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Improving Agri-Food Sector Productivity in Indonesia Through Information and Communication Technologies

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3.1 Introduction

The productivity of Indonesia's agri-food sector, especially rice, has decreased over the past few years. According to the study by Yuan et al. (2022), the average rice yield per hectare in Indonesia decreased in the period 2015–2020. Moreover, since the early 2000s, Indonesia's average rice yield per hectare has been overtaken by Viet Nam, which now ranks at the top in the Southeast Asian region. This decline in rice productivity in Indonesia also occurred at the same time as the rice harvest area was decreased (Yuan et al. 2022). Because most Indonesian people rely on rice for their dietary energy requirements, it is important to raise productivity (Mariyono 2014). In this regard, Simatupang and Timmer (2008) described four possible reasons why Indonesian rice productivity has been declining or stagnant. These are the conversion of arable land to other uses, the degradation of irrigation systems, overintensive land use, and the decreasing emphasis on technology innovation and dissemination (Simatupang and Timmer 2008).

One of the reasons for the declining emphasis on technology innovation and dissemination is the decline in the quantity and quality of information conveyed by public extension servants to farmers over the past few years (Amanda 2019; Rachman 2016). This is of course very unfortunate, bearing in mind that information can play an important role in influencing farmer behavior and agricultural production. Moreover, because information is viewed as a tool for reducing uncertainty and risk in the production process to some degree, farmers are required to

have access to high-quality, effective information (Ma, Zheng, and Deng 2022). Farmers rely on accurate information to improve performance in production planning, cultivation practices, post-harvest handling, and marketing decisions (Pereira 2009).

Today, to foster the spread of information and knowledge sharing, several information and communication technologies (ICTs) have been promoted and utilized by governments, farmers, and other actors in various parts of the world. According to the literature, ICT adoption by farmers in developing countries can enhance farm productivity (Marwa et al. 2020; Ogutu, Okello, and Otieno 2014; Rajkhowa and Qaim 2021), increase farm income (Marwa et al. 2020; Rajkhowa and Qaim 2014), induce better usage of input (Ogutu, Okello, and Otieno 2014; Rajkhowa and Qaim 2021), and improve organic fertilizer application (Ma, Zheng, and Deng 2022; Wang et al. 2022). Based on the above literature, we expect that ICT utilization by rice farmers in Indonesia will improve productivity as well as providing other benefits.

A fairly common form of mobile ICT utilization among farmers in Indonesia is the use of social media such as WhatsApp and YouTube to exchange information and knowledge, and to market their products. In addition, the use of e-commerce for marketing agricultural products has also begun to be prevalent in Indonesia, although it is not yet massive. Most farmers in Indonesia—about two-thirds—use smartphones and are active on social media, often in dedicated farmer groups. However, only about 20% use social media to buy or sell, with even fewer—under 5%—being active on e-commerce sites (Soon, Tan, and Wibowo 2021). Meanwhile, the use of farm management apps is not as massive as social media among Indonesian farmers.

In this regard, this research will address the following questions:

- (1) How widespread is the adoption of social media, e-commerce, and farm management apps by farmers?
- (2) What are the determinants and impact of social media adoption on farm productivity and other indicators?
- (3) What are the drivers or barriers of e-commerce adoption?
- (4) What aspects and features of farm management apps are most needed by farmers?

To answer these research questions, we collected and analyzed data from a sample of rice farmers in Yogyakarta and Jawa Tengah provinces. Rice farmers in Yogyakarta and Jawa Tengah provinces were chosen because rice farming in Indonesia has been concentrated in Java island (Mariyono 2014; Simatupang and Timmer 2008) and these provinces are located in the middle of this island. Moreover, the percentage of farmers who use the Internet in these provinces

was above the national average in 2018 (BPS 2018). Unfortunately, the poverty rate in these provinces is higher than in other provinces in Java islands and Indonesia as a whole (BPS 2022). Thus, we believe that observations on rice farmers in Yogyakarta and Jawa Tengah provinces will provide an interesting case study.

Much research has been conducted on rice farming in Indonesia—for example, by Mariyono (2014), and Otsuka (2021), and Simatupang and Timmer (2008),—but not many studies have focused on the use of ICT in rice farming (e.g., Santoso et al. 2023). Therefore, our study will try to fill this gap in the literature by providing an assessment of whether ICT utilization in the form of social media, e-commerce, and farm management can improve rice farm productivity in Indonesia. As regards the determinants and impact of social media adoption by farmers, this research was inspired by a previous study conducted by Morris and James (2017). Morris and James (2017) investigate the current use and potential of social media, and barriers to its adoption, by Welsh sheep farmers. In contrast to their research, which uses descriptive statistics to analyze the factors that influence social media adoption, this study uses propensity score matching (PSM) techniques.

3.2 Overview of ICT Utilization in Agriculture

Information and communication technologies (ICTs) can be utilized in agriculture in various ways (El Bilali and Allahyari 2018). The adoption of ICTs is expected to deliver information more quickly at lower costs and enable stakeholders in agriculture to communicate with each other in a timely way and without distance barriers. This study focuses on the utilization of social media, e-commerce, and farm management apps for farming purposes.

3.2.1 Social Media

Public extension programs have historically been used to spread agricultural knowledge in developing countries. Extension personnel visit and instruct individual farmers or farmer groups. However, there are two significant downsides to this established method of information transmission: first, only a very small number of farmers can be contacted due to the significant transaction costs associated with personal visits; and second, the information made available through this route is frequently general and not always adequately tailored to the unique requirements and circumstances of farmers. By lowering transaction costs and enhancing the quality of the information delivered, the use of digital methods and technology has the potential

to increase the efficacy of agricultural extension services (Rajkhowa and Qaim 2021).

According to the literature, social media can serve the agricultural sector in a number of ways, including marketing and consumer engagement, lobbying and campaigning, networking and knowledge sharing, and crisis communication (Das and Pradip 2021; Mills et al. 2019). Farmers utilize social media platforms to communicate and collaborate with other farmers and agricultural experts. Social media not only provides solutions to agricultural marketing problems but also helps in sharing information and creating awareness. In addition, social media is an appropriate platform for sharing farmers' success stories (Das and Pradip 2021). Social media also enables researchers and extension services to closely monitor and understand a farmer's distress and their problems, and to evaluate their efforts toward agricultural development (Valsamidis et al. 2013). Therefore, social media can be perceived as generic digital extension services in this context. A more personalized digital extension service is farm management apps, as explained in the subsection below.

The most popular social media platforms for agricultural information are WhatsApp, Facebook, and YouTube because of their easy access and quick reach (Petril'ák, Janšto, and Horská 2020). In many Southeast Asian economies, for example, Facebook has been used by input producers and farmers to share advice on agriculture practices and market information. Moreover, Facebook has provided a platform for personalized agricultural advice in the absence of public extension services and for broader discussion over the directions of agriculture. Furthermore, this social media platform is also used by farmers, input producers, and social enterprises to advertise their products (Faxon 2023).

