Research Article

Intensity, Purposes and Drivers of Digital Technologies Adoption: Lessons from Shallot Farmers at Various Agroecological Zones in Yogyakarta Province, Indonesia

Alif Haidir Adana[1,2], Irham[3]*, Lestari Rahayu Waluyati[3] and Arini Wahyu Utami[3]

[1]Doctorate Program of Agricultural Science, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta; [2]Agribusiness study program, Agriculture Faculty, Universitas Muhammadiyah Jakarta, Banten, Indonesia; [3]Department of Agricultural Socio-Economic, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Abstract | This study examines how shallot farmers in different agroecological zones in Yogyakarta Province perceive digital technologies and what drives their adoption. Yogyakarta, Indonesia's most digitally literate province, was selected for the study. 316 shallot farmers were randomly selected from lowland, highland, and coastal agroecological zones. Data analysis included descriptive statistics and binary logistic regression. Researchers found that farmers in different agroecological zones use smartphones and mobile apps (search engines and social media) more to get pricing information and learn better growing practices. Younger farmers with more education and training are better able to embrace digital technology than older farmers with less education and training. These findings suggest that demographic socio-economically relevant digital technology training courses might motivate farmers to employ digital technologies in their agricultural activities from production to selling.

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***Correspondence** | Irham, Department of Agricultural Socio-Economic, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia; **Email:** irham@ugm.ac.id
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Introduction

Indonesia, like other developing nations, relies on agriculture for economic development (Byerlee *et al*., 2009; Kante *et al*., 2017; Prasetyo *et al*., 2024). Agriculture confronts several problems in the industrial revolution 4.0, but inadequate technology adoption and innovation are the largest (Kolawole *et al*., 2017). Digital technology is heavily used in agriculture. Digital technology in farming uses internet, mobile phones, sensors, automation, and robots to collect and analyse data for efficient production and marketing (Bolfe *et al*., 2020; Hoang and Tran, 2023).

Farmers face many challenges, including limited credit, difficult farming decisions due to unpredictable weather, limited market information, and transportation of products from agricultural locations to markets. Digital technology can help farmers increase crop yields, reduce costs, access new markets, increase profits, and improve agricultural sustainability and food security (Mariyono *et al*., 2022; Miine *et al*., 2023; Pascucci *et al*., 2023).

The Indonesian government is currently placing digitalization one of the important pillars to improve economic welfare and strengthen national resilience. By accelerating digitalization in various sectors, including agriculture, to expand access to digital technology for the community, it is expected to create an inclusive and competitive ecosystem at the national and global levels. However, just 8.88% of Indonesian farmers utilise the internet. Data in BPS (2023) reports 82.41% of farmers are not online. Digital transformation in agriculture is a difficult "homework" for the government. This is crucial to understanding farmers views on using digital technologies to manage their farms.

Since shallots are one of the government's strategic commodities, they were chosen to study farmers digital technology perceptions and adoption factors (Prasetyo *et al*., 2024). Shallots may be grown in many places and have several uses, including medicine, food, and flavouring (Amiri *et al*., 2021). Research sites were chosen from lowland, highland, and coastal agroecological zones to make this study more comprehensive. Agroecological zones directly affect environmental factors like soil, climate, infrastructure development, population, vegetation, temperature, and humidity, which can affect production performance and efficiency (Asante *et al*., 2019; Shah *et al*., 2021). Socially, agroecological zones alter farm families' susceptibility and adaptation capability due to differences in family characteristics, infrastructure access, livelihood diversification, and technology availability (Dendir and Simane, 2019).

Many reseachers have studied the use of digital technology in agriculture, particularly among farmers (Li *et al*., 2022) in Ghana, (Ahikiriza *et al*., 2022) in Uganda, (Abdullahi *et al*., 2021) in Somalia, (Ibrahim *et al*., 2018) in Malaysia, (Khan *et al*., 2022) in Pakistan, (Caffaro *et al*., 2020) in Italy, (Yoon *et al*., 2020) in Korea, and (Chunfang *et al*., 2024; Wang *et al*., 2024) in China. However, none of these studies have been linked or based on agroecological zones. To address this vacuum, this research examined farmers views of digital technology and the variables that drive its adoption in Yogyakarta's agroecological zones.

Materials and Methods

The highest digital literacy index in Indonesia is in Yogyakarta, where this study was performed. However, Yogyakarta is categorized as the poorest region in Java with a gini ratio of 0.459 or the highest in Indonesia. The study focused on three sub-districts, namely: Sentolo (lowland area with slope < 8%), Imogiri (highland area with slope > 40.1%) and Sanden (coastal area with slope < 8% and sandy soil condition with only 50-100 meters from the beach). These locations are the largest shallot production areas in Yogyakarta. These sub-districts reflect distinct agroecological zones in the province and have the capacity to represent agricultural methods, land conditions, socioeconomics, and culture. Agroecological zones may provide different information on Indonesian smallholder farmers digital technology adoption.

