during the pandemic made it difficult for the Indonesia Ministry of Agriculture to implement activities related to digital agriculture technology such as digital monitoring and auditing systems for administrative regions (Latifah 2020). However, the pandemic has accelerated the implementation of Agriculture 4.0 and has urged SMEs, millennials, and university students to innovate and conduct research related to digital agriculture technology practices (Gandasari 2020; Sondakh, Rembang, and Syahyuti 2020; Rapitasari 2021). Digital apps, such as Amouras (Latifah 2020) and Takesi (Gandasari 2020), have also been developed.

Agricultural producers and consumers have shifted their mindsets to benefit from the social media during the pandemic (Chaerani et al. 2020). They harnessed online platforms for marketing and e-marketplaces, such as Shopee, Tokopedia, Lazada, Bukalapak, Blibli, Sayurbox, TaniHub, and Kecipir (Vinolina 2020; Ibrahim and Mufriantie 2021). Also, the pandemic caused new regulations in support of the application of digital agriculture technologies to be issued. For instance, STRANAS KA: National Strategy for Artificial Intelligence 2020–45 envisaged food security as a significant area for AI development.

COVID-19 has altered the development of the agrifood industry in Indonesia (Appendix Table 2) as political strategies have been taken to address the pandemic. A few agrifood-based strategies are identified to address the pandemic, namely:

1. implementation of the National Movement of 1000 Digital Startups: The Digital Energy of Asia;
2. Satu Data Indonesia regulated under the President Regulation No. 39 Year 2019 on One Data Initiative; and
3. STRANAS KA: National Strategy for Artificial Intelligence 2020–45.

The last two strategies are still being implemented postpandemic. Most activities in the policy are implemented via online instead of face-to-face. The national activities proposed under these strategies were suspended.

Figure 4. Map of digital agriculture technologies related to COVID-19 developed in this study

A website was created under the National Movement of 1000 Digital Startups,[4] which shows that as of 16 November 2021, more than 1,160 startups in 20 cities (including agrifood startup companies) and online activities (e.g., seminars, workshops, and other capacity building) were operating online during the pandemic. According to the Ministry of Communication and Informatics (Rizkinaswara 2021), the pandemic has the potential to create significant momentum in accelerating and developing digital startups.

Purbasari, Muttaqin, and Sari (2021) also stated that the GoI encouraged SMEs to proactively connect with digital platforms to cope with the effects of the pandemic. Their study also revealed that during the pandemic, the Digital User Citizenship element was still in a relatively weak position. However, digital technology entrepreneurship and multisided digital platforms are in an auspicious position to grow continuously, along with the increased number of digital SMEs and the widened online market base. However, Indonesia's startups decreased from 2,400 companies in 2019 to 2,311 companies in 2021, albeit it still ranked among the world's five biggest startup centers.

To address the COVID-19 pandemic, some startup companies applied strategic measures, such as changing the business model, applying work performance and behavior management, adding new digital features, conducting brand awareness campaigns, and transforming organizational and financial arrangements. For instance, Google, Temasek, and Bain & Company (2021) reported that 72 percent of consumers preferred digital food delivery services during the pandemic because they were more convenient and easier to use. Gross Merchandise Value in the transportation and food sector has experienced double-digit growth since 2020 and is projected to increase by about 25 percent from 2021 to 2025. Contactless food delivery platforms (e.g., GoFood, GrabFood,

4 https://1000startupdigital.id/tentang/

ShopeeFood) were highly beneficial during the pandemic to prevent the transmission of COVID-19 and to avoid human-to-human interactions.

Meanwhile, Muttaqin, Taqi, and Arifin (2020) reported that the work pattern performed by startup companies in running their business has also changed; employees need to have reasonable control and leadership. Pramono et al. (2021) cited that during the pandemic, startup behaviors (i.e., agility, entrepreneurship capability, business transformation, and opportunity) had the most significant influence on organizational structure characteristics and had a partial effect on startup performance. However, leadership technology did not have a significant effect on the same.