Despite the various benefits it generates, there are also some challenges of social media utilization in agriculture (Suchiradipta and Saravanan 2016). These challenges include but are not limited to:

- (1) **Information explosion.** The amount of content published on a single topic is very high and a lack of monitoring often results in scientific errors. The huge amount of information may confuse inexperienced users and can be more harmful than beneficial.
- (2) **Quality control.** The quality control and monitoring of postings produced are quite vital. Content filtering needs to be taken very seriously on social media.
- (3) **Literacy.** Social media use requires both educational and technical literacy, which are both lacking among much of the population, particularly women in many developing nations.

3.2.2 E-Commerce

In many developing countries, the existence of small-scale farming systems and market imperfections makes it difficult for smallholder farmers to benefit from market transactions (Li et al. 2021). Smallholder farmers traditionally sell their products to intermediaries. On the one hand, intermediaries take advantage of farmers' information asymmetry and unaffordable transaction costs to access the national market, and thereby purchase products from farmers at low prices (Ma and Abdulai 2016). Farmers are compelled to accept a low price to avoid the risks of not selling, or market uncertainties. In this case, farmers are just price takers and intermediaries have monopsony power (Liu et al. 2021).

On the other hand, the transaction cost literature views the institution of intermediaries as a cost-cutting arrangement between sellers and buyers (Landa 1981). According to Rubinstein and Wolinsky (1987), intermediaries are a time-saving institution since they reduce the time it takes for sellers and buyers to negotiate a transaction. Moreover, Li (1998) argues that intermediaries provide efficiency benefits by bridging information asymmetry. Specifically, intermediaries are an efficient institution in markets where quality uncertainty is high. However, today those functions are partially reduced by the rapid development of e-commerce transactions.

By adopting e-commerce, farm households may avoid intermediaries and offer their products directly to consumers via their online e-shops. In other words, selling products through e-commerce might allow farmers to serve as both producers and sellers (Arromdee and Suntrayuth 2020). Additionally, since the unit transaction costs are high in almost all transactions for smallholder farmers (Poulton, Doward, and Kydd 2010), avoiding some or all intermediaries by selling products online might result in lower transaction costs. A lower level of transaction costs results in better sales revenue for the same amount of quantity sold, and thus higher household income (Li et al. 2021). Moreover, e-commerce can be a tool for farmers to create product differentiation, such as adding organic labeling, indicating the specific types of products, providing special packaging, or proceeding with marketing strategies (e.g., advertising, branding, and storytelling) (Arromdee and Suntrayuth 2020).

At the same time, the marketing cost increases tremendously when operating e-commerce, as intermediaries are eliminated and farmers are required to bear considerable additional costs that were previously paid by intermediaries, particularly for distributing and delivering products to consumers. Understandably, e-commerce products are sold to online consumers who are scattered, and the portion of each sale is small.

In this regard, a high frequency of deliveries and many more packages are required (Liu et al. 2021). These packaging and delivery processes are sometimes more time-consuming than traditional transactions. Moreover, the availability of stable and good internet connections as well as electricity and road infrastructure in rural areas in developing countries is still a major challenge of wider adoption of e-commerce.

3.2.3 Farm Management Apps

The idea behind farm management apps is similar to that of farm management information systems. Farm management apps can be defined as smartphone apps that can provide product- and site-specific advisory services and market information for farmers. These apps aim to support farmers with more detailed information and hence enable them to make better decisions on resource allocation. In other words, farm management apps can act as a decision support tool for farmers. Examples of farm management apps include Farmex for vegetable farmers in India (Rajkhowa and Qaim 2021) and iCow for dairy farmers in Kenya (Marwa et al. 2020).

Farmex helps its users plan season-wise cropping activities and provides information on best practices for cultivating certain vegetable crops. The platform also provides advice on the types and quantities of inputs to use, as well as on relevant pests and diseases and how to control them. Moreover, the platform makes suggestions on specific input brands and suppliers (Rajkhowa and Qaim 2021). Meanwhile, the iCow platform offers innovative services that include weekly messages on various livestock and agricultural topics, livestock calendars, farmers' SMS library, and expert directories. The logic is that digital information on vaccination, spraying, mastitis control, deworming, hygiene, and other dairy management practices improves animal health, reduces the incidence of disease outbreaks, and consequently reduces the intake of antibiotics. Nutrition also improves due to information on fodder management, proper feeding, and feed quality (Marwa et al. 2020).

3.3 Conceptual Framework

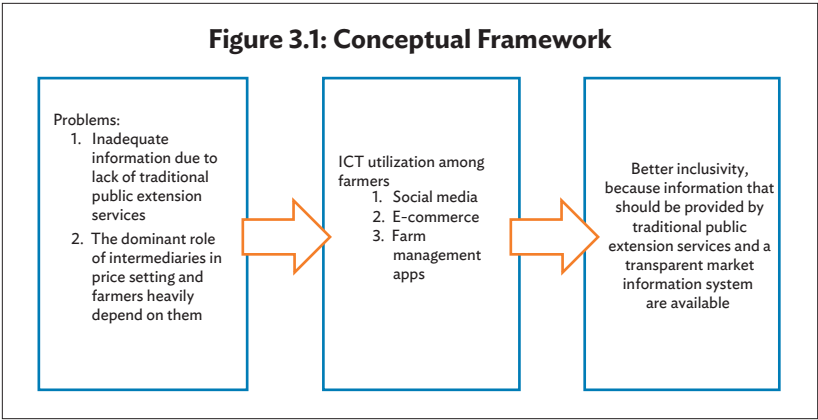
Traditional farmer extension services in Indonesia are usually lacking because of the limited budget provided by local governments and limited outreach (Martini, Roshetko, and Paramita 2017), especially in remote areas. Insufficient extension services and poor access to information further exacerbate the gap in technology adoption and contribute to low levels of farm productivity. Social media adoption by farmers would

be a solution to complement traditional farmer extension services and increase outreach, thus contributing to greater inclusivity (Das and Pradip 2021; Morris and James 2017; Riley and Robertson 2021). Farm management apps can also create inclusive benefits because they provide site-specific information to farmers regarding, for example, price, weather forecasts, input and output market, pest and disease control, etc.

Furthermore, most farmers in Indonesia are linked with intermediaries to finance their operations and market their products. Intermediaries include village-based collectors, township traders, and urban traders (Otsuka 2021). Village-based collectors usually buy paddy from farmers at a price below the market price. After that, they sell the paddy to township traders and the township traders mill the paddy into rice before the rice is sold in the market by urban traders. However, most smallholder farmers do not sell all their yields: They consume a portion of the harvest themselves. They usually call or bring the yields to the nearest rice mill and then bring the rice home or share it with the landowner if they are sharecroppers.

Social media and e-commerce can provide more information about product prices and are expected to impact farmers' decisions to sell their products. Moreover, farmers can access a wider market and credit by utilizing these ICTs. This is quite possible because limited access to capital and limited market participation often dampens farmers' incentives to use better production techniques that have the potential to increase the productivity of their landholdings and enhance their access to high-value markets (Ogotu, Okello, and Otieno 2014). Farmers' greater market participation and greater access to credit will result in more inclusive agricultural development. Moreover, rice trading through e-commerce also partially shortens the supply chain of rice and hence reduces the transaction costs for selling rice. Figure 3.1 summarizes the conceptual framework of this study.

