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DOES INTERNET USE FOR AGRICULTURAL PURPOSES IMPACT SUSTAINABLE AGRICULTURE ADOPTION? EVIDENCE FROM INDONESIAN FARMERS

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Abstract: This study analyses the impact of Internet use for agricultural purposes on the adoption of Sustainable Agricultural Practices (SAP). Cross-sectional data were collected from 257 farmers in Indonesia and analysed using Propensity Score Matching (PSM). The results indicate seven sustainable agricultural practices implemented by farmers in Indonesia, namely the use of (1) organic fertilisers, (2) bio-pesticides, (3) bio-herbicides, (4) field border plants, (5) crop rotation, (6) artificial irrigation, and (7) irrigation canal filters. The results also show that farmers' decisions to use the Internet are significantly influenced by the number of family members, education, and farming experience. Meanwhile, the PSM results reveal that the Internet can improve agricultural practices. The findings suggest the need to increase farmers' digital literacy and skills for agricultural purposes and optimise the Internet to disseminate information about sustainable practices.

Keywords: Internet, propensity score matching, sustainable agricultural practices, Indonesia.

Introduction

In the past decades, research has shown that agricultural intensification can have negative impacts, such as environmental pollution, public health issues and biodiversity degradation. If left unaddressed, these negative impacts can threaten agricultural productivity and environmental sustainability, jeopardising agricultural production and national food security in the long term (Alavaisha *et al.,* 2019; Midingoyi *et al*., 2019). Therefore, farmers need to adopt Sustainable Agricultural Practices (SAP) to minimise agricultural pollution and increase productivity in the long term (Ma & Wang, 2020). Food and Agriculture Organisation (FAO) defines SAP as non-pollutant agricultural activities that conserve resources and provide socioeconomic benefits. Based on this understanding, the SAP activities implemented globally include (1) land conservation, (2) multiple cropping, (3) the use of superior varieties, cropping patterns, and organic fertilisers, (4) minimal use of pesticides, and (5) more use of biochemicals (Zeweld *et al*., 2017; Adolwa *et al.,* 2019; Midingoyi *et al*., 2019).

Studies in various countries have highlighted the importance of SAP in the sector as it can boost farmers' socioeconomics and maintain environmental sustainability (Abdulai & Huffman, 2014; Manda *et al*., 2016; Zeweld *et al*., 2017; Makate *et al*., 2017a; Ma & Wang, 2020). For example, in Ghana, farmers applying SAP benefitted economically from the increased production and net return (Abdulai & Huffman, 2014). Their yield and income were higher than those who did not adopt SAP. Likewise, in Zambia, farmers improved their yields and income by applying SAP (Manda *et al*., 2016), and so did farmers in South Africa (Makate *et al*., 2017b), Ethiopia (Zeweld *et al*., 2017), and China (Ma & Wang, 2020).

Previous research has also examined the determinants of farmers' decisions to apply SAP to improve the adoption rates (Kassie *et al*., 2013). Research has also shown that the adoption rates in developing countries are low (Adolwa *et al.,* 2019), especially in Indonesia. One possible explanation is that previous research has only focused on farmers' characteristics and institutional factors. Considering this, the findings might not have captured the condition holistically. Therefore, the practical implications derived from previous research may be ineffective. For example, information related to SAP may not be evenly distributed to farmers, especially smallholder farmers with limited access to agricultural information sources, such as the Internet. In this digital era, information is accessible more quickly (Ma & Wang, 2020), including information related to SAP. Therefore, we assume that farmers' access to the Internet can increase the adoption rate of SAP in the agricultural sector.

To date, research on the impact of Internet access on SAP adoption rates among farmers remains scarce, especially in Indonesia. This study aims to fill this gap by examining the impact of Internet access on farmers' SAP adoption rates and contribute two-fold to the current literature. First, we provide novel empirical evidence from an agricultural country m Indonesia, which uses a lot of chemicals for farming. To the best of our knowledge, this will be the first evidence of how Internet access impacts SAP. Second, we look at the role of Internet access influence on farmers' decisions as to which sustainable practices to apply when farming.

Research Methodology

Research Data

The data for this research was collected from July to August 2022 in East Java, Indonesia, using a multi-stage sampling method to determine the locations. First, three districts were selected based on (1) the information about SAP applications (such as organic farming) obtained from the provincial agriculture office and (2) information about locations with the highest and lowest Internet access in East Java obtained from the ICT Management Agency. Using this information, three locations were selected: Malang, Pasuruan, and Banyuwangi. Second, one sub-district from each location was selected based on the information from the municipal agricultural office, resulting in three sub-districts. Third, two villages were selected from each sub-district, resulting in six villages being chosen as research sites. Finally, 50 farmers were randomly selected from each village, resulting in 300 respondents. Respondents with invalid information were excluded from the study, so the final number of respondents was 257.