Similar to the 1000 Digital Startups program, the secretariat of One Data Indonesia also constantly updates its datasets, particularly on agrifood, to the One Data Indonesia portal[5] during the pandemic and postpandemic. In STRANAS KA 2020–45, food security is one of the main targeted areas for AI implementation.

CONCLUSION

Studies in Indonesia on digital technologies mainly concentrate on IoT, GPS and GIS, websites, AI, big data, and robotics, with IoT as the most studied digital technology in the country's agricultural sector. Java island is still considered the biggest producer of digital agriculture studies before and during the COVID-19 pandemic. Digital agriculture practices have also been utilized to embody agriculture 4.0, including smart farming and precision farming. The practices have been accelerated to develop, most notably during the COVID-19 pandemic and the "new normal" era.

Digital technologies have been integrated into companies (i.e., MSMEs, industries, and startups) for e-commerce, farmers advisory, mechanization platforms, digital marketplace, traceability, food delivery, and/or peer-to-peer lending. However, these companies are primarily headquartered on Java island, and they need to scale up and upscale in other islands in Indonesia to expedite the implementation of agriculture 4.0. The GoI, therefore, needs to support the ecosystem of digital research and its development on other islands to nudge the distribution equality of digital agrifood development, especially in terms of infrastructure, literacy, and talents.

Data privacy and cyber security on digital agriculture applications in Indonesia are now becoming a primary concern; thus, the GoI also needs to enact specific measures (policies) to tackle the misappropriation of digitalization.

The development of startups needs governmental support, and this has been implemented through mainstreaming into national strategies, including national action plans, policies, initiatives, and visions. However, minimal agrifood-based strategies can accommodate the importance of agrifood digitalization during the pandemic and postpandemic. The study also finds that most of the strategies contained these issues only before the pandemic. The GoI should continue implementing the strategic measures (policies and regulations) with a few agile changes, namely, prodigitalization of agrifood systems during and postpandemic. For instance, digital infrastructures (i.e., free and open internet access) and digital education need to be equally distributed to other islands to help facilitate economic recovery after the pandemic. Due to social distancing and national lockdown regulations, the pandemic has negatively affected the implementation of various activities of agrifood systems. The negative effects include decrease in domestic food production, yield and productivity, and food supply and availability.

In digital agriculture, some projects and interventions requiring virtual actions to be taken in the field have also been affected, which has led to the implementation of projects to be suspended. However, most studies stated that the pandemic has boosted the adoption of digitalization in agrifood systems in Indonesia. Digital technologies have transformed physical presence into a virtual one to respond to COVID-19.

5 https://data.go.id/

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Appendix . Types of agriculture digitalization-based disruptive technologies

Type of Digital Technologies	History	Description	Uses in Agriculture
AI	Coined by John McCarthy, Alan Turing, Marvin Minsky, Allen Newell, and Herbert A. Simon in a conference at Dartmouth College, Hanover, New Hampshire in 1956	Designed to simulate human intelligence and programmed in machines to mimic human actions	Integrated with remote sensors to detect soil moisture content and for automated irrigation Integrated with a drone for pesticides and herbicides spraying and plants monitoring (Talaviya et al. 2020) Integrated with AI for crops selection, fertilizers selection, field management, and crop harvesting (Jha et al. 2019)
IoT	First introduced by Kevin Ashton in 1999 as during a presentation to Procter & Gamble.	Devices (e.g., machines, equipment, software, and other things) are interconnected with the internet to gather and analyze data and to create actions	Integrated into agriculture in the form of intelligent agriculture applications, services, and sensors (Ayaz et al. 2019) Used specifically for agriculture planting and management monitoring, irrigation, fertilizer and yield management services, and plants and agriculture environmental monitoring (Doshi, Patel, and Bharti 2019)
Blockchain	First used as public ledger for transactions Invented by Satoshi Nakamoto (using a pseudonym) in 2008	Referred to as distributed ledger technology, storing distributed databases across the whole computer system or among participating parties	Used in agriculture insurance, food supply chain, smart farming, and e-commerce of agricultural products (Xiong et al. 2020) Used in the agribusiness sector to promote more reliability and agility in information with a reduced cost (Rocha, de Oliveira, and Talamini 2021)
Big data	First coined by Roger Mougalas from O'Reilly Media in 2005 Refers to a large data set that is impossible to harness traditional business intelligence tools	Large amounts of digital datasets are generated from digital sources, and thus require advanced computer storage and analysis technologies	Provides predictive insights in farming operations, drives real-time operational decisions, redesigns business processes for game-changing business models (Wolfert et al. 2017) Recasts conventional process-driven agriculture, and plots the course for more innovative and data-driven farming (Lioutas et al. 2019)