Information that farmers have obtained from ICTs, such as social media, e-commerce, or farm management apps, can also increase knowledge and awareness regarding environmental issues. This knowledge and awareness will further develop if farmers share them with fellow farmers or those closest to them. Accordingly, this encourages farmers to change their production behavior, especially regarding input allocation. Farmers could either reduce existing input that damages the environment (e.g., chemical fertilizer, chemical pesticide) or apply more environmentally friendly input (e.g., organic fertilizer, organic pesticide) (Ma, Zheng, and Deng 2022; Wang et al. 2022).



3.4 Data and Methods

3.4.1 Data

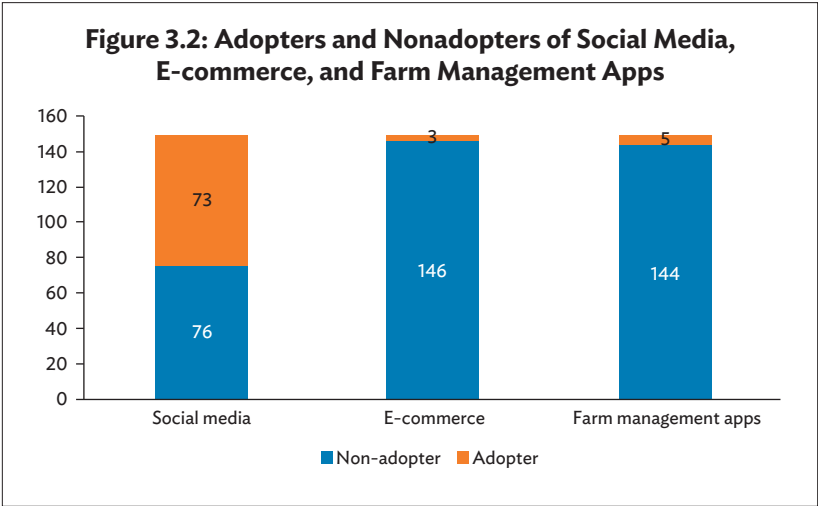
This study uses a stratified random sampling method in collecting data from a sample of rice farmers in four districts in Yogyakarta province (Kulon Progo, Bantul, Sleman, and Gunung Kidul) and four districts in Jawa Tengah province (Klaten, Boyolali, Purworejo, and Magelang) that are located near to each other. These districts have similar agroecological conditions and the socioeconomic characteristics of their residents are also similar. In each district, we selected 15–20 farmers from two subdistricts. In total, our sample consists of 149 rice farmers¹. The survey was held from June to August 2023.

Inclusion criteria in this study are farmers who have owned and cultivated their land during the last year, while farm workers (planters, harvesters, tractor drivers, etc.) who work on landholders' farms were not sampled. Sharecroppers and tenant farmers are also included in our analysis, as long as these farmers can make their own decisions regarding input use and output sales.

¹ Apart from respondents who were part of the pilot study, we conducted a survey of 182 farmers. However, we did not include the remaining 33 farmers as respondents, because their data were incomplete. These incomplete data were caused by respondents not recording agricultural activities in the last year. Even though our sample size is small, the socioeconomic characteristics and agroecological conditions of the areas we surveyed are relatively similar, so we hope that the data we obtain can be analyzed appropriately using the method we propose.

To ensure more reliable estimates, we first conducted a pilot study to test the questionnaire and the ability of the enumerators to execute it. The pilot study was conducted in Nanggulan subdistrict in Kulon Progo district with ten rice farmers. Accordingly, the questionnaire was modified. Second, enumerators were well trained, and effective ways of conducting the survey were tested. All interviews were conducted in Bahasa Indonesia or the Javanese language.

Figure 3.2 displays the characteristics of our respondents in this study. For social media adoption, we can conduct an econometric analysis because the proportion of adopters and nonadopters is relatively similar. Meanwhile, for the utilization of e-commerce and farm management apps, we can only further elaborate with descriptive statistics.



3.4.2 The Determinants and Impact of Social Media Adoption: Propensity Score Matching (PSM)

Propensity score matching (PSM) is a common method for evaluating the impact of policy intervention in the agriculture and food sectors. Examples include the study of Becerril and Abdulai (2010); Fischer and Qaim (2012); Li et al. (2021); Mwenda et al. (2023); Ogutu, Okello, and Otieno (2014); Rajkhowa and Qaim (2021); and Sadono (2018). With this method, we can identify the determinants of adoption as well as

the impact of social media utilization. Moreover, PSM can also solve the selection bias problem due to observed characteristics, as social media adoption by farmers is not a random behavior, and the degree of the impact of social media on farmer behavior also varies according to their characteristics.

A propensity score is the conditional probability of assignment to a particular treatment given a vector of observed covariates (Rosenbaum and Rubin 1985). It can be specified as:

$$p(X) = \Pr[D = 1|X] = E[D|X]$$

$$p(X) = F\{h(X_i)\}. \quad (1)$$

where $F\{\cdot\}$ is a normal or logistic cumulative distribution function and X is a vector of observed covariates (Becerril and Abdulai 2010).

The propensity scores can be generated using either a binary probit or logit model. The probit model assumes a standard normal distribution of the error term, whereas the logit assumes a logistic distribution (Cameron and Trivedi 2005; Ogutu, Okello, and Otieno 2014). Since we cannot determine a priori that the error term has a normal distribution (Ogutu, Okello, and Otieno 2014), this study uses a logit model to generate the propensity scores for social media adoption.

After estimating the propensity scores, we match treatment and control group farmers using three different matching algorithms, namely nearest neighbor matching (NNM), radius matching (RM), and kernel-based matching (KBM). Using and comparing different matching algorithms is common as a robustness check. After matching treatment and control group individuals based on their propensity scores, the ATT is calculated (Rajkhowa and Qaim 2021). We estimate the ATT as follows:

$$ATT = E(Y(1)|D_i = 1, p(X)) - E(Y(0)|D_i = 0, p(X)). \quad (2)$$

where $Y(1)$ is the outcome variable when the household is a social media adopter, $Y(0)$ is the outcome variable when the household is a nonadopter, D_i is a dummy variable indicating household i 's social media adoption status, and $p(X)$ is the propensity score. All regression models are estimated using STATA version 13 software.

The treatment variable in this study is social media adoption for farming purposes by farmers². It is a binary variable, where for adopters

² We realize that farmers can use social media for other purposes outside of agriculture. Therefore, during the survey we were very careful and thorough in asking farmers: "For what purposes do you use social media?"

the value is one and for nonadopters it is zero. Next, we use several covariates to control possible observable characteristics that affect farmer decisions on whether to adopt social media. We select these covariates based on the literature on social media (Morris and James 2017) and other ICT-based decision support tool adoption by farmers (e.g., Marwa et al. 2020; Mwenda et al. 2023; Ogutu, Okello, and Otieno 2014; Rajkhowa and Qaim 2021). These variables are the age of the household head, education level, household size, farm experience, distance to the nearest market, farm size, land ownership, off-farm employment, and farmer group membership.