A cross-sectional survey was used to study smallholder farmers' digital technology use. Smallholder farmers sample requirements include: (1) farmers who have harvested shallots (at least once), and (2) living and owning agriculture land in the research location area/village. The initial plan for the sample size of this study was 330 farmers, however challenging conditions during the survey process and concerns about the reliability of the data collected resulted in only 316 valid questionnaires. The details of the samples used in this study were: 108 lowland farmers, 104 highland farmers and 104 coastal farmers. Informed consent was obtained from each participant prior to the survey, in compliance with ethical research standards.

A questionnaire with questions on (a) farmer demographics and socioeconomic characteristics, (b) digital agricultural technology types and intensity, and (c) the purpose of using digital technology in farming was created and given to respondents. For field questionnaire management, four skilled enumerators were employed. In-depth interviews from September 2024 to January 2025 collected data.

This study employed descriptive and inferential statistics. Binary logistic regression analysis (Hoang and Tran, 2023) was used to estimate the influence of independent variables (demographic, socioeconomic, and institutional characteristics of smallholder farmers) on the dependent variable (digital technology adoption). Following the postulation, the binary logistic regression model is created.

$$Ln\left[\frac{Pi}{1-Pi}\right] = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots\ldots \beta nXn$$

Pi is the likelihood of farmers adopting digital technologies. The chance of farmers not using digital technology is 1–*Pi*. The intercept is β0. The slope of the equation in the model is *β1, β2,…βn*. Table 1 shows this study's variable definitions and unit measurements. SPSS was used to assemble and analyse data in each agroecological zone. The study's hypothesis was H0: βi = 0 and H1: βi ≠ 0. Hypothesis testing used 0.1, 0.05, and 0.01 significance levels.

Results and Discussion

Demographic and socio-economic characteristics of farmers

Firstly, the demographic and socioeconomic characteristics of the selected farmers are described (see Table 2). With regard to the adoption of digital technology, farmers in the coastal area demonstrate a higher percentage than those in the high and lowlands. This is attributable to the fact that farmers in coastal areas manage marginal land, a practice that necessitates innovations in farm management, which can be obtained through digital technology platforms. The average farmer in the research location is approximately 50 years old and has cultivated shallots for more than 15 years. The majority of farmers have received education below to the level of senior high school, and farmers' access to credit, training and organization is relatively the same for farmers in lowland, highland and coastal areas. These characteristics illustrate the human capital of farmers who have the potential to influence the decisions made in running their farming business (agribusiness management) (Prasetyo *et al*., 2024).

Table 1: *Definition and unit measurement of selected variables.*

Variables	Explanation	Category	Measurement
Dependent variables			
DTA	Use of at least one type digital technology	Dummy	1 = User, 0 = Non User
Independent variables			
Age	Age of farmers	Continuous	Years
EDU	Level of education of farmers	Continuous	Years
Gender	Gender of farmers	Dummy	1 = male; 0 = female
Farm exp	Farming experience	Continuous	Years
Farm size	Farm size	Continuous	Meters
Credit	Access to credit programs	Likert scale	1 = Very difficult; 5: Very accessible
Training	Access to training programs	Likert scale	1 = Very difficult; 5: Very accessible
CBO	Access to community-based organization	Likert scale	1 = Very difficult; 5: Very accessible

Table 2: *Demographic and socio-economic characteristics of farmers.*

Farmers characteristics		Value		
		Lowland farmers	**Highland farmers**	**Coastal farmers**
Digital agricultural technology adoption	User	49 (45.4)	51 (49.1)	56 (53.8)
	Non-user	59 (54.6)	53 (50.9)	48 (46.2)
Age	Average years	52.88	50.73	51.83
Education level	Average years	8.31	8.61	9.51
Gender	Male	81	61	90
	Female	27	47	14
Farming experiences	Average years	20.56	20.22	18.92
Farm size (meters)	Average farm size	2074.07	1708.65	1172.93
Access to credit programs	Mean	4.06	4.21	4.16
Access to training programs	Mean	2.81	3.76	2.84
Access to community-based organization	Mean	3.58	4.63	4.36