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Appendix continued

Type of Digital Technologies	History	Description	Uses in Agriculture
Smartphone	Discovered in 1994 as IBMs Simon (the first smartphone) featured with apps and touch-screening	Highly advanced features that are combined with mobile phone and connected with internet	Integrated with camera and GPS as a sensor for farming management, extension services, and information systems (Pongnumkul, Chaovalit, and Surasvadi 2019) Used to inform decision making for sustainable fertilizer management (Golicz, Hallet, and Sakrabani 2021)
Uncrewed aerial vehicle UAV	Invented in 1917 by Elmer Sperry, Peter Cooper Hewitt, Josephus Daniels, and Glenn Curtiss to provide the Navy with its first uncrewed aircraft, the aerial torpedo Founded later in the 1970s by Abraham Karem (known as the Drone Father) in the form of UAV (drone) technology	An aircraft without human onboard operators run remotely by a human operator or autonomously by an onboard computer	Used in precision agriculture to spray the pesticides to avoid the health problems (Mogili and Deepak 2019) Used to count plants, nutrient applicator sprayer, mapping, and normalized difference vegetation index plant health indexing (Norasma et al. 2019)
Digital employees or workspace	Introduced by Paul Miller in his book *Digital Workplace: How Technology is Liberating Work* in 2012 Promoted in 2009 by John Mcconnell as a "web office," "online office," and "web workplace" via his intranet session.	A team of automated employees or workers with digital skills who are in the form of robots and are trained to perform tasks equivalent to physical employees/workers	Provide quick, reliable, and secure access to agriculture data from customers via multiple devices to reduce the times used for searching information and improving the agriculture system.
Virtual reality	Invented in 1957 by Morton Heilig with the name of Sensorama, a multimedia device made from virtual reality technology In 1987, the term "virtual reality" was coined by Jaron Lanier	Computer-based simulation enables a person to interact with an artificial three-dimensional environment synthetically or virtually	Used for virtual agriculture research to reduce experiment costs, shorten the research time, and get visualized process and experiment (Li 2008) Applied for agriculture scientific research and teaching, goods circulation, and agricultural machinery design and manufacturing (Yu et al. 2010).
Augmented reality	Coined by Tom Caudell and David Mizell in 1990 for its terminology Sensorama, which could deliver visuals, sounds, vibration, and smell to the viewer, was created by Morton Heilig in 1957	Real-world objects that are enhanced by superimposing computer-generated information	Contributes to the optimum management of agriculture farms, including water quality management, remote collaboration, and boardroom discussion (Xi, Adocock, and McCulloch 2018) Used to improve rural emergency response by providing an up-to-date view of on-farm hazard information (Weichelt et al. 2018)