Meanwhile, the outcome variables in this study are farm productivity, knowledge on the benefits of organic fertilizer, organic fertilizer adoption, organic pesticide adoption, and credit access.

- Farm productivity is measured using rice yield per acre. To ensure comparability with farmers who own and operate their land, sharecroppers and tenant farmers were asked about the yield before they shared it with their landholders. We argue that average farm yield is a more appropriate measure of productivity than average yield value in our case, because not all farmers sell all their yields, especially among smallholders.
- Knowledge of the benefits of organic fertilizer is measured as a binary variable, in which the value is one if farmers know and zero otherwise.
- For adopting organic fertilizer, we use a categorical variable because in our case, some farmers used chemical fertilizer and others used organic fertilizer. However, there is also a case for both fertilizers usage by few farmers. We categorize the application of fertilizers based on the positive environmental impacts yielded: 3 for organic fertilizer, 2 for a combination of organic and inorganic fertilizers, and 1 for inorganic fertilizer.
- The adoption of organic pesticide, as in the case of organic fertilizer, is measured using a categorical variable. Besides the utilization of organic and inorganic pesticides, there are also some cases of not utilizing pesticides. This is possible because pesticide is considered a preventive input (Mariyono, Kuntariningsih, and Kompas 2018). If farmers observe many pests in their crops, they tend to use pesticides, and vice versa. As in the case of fertilizer, we categorize pesticide based on the resulting positive environmental impacts – 3 for organic pesticide, 2 for not using pesticide, and 1 for inorganic pesticide.
- Lastly, credit access is measured using a binary variable in which the value is one if farmers access credit and zero otherwise.

3.4.3 Descriptive Statistics for E-commerce and Farm Management Apps Adoption

Since e-commerce is rarely adopted by rice farmers in our sample, we seek to identify what the barriers are that prevent them from adopting it. As stated by Liu et al. (2021), e-commerce products are sold to online consumers who are scattered, and the proportion of each sale is small. In this regard, a lot more packages and frequent deliveries are required (Liu et al. 2021). Farmers usually don't have enough time to carry out this process. Farmers are also still afraid to conduct online transactions because of the difficulty in identifying the credibility of the seller, or the possibility of fraud, misuse, or intrusion of information due to the disclosure of financial, product, or other private information through an insecure online payment port (Biucky, Abdolvand, and Harandi 2017). Moreover, a lack of knowledge on how to operate the platforms often limits farmers' participation in e-commerce trading. On the other hand, because most farmers sell their goods directly to intermediaries, the cost of delivery and packaging materials for non-e-commerce products is quite low. These cases require very little or no delivery and packaging by the farmers themselves (Liu et al. 2021).

Furthermore, because there are very few farm management app adopters in this study, our results can be perceived as an early assessment of farmers' need for those apps. To assess the need for farm management apps among farmers, we will develop a Likert scale-based analysis that contains the various aspects of the apps and its features. We adapt and develop the aspects and features of the apps based on the literature on similar ICT-based decision-support tools utilized by farmers in other countries. In regard to the aspects, based on observations of farmers in Bangladesh, Tithi et al. (2021) discovered that an ICT service is more likely to be adopted in a region if it meets the context-specific information requirements, is compatible with the users' literacy level, and is not financially expensive. Irungu, Mbugua, and Muia (2015) also stated that ICT tools need to be simple and affordable. Meanwhile, in terms of the features, we refer to previous studies that identify the information mostly needed by farmers for production and marketing activities. For instance, Mittal, Gandhi, and Tripathi (2010) found that smallholder farmers in India cited weather, seed information, market prices, plant disease, and pest control as their top information requirements. Bounkham, Ahmad, and Yaseen (2022) found that the top three kinds of information needed mainly by vegetable farmers in the Lao People's Democratic Republic are on pest and disease control, markets and market prices, and weather forecasts.

3.5 Results and Discussion

3.5.1 Descriptive Statistics

All farmers in this study are lowland rice growers with varying types of irrigation, such as technical irrigation and rainfed crops. Figure 3.3 shows the distribution frequency of land size and crop productivity of rice farmers in this study. On average, farmers are smallholders with low productivity, which is a general phenomenon in Javanese rice farming (Nooteboom and Kutaneegara 2023). The productivity of most farmers in our sample is below 1 kilogram per square meter. The land size is also small—below 5,000 square meters or 0.5 ha. Because of this small land size, most farmers find it difficult to achieve economies of scale.

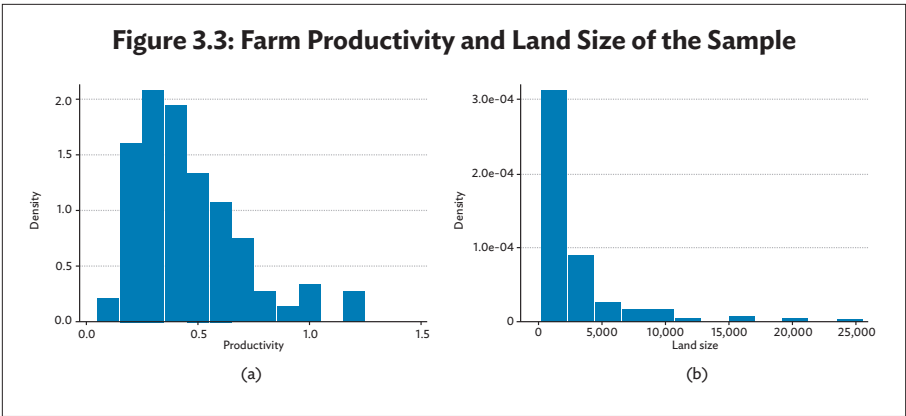
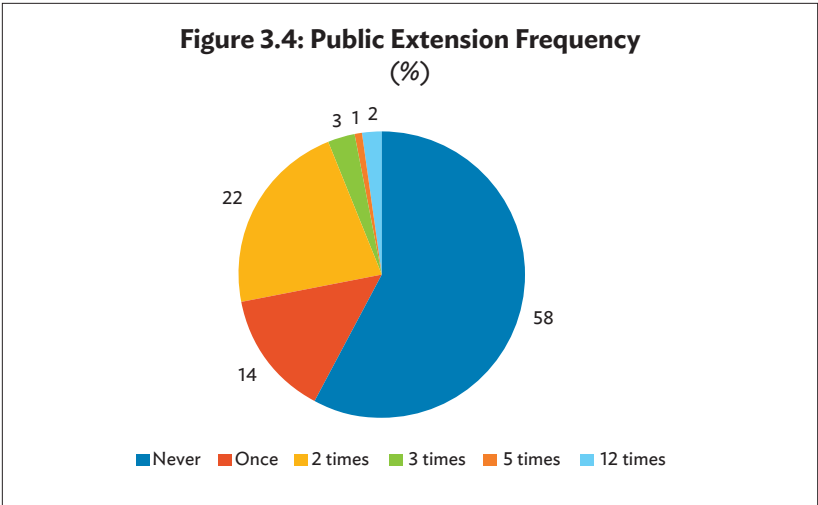


Figure 3.4 shows the extension frequency received by farmers in the last year. It can be seen that more than half of the farmers in our sample didn't receive extension visits from government officers in the last year. Only 36% of farmers receive two or fewer visits from the officers, and the remainder receive three or more visits a year. Apart from extension services, most farmers in our sample also search for and receive information on how to grow crops and manage pests from fellow farmers and input providers, either through face-to-face interaction or via social media.