Table 3: *Types and intensity of digital technologies used by farmers.*

Name of digital technologies	The extent of use of digital technologies (%)								
	Lowland farmers			Highland farmers			Coastal farmers		
	Never	Some times	Daily use	Never	Some times	Daily use	Never	Some times	Daily use
Hardware									
Handphone	72.22	0.00	27.78	63.46	0.00	36.54	49.04	0.96	50.00
Smartphone	54.63	1.85	43.52	50.96	0.00	49.04	25.96	0.96	73.08
Personal computer	95.37	3.70	0.93	99.04	0.96	0.00	93.27	1.92	4.81
Laptop	95.37	3.70	0.93	92.38	4.76	2.86	91.35	1.92	6.73
Mobile applications									
Search engine	56.48	8.33	35.19	53.85	1.92	44.23	39.42	5.77	54.81
Social media	54.63	6.48	38.89	51.92	0.00	48.08	29.81	2.88	67.31
Weather forecast	87.04	0.00	12.96	85.58	0.00	14.42	86.54	2.88	10.58
Smart farming									
Artificial intelegence	100.00	0.00	0.00	100.00	0.00	0.00	98.08	0.00	1.92
Internet of things	100.00	0.00	0.00	100.00	0.00	0.00	99.04	0.00	0.96

Table 4: *The purpose of using digital technologies by farmers.*

Purposes in adopting digital technologies	Lowland farmers		Highland farmers		Coastal farmers	
	N	Percent	N	Percent	N	Percent
Accessing weather/climate information	15	13.89	27	25.96	27	25.96
Purchasing production inputs	23	21.30	31	29.81	39	37.50
Accessing agricultural extension services	7	6.48	20	19.23	30	28.85
Searching price information	43	39.81	51	49.04	50	48.08
Learning better cultivation techniques	47	43.52	48	46.15	51	49.04

Types and intensity of digital technologies used by farmers

As shown in Table 3, the proportion of respondents who use digital technology is divided into three categories: Hardware, mobile applications, and advanced technology (smart farming). The predominance of smartphones, which have become the preferred choice for many individuals across various geographical locations, is unsurprising. In contrast, personal computers and laptops are utilized less frequently due to their complexity and limited flexibility (Jolex and Tufa, 2022). The high intensity of smartphone usage is positively correlated with the use of software such as search engines and social media, which are inseparable components. In contrast, complex and sophisticated digital technologies such as AI and IoT is almost never used by farmers (Bolfe *et al*., 2020).

The purpose of using digital technologies by farmers

A survey was conducted to ascertain the importance of digital technologies to farmers. The results, presented in Table 4, indicate that the majority of farmers use digital technologies to access price information prior to harvest. This practice enables them to anticipate price fluctuations and asymmetric information between sellers and potential buyers. This approach is undertaken to prevent both farmers and buyers from experiencing disadvantage in pricing determination. Consequently, monitoring price movements in the wholesale market is of paramount importance for farmers. Additionally, farmers use digital technologies to search for information and learn better cultivation techniques through videos or articles. Pest attacks represent a significant challenge confronting farmers across all three locations. To address this issue, farmers utilize digital technologies to acquire knowledge on effective pest management strategies, including the identification of suitable pesticide doses and mixtures.

Driving factors affecting farmers use of digital technologies

Table 5 presents the results of the binary logistic regression model analysis for farmers adoption of digital technologies in three different agroecological zones: Lowland, upland, and coastal area. The chi-square statistics are highly significant, indicating a significant relationship between the independent

Table 5: *Estimation of regression model for farmers' adoption of digital technologies.*

Variables	Lowland farmers			Highland farmers			Coastal farmers		
	B	Sig.	Exp. (B)	B	Sig.	Exp. (B)	B	Sig.	Exp. (B)
Constant	4.861	0.104	129.099	2.03	0.691	7.613	1.717	0.58	5.568
Age	-0.159***	0.000	0.853	-0.189***	0.001	0.827	-0.124***	0.000	0.883
Edu	0.265***	0.003	1.304	0.608***	0.000	1.836	0.268**	0.017	1.308
Gender	0.303	0.697	1.354	3.032***	0.001	20.732	1.866**	0.032	6.464
Farm exp	-0.039	0.194	0.962	0.046	0.201	1.047	-0.019	0.487	0.982
Farm size	0.000	0.306	1.000	0.000*	0.062	1.000	0.000	0.211	1.000
Credit	-0.797*	0.064	0.451	-0.142	0.829	0.868	-0.059	0.89	0.943
Training	1.031**	0.020	2.804	-0.231	0.627	0.794	0.76**	0.015	2.138
Cbo	0.343	0.337	1.409	0.332	0.701	1.380	-0.082	0.896	0.921
Chi-square test	80.190***			79.807***			53.222***		
Nagelkerke R2	0.701			0.714			0.535		
-2 Likelihood test	68.603			64.329			90.336		

variables and farmers adoption of digital technologies. The estimated model's robustness is substantiated by the Nagelkerke R^2 value, which exceeds 0.50. This suggests that a minimum of 50% of the observed variation in digital technology adoption can be attributed to the factors incorporated within the logistic regression model.