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Appendix continued

Type of Digital Technologies	History	Description	Uses in Agriculture
Robotics	Built by Al-Jazari in 1206 for a programmable humanoid robot Coined by Isaac Asimov in 1941 for a word of "robotics" In 1956, Joseph Endgelberger and George D. Devol were responsible for the birth of the robotics industry.	A technology acquired from a multidisciplinary field of science and engineering with the primary producers of robots that can substitute for or assist human actions	Used for land preparation before planting, sowing/planting, plant treatment, harvesting and yield estimation, and phenotyping (Oliveira, Moreira, and Silva 2021) Has the potential to take off a load of labor shortage and increase productivity (Kushwaha et al. 2016)
Automation	First coined at the Ford Motor Company by D.S. More complex in 1946 to describe the increased use of automatic devices and controls	Technologies are produced to operate automatically with minimizing human interventions	Used in agriculture maintenance, control of insecticides and pesticides, water management, and crop monitoring (Puranik et al. 2019) Used in field machinery, irrigation systems, greenhouse automation, animal automation systems, and automation of fruit production systems (Edan, Han, and Kondo 2009)
3D printing	First introduced in 1984 through a patent filed by Charles Hull on stereolithography	A process to create or manufacture three-dimensional objects from materials being added together with the assistance of a computer	Provides an engineering solution for customized food design and personalized nutrition control, a prototyping tool to facilitate new food product development, and a potential machine to reconfigure a customized food supply chain (Sun et al. 2015) Used as a soilless cultivation substrate for hydrogels 3D printed with incorporating microorganisms (Kalossaka et al. 2021)

Appendix Table 2. Indonesia digital agriculture policies and initiatives

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
National Industrial Development Master Plan 2015–35	National plan: Indonesian government issued Government Regulation No. 14 of 2015 on the Master Plan of National Industry Development (Rencana Induk Pembangunan Industri Nasional) 2015–35. Aims to fulfil the mandate of Law No. 3 of 2014 concerning the industry, in line with RPJMN 2015–19	Implemented together with Governmental Regulation No. 14 of 2015 Designed as the implementing rules and regulations of Law No. 3 of 2014 for the industry Guides government and industrial actors in planning and developing industries in Indonesia for the next 20 years	Main actor: Ministry of Industry Supporting actors: Indonesian Chamber of Commerce and Industry, relevant institutions, industry actors, and universities	Food and agriculture upstream industry as the mainstay sector prioritized under the national plan In the plan, the industry has not yet connected with digital technologies Digital technologies connected directly to the manufacturers of electronic and ICT and to the manufactures of capital goods, components, supplementary materials, and services	Adopted in June 2015 and has not yet considered the COVID-19 pandemic	N/A	N/A
National Movement of 1000 Digital Startups: The Digital Energy of Asia	National initiative	An early-stage digital start-up development program to facilitate participants to network and form a team and to get assistance As of 5 July 2021, this initiative has engaged more than 1,160 startups in 20 cities.1	Main actor: Ministry of Communication and Information Technology. Other actors: Indonesia startups	Agriculture and fishery sectors included in the initiative to streamline digital technology use for start-up development Supports startups under the sector2	Established in 2016, and is still operational to date COVID-19 pandemic as one of the accelerating factors and challenges of the start-up implementation	Planned programs (online YouTube incubation and workshop) were mostly conducted online during the pandemic	N/A

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
National Research Master Plan 2017–45	National plan	Created to align long-term research needs with the direction of national development related to science and technology within period of 2017–45	Main actor: Ministry of Research, Technology, and Higher Education Supporting actors: Research-based governmental institutions and other ministries	Includes the food or agriculture sector but not directly connected with digitalization or digital technology	Created due to the COVID-19 pandemic Food derived from agriculture sector as a main research focus	N/A	N/A
Presidential Regulation No. 74 of 2017 on Roadmap of the National Electronic-Based Trading System (e-Commerce Road Map) 2017–19	National policy	Rules the acceleration and development of a national electronic-based commerce system (e-commerce) Provides direction and steps in preparing and implementing commercial transactions that are based on a range of electronic devices and procedures	Main actors: Coordinating Ministry for Economy, Ministry of Home Affairs, Ministry of Commerce, Ministry of Cooperatives and Small and Medium Enterprises, Ministry of Transportation, Governor of Bank Indonesia and Chairman of Board of Commissioners of the Financial Services Agency Supporting actors: Financial services authority, venture capital association/angel capital, e-commerce and digital economy association	Includes the development of logistic system for rural to urban community (e.g., farmers and fisherfolk)	Effective as of 3 August 2017 but do not include the COVID-19 pandemic issue	N/A	N/A