Farmers who are members of farmer groups tend to have a higher probability of receiving face-to-face extension services (see Table 3.1). Although social media adopters tend to receive more extension visits, the difference from nonadopters is not significant based on our t-test results. This means that whether a farmer has received an extension visit or not, the probability or likelihood of adopting social media is the same. In other words, social media can act as a complement to public extension services provided by the government for members of farmer groups. Additionally, social media can play a role in increasing the reach of information to farmers who are not members of farmer groups.

Table 3.1: Extension Visits by Social Media Adopters and Members of Farmer Groups

Extension Visits by	Obs.	Mean	t-stat	p-value
Social media adopters	73	1.082	-0.862	0.195
Nonadopters	76	0.816		
Members of farmer group	122	1.074	-1.768	0.040
Nonmembers	27	0.370		

Figure 3.5 shows the social media platform adopted by farmers and its purposes. WhatsApp and YouTube are most widely adopted by farmers in this study (Figure 3.5a). Most farmers utilize social media to exchange information with fellow farmers regarding farming methods (Figure 5b). Moreover, they also utilize social media as a medium for promoting and selling agricultural products. Among the 73 rice farmers who have adopted social media, only 11 adopted it for less than one year (Figure 3.5c). A total of 29 farmers adopted it for one to three years, 19 farmers for three to six years, and the rest for more than six years.

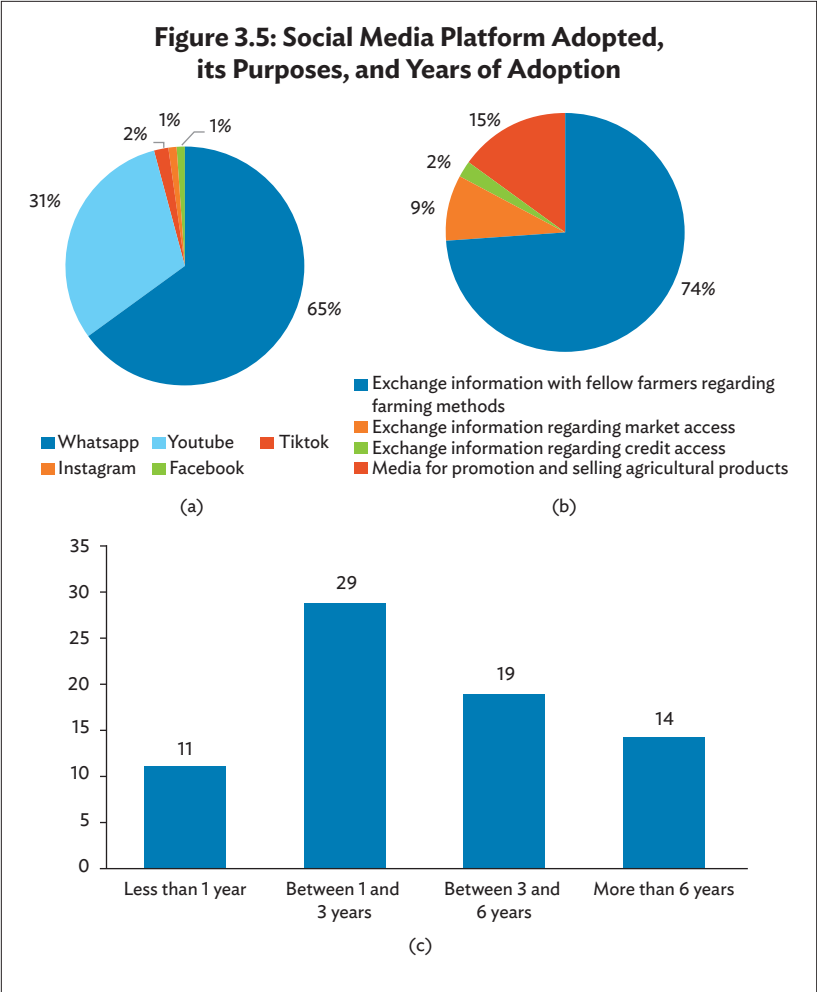


Table 3.2: Descriptive Statistics

Variables	Unit Measurement	Mean			Difference	Percentage Difference	T-stat
		Nonadopters	Adopters	Total Sample			
Outcome variable							
Productivity	Kilogram per m²	0.454	0.470	0.462	-0.016	-3.51	-0.404
Organic fertilizer application	1 = inorganic fertilizer	1.605	1.740	1.671	-0.134*	-8.38	-1.531
	2 = combination of inorganic and organic fertilizer						
	3 = organic fertilizer						
Organic fertilizer knowledge	1 = yes, 0 = no	0.434	0.712	0.570	-0.278***	-64.05	-3.548
Organic pesticide adoption	1 = inorganic pesticide	1.263	1.370	1.315	-0.107	-8.45	-1.039
	2 = do not use pesticide						
	3 = organic pesticide						
Credit access	1 = yes, 0 = no	0.105	0.205	0.154	-0.100**	-95.21	-1.698
Control variable							
Age	Years	57.855	52.630	55.295	5.225***	9.03	3.260
Education	0 = Didn't finish elementary school	1.921	2.726	2.315	-0.805***	-41.90	-4.514
	1 = Elementary school or equivalent						
	2 = Junior High School or equivalent						
	3 = Senior High School or equivalent						
	4 = Diploma						
	5 = Bachelor						
	6 = Postgraduate						
Household size	Persons	3.961	3.836	3.899	0.125	3.15	0.568
Farming experience	Years	27.276	23.068	25.215	4.208**	15.43	1.825
Gender	1 = male, 0 = female	0.803	0.863	0.832	-0.060	-7.52	-0.983
Distance to the nearest market	Log of meters	7.707	7.762	7.734	-0.055	-0.71	-0.352
Farm size	Log of m²	7.325	7.424	7.374	-0.100	-1.36	-0.612
Land ownership	1 = yes, 0 = no	0.645	0.644	0.644	0.001	0.14	0.011
Off-farm employment	1 = yes, 0 = no	0.500	0.630	0.564	-0.130*	-26.03	-1.604
Farmer group membership	1 = yes, 0 = no	0.803	0.836	0.819	-0.033	-4.11	-0.520

Notes: *significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.

Table 3.2 presents descriptive statistics, disaggregated by social media adopters and nonadopters. On average, social media adopters are younger, more educated, less experienced in rice farming, and have greater off-farm employment than nonadopters. Social media adopters are five years younger than nonadopters. With regard to education level, rice farmers in this study are mainly junior high school graduates. Social media adopters are junior to senior high school graduates, while nonadopters are elementary to junior high school graduates. Social media adopters have at least 23 years of farming experience, while nonadopters have four years more experience in farming. In terms of off-farm employment, there are 46 adopters and 27 nonadopters who have jobs other than farming, respectively. Meanwhile, the remaining 76 farmers, either social media adopters or not, worked fully in farming.