Factors affecting lowland farmers use of digital technology include age, education level ($p \leq 0.01$), access to training ($p \leq 0.05$), and availability to financing ($p \leq 0.1$). These factors influence lowland farmers' digital technology adoption. The use of digital technology by highland farmers is strongly influenced by four factors: Age, education level, gender ($p \leq 0.01$), and farm size ($p \leq 0.1$). These factors affect highland farmers' digital technology adoption. The use of digital technology by coastal farmers is highly influenced by four factors: age ($p \leq 0.01$), education level, gender, and availability to training ($p \leq 0.05$). Coastal farmers' digital technology use depends on several factors.

Farmers in developing and developed nations have been studied on digital agricultural technology (see Hoang and Tran, 2023; Jolex and Tufa, 2022; Kernecker *et al*., 2020; Mansour, 2023). These studies seldom address or relate agroecological zones. A statistically significant negative link exists between farmers' age and digital technology usage across all agroecological zones. This shows that younger smallholder farmers are better able to use digital technologies in farming. This is because younger farmers in the study area are more used to using digital technologies than older ones. Age has been shown to affect farmers technology adoption (Ahikiriza *et al*., 2022). Hoang and Tran (2023) revealed that younger, more educated smallholder farmers embrace digital tools more often. Thus, smallholder age should be addressed in any extension program or development plan to encourage farmers to use digital technology.

Digital technology usage is positively and significantly correlated with farmers' education level throughout agroecological zones, showing that farmers with higher education are more likely to acquire agricultural information online. This research supports Ma and Wang (2020) claim that improved education improves farmers internet usage. This is likely because certain internet information is presented in written form, which requires reading and comprehension skills. The study also found that gender has a positive and significant relationship with farmers digital technology adoption in the highlands and coastal areas, but is not significant for farmers in the lowlands. This suggests that male farmers are more likely to adopt digital technology in their farming activities, which is in line with the findings of Tong *et al*. (2024) although in that study, gender did not have a significant effect.

Farm size has been identified as a variable that exhibits a positive and significant relationship with the adoption of digital technology, specifically among farmers in the highlands. The larger the land managed by farmers, the greater the opportunity to adopt digital technology. This relationship suggests that farmers with larger land areas tend to be more profit-oriented, leading them to continually seek methods to enhance the effectiveness and efficiency of their farming activities. The adoption of digital technology is a notable strategy employed in this pursuit. In a similar vein, Hoang and Tran (2023) found that smallholder farmers with larger farms were more likely to adopt mobile applications compared to those with smaller farms. This suggests that smallholders with smaller farms may face challenges in realizing a prompt economic return on their investments due to the limited scale of their operations.

Recent findings have indicated a negative and significant relationship between digital technology adoption and access to credit programs among farmers in lowland regions. In contrast, this relationship is not significant among farmers in highland and coastal areas. Farmers with stronger finance access are less likely to utilise digital technologies. These results contradict Abebe and Cherinet (2019), who found a favourable correlation between loan availability and farmers' marketing use of ICT. Farmers in the lowlands, who cultivate shallots once a year, are risk-averse and avoid speculation. Consequently, if they get credit for their farming business, they will tend to do activities that they are used to doing according to their experience to minimize the potential for failure in their farming business which results in non-performing loans.

Access to training positively and significantly affects digital technology adoption among lowland and coastal farmers but not highland farmers. Farmers that get formal and non-formal training are more inclined to utilise digital technology. This research supports Abebe and Cherinet (2019) who showed that trained farmers utilise digital technologies better than untrained farmers. Finally, in this study, only two variables, namely farming experience and access to community-based organizations, were not significant for farmers digital adoption across agroecological zones.

Conclusions and Recommendations

This study shows that younger farmers with higher education levels and access to training are in a better position to adopt digital technologies, compared to older farmers with lower education levels and limited access to training. Smartphones and Mobile applications (search engines and social media) are the most preferred and frequently used digital platforms by farmers across agroecological zones with the main purpose of searching price information and learning better cultivation techniques. It is highly recommended for the government to accelerate the digitalization of the agricultural sector to create a farmer succession/regeneration policy and provide various formal and non-formal training on the use or integration of digital technology in farming activities by collaborating with various parties who have experience in integrating digital technology and farming activities such as TaniHub, MSMB, JALA and Habibi Garden. Collaboration with these organizations will be meaningfull because they already have a lot of experience and understand the methods in digital transformation of the agricultural sector. Further research is recommended to investigate the barriers faced by farmers in adopting digital technology and link farmers' use of digital technology to the profitability of their farms.

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Novelty Statement

This articles originality is the absence of examination of farmers opinions and variables that drive digital technology adoption in underdeveloped nations by agroecological zone.

Author's Contribution

Alif Haidir Adana: Conceptualization of ideas, data collection, formal analysis, writing, review, and editing preparation

Irham, Lestari Rahayu Waluyati, Arini Wahyu Utami: Conceptualization of ideas, advisers, supervisors of data collection and analysis as well as reviewed the manuscript

Conflict of interest

The authors have declared no conflict of interest.

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