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
Making Indonesia 4.0 (Toward 2030)	National initiative	Guides the implementation strategy and roadmap for 4IR in Indonesia Focuses on 5 industrial sectors and 10 national priorities	Main actor: Ministry of Industry Supporting actors: Ministries, national and local government, industry associations, research and education institutions, and technology providers	Includes the food and beverage industry with the aim of achieving competitiveness at the regional level	Created before the COVID-19 pandemic and was designed toward 2030 Food and beverage is one of the main industrial sectors to attain regional competitiveness	N/A	N/A
Presidential Regulation No. 95 of 2018 on Electronic-Based Government System (SPBE)	National policy	Regulates the implementation of information security, certification, and audit management system in the implementation of Electronic-Based Government System Includes digital technologies that have the potential to develop in Indonesia	Main actors: National SPBE Coordination Team Supporting actors: Central agencies, local governments, employees of the State Civil Apparatus; individuals, communities, business actors, and other parties who utilize SPBE services	Food and agriculture not mentioned in the regulation and in the Master Plan Digital technologies integrated into the Master Plan (e.g., mobile internet, IoT, cloud computing, big data analysis, and artificial intelligence)	Issued and legislated in October 2018 or before the pandemic Food and agriculture sector not mentioned, but digital technologies clearly planned for development in Indonesia	N/A	N/A

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
Indonesia 2045: Berdaulat, Maju, Adil, dan Makmur (Sovereign, Progressive, Fair, and Prosperous)	National vision	Roadmap of Indonesia until 2045 Consists of four pillars: Human development and mastery of science knowledge and technology, sustainable economic development, equitable development, and consolidating national resilience and governance	Main Actor: Ministry of National Development Planning Supporting actors: All policy makers in the executive, judicial, and legislative circles; higher education; young generation; various professional institutions	Includes food security and farmers welfare and sector under Pillar 2 (i.e., sustainable economic development) Sector not directly interlinked with digital technology Digital technology interconnected with the industry and creative economy (Pillar 2) and infrastructure development and equity (Pillar 3)	N/A	Signed by Indonesian president in May 2019 Identified during the COVID-19 pandemic Pandemic not integrated into the plan	N/A

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
National Medium-Term Development Plan (RPJMN IV) 2020–24	National plan Set together with President Regulation No. 18 of 2020 on 27 January 2020 about RPJMN IV 2020–24	Five-year program (2020–24) that describes the Indonesian President's vision, mission, and programs after the general election in 2019 Last step of the National Long-Term Development Plan 2005–25, consisting of four pillars and seven agendas	Main actor: Ministry of National Development Planning Supporting actors: Ministries/ governmental bodies at national and local levels, other institutions, public-private sectors, and Indonesian citizens	Food and agriculture incorporated into Development Agenda No. 1 of RPJMN IV of 2020–24 (Strengthening Economic Resilience for Quality Growth) Sector not directly interlinked with digital technology	Digital transformation for 4IR included in the Macroeconomic Framework 2020–24 and in Mainstreaming RPJMN IV 2020–24 Digitalization integrated into the development agenda of RPJMN IV 2020–24 Adopted on 14 August 2019 without mentioning the COVID-19 pandemic	N/A	N/A