Additionally, adopters and nonadopters tend to have similar numbers of household members. The probability of male and female farmers becoming social media adopters is also similar. There is also an insignificant difference in land size and land ownership between these two groups, and the distance of their land to markets also seems similar.

Moreover, social media adopters tend to have better credit access³ and knowledge of the benefits of organic fertilizer than nonadopters. In addition, rice farmers who adopt social media tend to apply more organic fertilizer⁴ than nonadopters. It should be noted that all farmers in our sample apply fertilizer. Specifically, 54 farmers apply chemical fertilizer and only five fully apply organic fertilizer, while 90 farmers apply both of them.

While many of the differences in Table 3.2 are statistically significant, rice farmers who adopted social media and rice farmers who did not are still similar, so comparative evaluation after controlling differences seems justified.

3.5.2 Determinants and Impacts of Social Media Adoption

The results of the logit model are shown in Table 3.3. The age of farm household heads has a negative and significant effect on the probability of being a social media adopter. Meanwhile, education level exhibits a positive and significant effect. This implies that younger and better-

³ Credit access means credit from formal institutions (conventional banks, Sharia banks, etc.) and informal institutions (relatives, intermediaries, village organizations, etc.). The definition of credit has been mentioned in Indonesian Law No. 10/1998 on the amendments of Law No. 7/1992 on banking.

⁴ In this study, organic fertilizer refers to commercial organic fertilizer and farmyard manure (purchased and home-produced).

educated farmers are more likely to be social media adopters. Our finding is in line with Morris and James (2017), who found that younger and more educated sheep farmers in Wales are more likely to adopt social media. Young and more educated farmers have greater ability to learn new things, and are more accustomed to using the Internet, which helps them earn greater benefits from the social media adoption.

Based on these logit estimates, we calculated the propensity scores for matching treatment group farmers that adopted social media and control group farmers that did not. Figure 3.6 presents the distribution of propensity scores and the region of overlap and common support. From this figure it can be seen that there is a substantial overlap of the propensity scores of both groups, meaning that the assumption of common support is satisfied.

Table 3.3: Results of the Logit Model

Variables	Coefficient	Standard Error	p-Value
Age	-0.059**	0.026	0.025
Education	0.623***	0.189	0.001
Household size	-0.088	0.144	0.194
Farming experience	0.014	0.018	0.420
Gender	0.468	0.531	0.378
Distance to nearest market (log)	0.092	0.210	0.660
Farm size (log)	0.089	0.194	0.647
Land ownership	-0.379	0.416	0.362
Off-farm employment	0.426	0.408	0.296
Farmer group membership	0.061	0.478	0.899
Constant	-0.045	2.582	0.986
Observations	149		
Log-likelihood	-88.828		
Prob > chi ²	0.001		
Pseudo R ²	0.140		

Notes: *significant at the 10% level, **significant at the 5% level, ***significant at the 1% level.

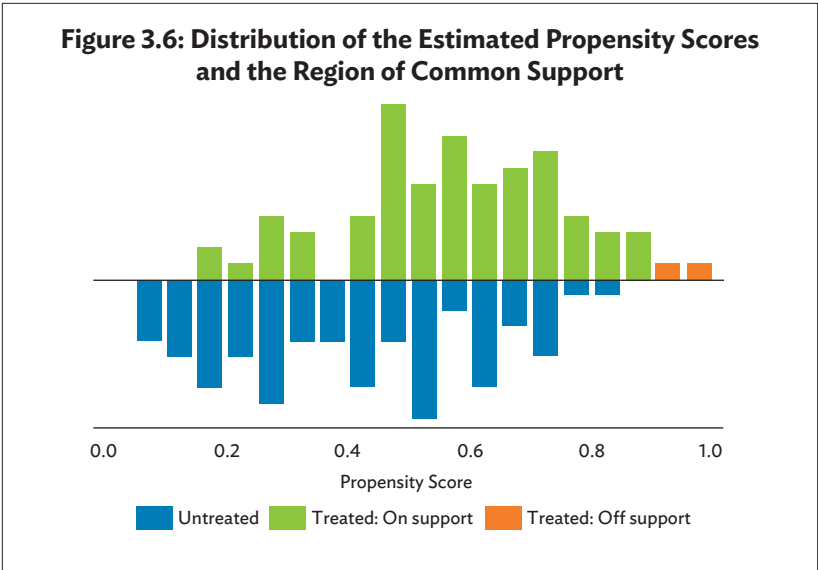


Table 3.4 presents the quality of the matching procedure. After matching, the Pseudo R^2 and LR χ^2 values dropped, and the propensity score model became statistically insignificant, meaning that the observable characteristics of social media adopters and nonadopters in the matched sample did not differ significantly. Moreover, there was a considerable reduction in mean and median biases between the unmatched and matched samples. The percentage reduction in bias is greater than 20%, a value suggested by Rosenbaum and Rubin (1985) as a sufficiently large enough reduction in standardized bias.

Table 3.4: Matching Quality

Sample	Pseudo R^2	LR χ^2	$p > \chi^2$	Mean Bias	Median Bias
Unmatched	0.141	29.17	0.001	23.4	13.1
Matched	0.040	7.36	0.691	12.1	10.3
Bias reduction (%)				48.29	21.37

After matching, the ATT for the various outcome variables can be calculated according to Equation (2). The results are shown in Table 3.5. Interestingly, the ATT of the productivity variable was not significant across the three matching methods, implying that the impact of social media adoption for farming purposes on productivity is not significant. However, we find robust evidence that social media adopters have better knowledge of the benefits of organic fertilizer and credit access than nonadopters. The treatment effect on organic fertilizer knowledge was between 0.233 and 0.273, implying that adopting social media increased the probability of having more knowledge on the benefits of organic fertilizer by around 0.233 to 0.273. Meanwhile, the treatment effect on credit access was between 0.128 and 0.182, meaning that adopting social media increased the probability of accessing credit by around 0.128 to 0.182.

In the above specification, the treatment group is rice farmers who adopt social media for farming purposes, regardless of how long they adopt it for. For sensitivity analysis, the treatment variable is social media

**Table 3.5: Average Treatment Effects on the Treated (ATT)
When the Treatment Variable Is Social Media Adoption**

Outcome Variable	Matching Method	Treated Group	Control Group	ATT	T-stat
Productivity	Nearest neighbor matching	0.468	0.451	0.017	0.40
	Radius matching	0.465	0.430	0.035	0.76
	Kernel-based matching	0.468	0.429	0.040	0.57
Organic fertilizer application	Nearest neighbor matching	1.727	1.621	0.106	1.15
	Radius matching	1.732	1.715	0.018	0.17
	Kernel-based matching	1.727	1.742	-0.015	-0.13
Organic fertilizer knowledge	Nearest neighbor matching	0.712	0.455	0.258***	3.09
	Radius matching	0.732	0.499	0.233***	2.60
	Kernel-based matching	0.712	0.439	0.273**	2.32
Organic pesticide adoption	Nearest neighbor matching	1.348	1.242	0.106	0.99
	Radius matching	1.380	1.292	0.089	0.77
	Kernel-based matching	1.348	1.288	0.061	0.49
Credit access	Nearest neighbor matching	0.227	0.091	0.136**	2.16
	Radius matching	0.211	0.084	0.128**	1.92
	Kernel-based matching	0.227	0.045	0.182**	2.35

Notes: *significant at $\alpha = 10\%$, **significant at $\alpha = 5\%$, ***significant at $\alpha = 1\%$.