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
President Regulation No. 39 of 2019 on One Data Initiative (Satu Data Indonesia)	National policy	Controls the implementation of One Data Initiative Has a number of regulated principles: Meeting data standards, having metadata, complying with data interoperability rules, and using reference codes and/or master data Do not mention the use of digital technology Has important role in digital transformation development, especially during the pandemic	Main actors: Executive Office of the President and Ministry of National Development Planning Supporting actors: Designated national and local government	Designed to provide an online sharing knowledge platform for communication and coordination; platform is still in development3 Food and agriculture data integrated into the portal	Issued on 12 June 2019 and do not mention clearly the COVID-19 pandemic and food and agriculture sector Data on COVID-19 and food and agriculture have been included in the updated portal of the initiative	Data on food and agriculture have been updated on the website Government continues to implement and improve the initiative	Data on food and agriculture have been updated on the website Government continues to implement and improve the initiative
STRANAS KA: National Strategy for Artificial Intelligence 2020–45	National plan	Consists of focus areas and priority areas of AI technology Contains food security as one of the AI main areas	Main actor: Agency for the Assessment and Application of Technology Supporting actors: Ministries, research institutions, universities, national to local government and other stakeholders	Includes food security as one of the AI main areas	N/A	Includes planned activities in health, research and education, and bureaucracy reformation to address COVID-19	Adopted the New Normal for the COVID-19 pandemic

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
					Pre-COVID	COVID	Post-COVID
Law of the Republic of Indonesia No. 11 of 2020 on Job Creation (Omnibus Law on Job Creation)	National policy	Regulates labor regulations, simplification of permits, investment requirements, and government administration Digitalization also incorporated into some articles of the law	Main actor: People's Representative Council Supporting actors: Ministries, industries, and investors	Mentions digital technology and industry revolution 4.0 for SMEs development, broadcasting, and land use Food and agriculture sector not directly connected with digital technologies	N/A	Issued on 3 November 2020 when the COVID-19 has not become a global issue Food and agriculture became the main sector of discussion but is not directly connected to digitalization	N/A
Ministry of Agriculture Regulation No. 4 of 2019 on Guidelines for Agricultural Human Resources Development Movement Towards World Food Barns 2045	National policy	Rules the Development Movement of Agriculture Human Resources Towards World Food Barns 2045, which aims to improve capacities and competencies of human resources Digital technologies are one of the innovation needed by millennial farmers who support the implementation of the movement	Main actor: Ministry of Agriculture Supporting actors: young people, farmers, agro-based institutions, and agriculture industries	Places young people between 19 and 39 years old as a main human resource/ millennial farmers for the implementation of the movement Young people required to be adaptive of digital technologies use	Issued on 10 January 2019 Establishes millennial farmers with knowledge on and skills in digital technologies as pivotal actors for the movement	N/A	N/A

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Appendix Table 2 continued

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Appendix Table 2 continued

Name of Strategy	Type of Strategy	Content	Responsible Stakeholders	Food and Agriculture Issues	Information Related to COVID-19		
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Ministry of Agriculture Decree No. 259 of 2020 on the Ministry of Agriculture Strategic Plan 2020–24	National policy	Details a medium-term strategic planning document of the Ministry of Agriculture for a period of five years from 2020 to 2024	Main actor: Ministry of Agriculture Supporting actors: Ministries and other agriculture agencies under the Ministry of Agriculture	Promotes digital transformation in the era of industry 4.0 in the agriculture sector, especially in information system Uses technologies such as Big Data, IoT, AI, and so forth	N/A	Adopted on 4 May 2020 during the COVID-19 pandemic Pandemic not yet highlighted in the guidelines and not yet been interlinked with digital technologies use and acceleration	N/A

Notes: (1) [1] For more details, see https://1000startupdigital.id/beranda/#penggerak
[2] List of the startups can be seen at https://1000startupdigital.id/beranda/#penggerak
[3] Can be accessed https://data.go.id/
(2) 4IR = Fourth Industrial Revolution
AI = artificial intelligence
IoT = Internet of Things
RIPIN = Rencana Induk Pembangunan Industri Nasional (Master Plan of National Industry Development)
SME = small and medium enterprise
SPBE = Electronic-Based Government System