Source: Authors' calculation (2023).

adopters for between one and three years. Hence, the treatment group is farmers who adopted social media for more than one year and the control group is farmers who have not adopted social media or adopted it for less than one year. With this specification, the number of farmers in the treatment group is 62 and the control group has 87. This sensitivity analysis is justified because it usually takes time for technology adoption to fully impact farmers. We run the same PSM procedure as before, and the matching quality is also good. As depicted in Table 3.2, the age of farm household heads and education level are significant determinants of social media adoption.

The results on ATT are shown in Table 3.6. The productivity variable becomes significant under Kernel-based matching. Moreover, organic pesticide adoption also becomes significant across three matching methods. However, credit access becomes insignificant. The possible reason for this is that in the early days of farmers using social media, they tried to find information about access to credit. After finding a suitable lender, they did not access credit information again in the following years because they are more focused on paying off the loan.

**Table 3.6: Average Treatment Effect on the Treated
When the Treatment Variable Is Social Media Adopters
for Between One and Three Years**

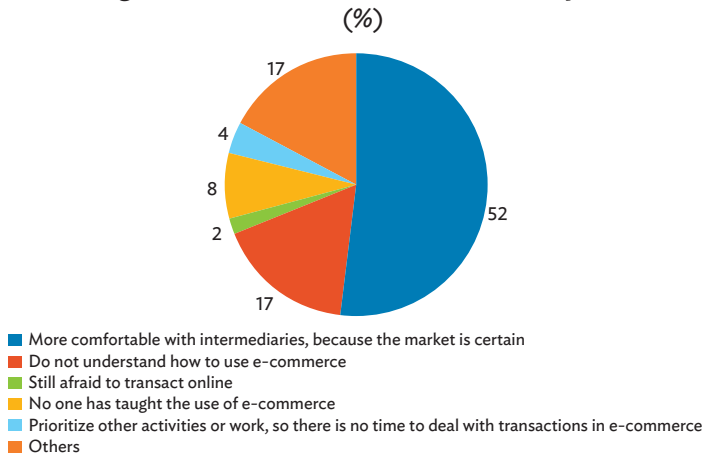
Outcome Variable	Matching Method	Treated Group	Control Group	ATT	T-stat
Productivity	Nearest neighbor matching	0.473	0.430	0.043	1.03
	Radius matching	0.473	0.435	0.038	0.88
	Kernel-based matching	0.473	0.351	0.122***	2.72
Organic fertilizer application	Nearest neighbor matching	1.726	1.645	0.081	0.84
	Radius matching	1.726	1.686	0.040	0.40
	Kernel-based matching	1.726	1.694	0.032	0.26
Organic fertilizer knowledge	Nearest neighbor matching	0.726	0.452	0.274***	3.20
	Radius matching	0.726	0.499	0.227***	2.62
	Kernel-based matching	0.726	0.597	0.129	1.10
Organic pesticide adoption	Nearest neighbor matching	1.435	1.194	0.242**	2.13
	Radius matching	1.435	1.234	0.202**	1.73
	Kernel-based matching	1.435	1.242	0.194*	1.47
Credit access	Nearest neighbor matching	0.177	0.113	0.065	1.02
	Radius matching	0.177	0.151	0.027	0.40
	Kernel-based matching	0.177	0.097	0.081	1.09

As in the previous specification (see Table 3.6), organic fertilizer knowledge is still significant, while organic fertilizer application is insignificant. This means that even though farmers who adopted social media experienced an increase in knowledge of the benefits of using organic fertilizer, this was not followed by greater use of organic fertilizer. Farmers are still reluctant to use more organic fertilizer because it requires a longer time and process for the benefits of organic fertilizer to be felt for the productivity benefits. This is also a challenge in the use of organic fertilizer in other countries (see Ma, Zheng, and Deng 2022).

Based on the ATT estimation results above, the use of social media by farmers can increase their information acquisition and knowledge regarding credit and the benefits of using organic fertilizer. Meanwhile, the impact of social media on productivity is only visible if farmers have used social media for more than one year. This is quite possible, since the information needed to increase agricultural productivity is related not only to credit and the use of organic fertilizer but also, for example, to pest management, farming business management, and the marketing of agricultural products. Apart from that, farmers also need time to understand this information and apply it in their daily lives, and ultimately have an impact on the productivity of their yields. This is also the case for organic pesticide application, in which farmers need time to understand how to use it and the benefits of using it before applying it to their fields.

3.5.3 Barriers to E-Commerce Adoption

This study finds that farmers selling rice through e-commerce is still not common. As can be seen in Figure 3.2, only three out of 149 farmers have used e-commerce to sell their rice. These farmers use the TaniHub platform to sell their rice harvests online. Farmers who have not used e-commerce stated that they still depend on selling rice through intermediaries and have a low level of ability in using e-commerce (see Figure 3.7). Even so, it is relatively common for traders to sell rice via e-commerce platforms such as Shopee (Unggara et al. 2021). Apart from that, because rice is a staple food for most Indonesian people, the product is very easy to find in traditional markets and minimarkets in rural areas.

Figure 3.7: Barriers to E-commerce Adoption

3.5.4 Aspects and Features of Farm Management Apps

This study also found that very few farmers have used farm management apps (see Figure 3.2). Of the 149 farmers surveyed, only five of them have used farm management apps. The farm management apps utilized by these farmers are Petani Cerdas, Dokter Tania, and Bertani. Many farm management app adopters and nonadopters in this study stated that they need, and would like, to use farm management apps in the future. They believed that the application of that kind of app could reduce their operating costs. This is quite reasonable, considering that the operating costs of farmers on the Java islands continue to increase (Yamauchi 2016).

Among the five aspects discussed in this study, the most important one according to farmers is that the application design is simple and easy for farmers to operate, followed by low subscription fees (Figure 3.8). Given that farmers in our sample, on average, are less educated and old (see Table 3.2), designing farm management apps that are simple is crucial. Also, because their operating costs continue to rise, it is also imperative to design apps that are affordable for them.

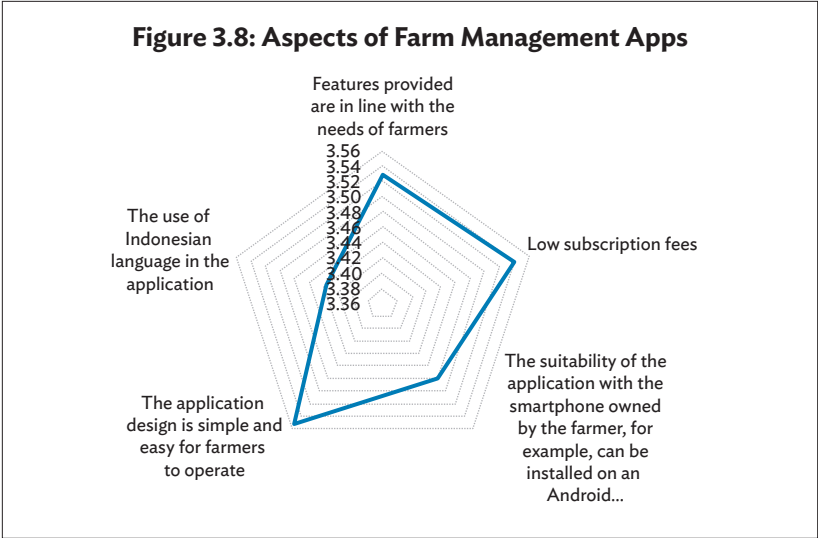
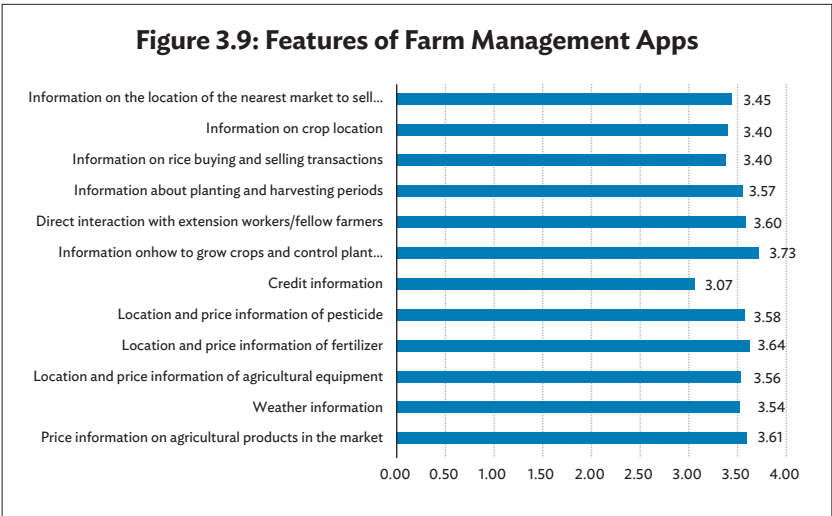


Figure 3.9 shows the average responses of farmers regarding the features of farm management apps. As can be seen, the four most important features according to farmers are: (1) information on how to grow crops and control plant diseases; (2) location of, and price information on, fertilizer; (3) price information on agricultural products in the market; and (4) direct interaction with extension workers/fellow farmers.



The importance of information on how to grow crops and control plant diseases and direct interaction with extension workers/fellow farmers is reasonable, considering that 58% of farmers in this study did not receive face-to-face extension services from the government (see Figure 3.4). Farmers believed that the presence of features like this can help them access information that they have not been able to obtain so far.

The location of, and price information on, fertilizer is also essential according to farmers, given that over the last year, it has become increasingly difficult for farmers to get subsidized fertilizer from the government. Some of these subsidized fertilizers are organic and some are chemical, but in general, they are still dominated by chemical fertilizers. Farmers stated that the distribution of subsidized fertilizer from the government was often not timely in relation to the planting season. This means that when the planting season arrives, subsidized fertilizer at kiosks appointed by the government is not yet available or, if it is, the quantity is very limited. As a result, farmers are forced to buy nonsubsidized fertilizers, which are much more expensive for meeting fertilizer needs or reducing fertilizer use with the risk of reduced harvest yields (Alta, Setiawan, and Fauzi 2021). With this information, farmers hope to be able to buy fertilizer elsewhere at more affordable prices.

Meanwhile, price information on agricultural products in the market is important for farmers because such information can influence farmers' decisions to plant and sell agricultural products. So far, they have relied heavily on intermediaries to sell their crops. Having price information can at least improve farmers' bargaining position when selling to intermediaries or to other places, including via e-commerce.

3.6 Conclusion and Policy Recommendations

This study found that social media adoption by rice farmers in Yogyakarta and Jawa Tengah provinces, Indonesia, is more prevalent than e-commerce and farm management apps. Based on our observations, social media can act as a complement to face-to-face extension services provided by the government to members of farmer groups. Moreover, social media can play a role in increasing the reach of information to farmers who are not members of farmer groups. The result of our PSM estimation indicates that younger and more educated farmers tend to be social media adopters. Further, social media adoption by rice farmers can increase farmers' knowledge of the benefits of organic fertilizer. However, it does not encourage these farmers to apply organic fertilizer to their crops. Social media adoption can also increase farm productivity and organic pesticide adoption, but only after at least one

year of adoption. In addition, social media utilization by farmers can also increase credit access during the first year of adoption. Therefore, increasing the adoption of social media by farmers must continue to be carried out given the many benefits that can be created.

With regard to the low adoption of e-commerce, this is because, in addition to their low ability to use e-commerce, most farmers are more comfortable selling to intermediaries since the market is more certain. Furthermore, even though currently there are only a few farmers in this study who use farm management apps, they admit that they need farm management apps in the future, especially to reduce operating costs. Therefore, in developing similar apps in the future in Indonesia, the aspects and features according to this study should be considered. The most important aspects according to farmers are easy-to-operate and low subscription fees. Meanwhile, the four most important features according to farmers are: (1) information on how to grow crops and control plant diseases; (2) location of, and price information on, fertilizer; (3) price information on agricultural products in the market; and (4) direct interaction with extension workers/fellow farmers.

Based on the findings of this study, the authors make the following policy recommendations. First, the government should encourage younger and more educated farmers as pioneers of digital farmers in their village, so they can act as a digital extension; this is because the effects of peers in farmer decision-making is strong and farmer-to-farmer extension is more effective in Indonesia. However, encouraging young farmers is not an easy task. It is also a major challenge in other parts of developing Asia and the Pacific. Existing farmers are getting older and not many of their next generation will continue farming. In our sample, for example, only 6% of farmers have a son or daughter who becomes a farmer. Young people find agriculture unattractive mainly due to the time and input investment as the traditional staples are slow to mature, risky, and often yield low returns (Irungu, Mbugua, and Muia 2015). Second, education on how to use e-commerce and the benefits of using this ICT should be enhanced. Third, although this study finds the important aspects and features of management apps based on observations in Yogyakarta and Jawa Tengah provinces in Indonesia, it may not be suitable to apply those aspects and features in other regions, or in other parts of Asia and the Pacific, because they are very context-specific. Therefore, further research should be conducted not only in Indonesia but also elsewhere in the region.

However, this study has several shortcomings. First, this research uses a small sample size, so it may not be able to represent the general situation of rice farmers in Indonesia. This may be due to the different agroecological conditions or different farming socioeconomic

characteristics in other rice-producing regions. However, because this study used a stratified random sampling technique, the sample is representative of both adopters and nonadopters (Fischer and Qaim 2012). Further studies that incorporate larger samples are highly recommended, as well as studies with longitudinal data. Second, the PSM method cannot control unobservable bias. However, we test the robustness of the impact results by using different matching algorithms.

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