The questionnaire was formulated based on (1) an extensive literature review by considering the research topic, problems, and objectives, and (2) interviews with key informants in the field, such as agricultural extension officers and agriculture agency workers. The interviews with key stakeholders were used to complement the literature review results so that the questionnaire's robustness is assured.

Data Analysis

a. Probit Regression Model

The Probit regression model was used to analyse the factors that affect farmers' access to the Internet, with the models and variables formulated as follows:

$$I_i^* = X_i\alpha + u_i;\ ICT_i^* = 1 \text{ if } ICT_i^* > 0 \text{ and } 0 \text{ otherwise} \qquad (1)$$

where *i* is the dependent variable measured by the dummy variable (1 if the farmer has access to the Internet and 0 otherwise); *X* is farmers' socio-demographics hypothesised to affect farmers' access to the Internet, including education, experience, age, number of family members, asset ownership, land status, and institutional involvement (Toiba, Nugroho, Retnoningsih, & Rahman, 2020; Syafrial, Rahman, & Retnoningsih, 2021; Rahman, Huang, Toiba, & Efani, 2022) is the coefficient of *X*; and is the error term.

b. Propensity Score Matching (PSM)

The PSM analysis was used to measure Internet access's impact on farmers' SAP adoption rate. PSM compares two treatment groups (Wijayanto, Lo, Toiba, & Rahman, 2022). In this study, the two groups are farmers who adopted SAP and those who did not. However, in the PSM analysis, comparisons can only be made between farmers with similar characteristics, which can be indicated by similar propensity scores. In other words, respondents with different characteristics had to be excluded from the analysis to make the comparison results accurate. The intensity of SAP adoption among respondents with and without Internet access was compared, but only those with the same characteristics. Econometrically, the PSM comparison technique can be written as follows:

$$PSMATT = E\{Y_{1i} - Y_{1i}A_i = 1\} = E[E\{Y_{1i} - Y_{1i}A_i = 1, p(X_i)\}] = E[E\{Y_{1i}A_i = 1, p(X_i)\} - E\{Y_{0i}A_i = 0, p(X_i)\}A_i = 1] \quad (2)$$

Finally, this study uses STATA version 16 to clean the data and execute the estimation strategy.

Results and Discussion

Descriptive Statistics

This section presents descriptive statistics and operational definitions of the variables used in this study. Table 1 shows that 69.6% of the farmers used the Internet in their agricultural activities. For example, they searched for information related to agricultural production, purchased agricultural inputs, sold crops, and found climate-related information on the Internet. The average score of agricultural practices was 2.074, which means the respondents had implemented two SAP components. Figure 1 shows the complete sustainable agriculture practices between adopters and non-adopters. Farmers in East Java implement seven sustainable practices, namely: The use of (1) organic fertilisers, (2) bio-pesticides, (3) bio-herbicides, (4) field border plants, (5) crop rotation, (6) artificial irrigation, and (7) canal filter irrigation. The most practiced is artificial irrigation, such as wells, at 86%, followed by field border plants at 79% and 69% practiced filters in their irrigation. The least practised at 43.2% was the use of organic fertiliser, (Table 1).

Regarding the socio-demographics, the average number of household members was three, and the average age was 54.43 years. The average education level was seven years (primary school graduates), which is relatively low. The average farming experience was 26,864 years. The average distance between the farmers' residences and agricultural lands was 4.56 km. The average land area was 7,606.341 m^2. Regarding land ownership, 84.4% of the respondents owned farmland. For social activities, 73.9% of the farmers in this study participated in cultural and religious activities. Only 2.7% of farmers joined agricultural organisations. As for income, the average was IDR2,711,576 per month.

Table 2 compares the characteristics between Internet users and non-users using a Mann-Whitney U Test. The results show that Internet users were younger and had more family members and higher education levels. However, they were significantly less experienced than farmers who did not use the Internet.

Factors Influencing Farmers' Decisions to Use the Internet

Probit regression analysis was used to study the factors influencing farmers' decisions to use the Internet. At this stage, the propensity score of each respondent was measured and used to examine the average treatment effect on the treated (ATT) in the PSM analysis. The results obtained from the probit regression are shown in Table 3, which indicate that farmers' decision to use the Internet is significantly influenced by family size, education level and farming experience.

Family size has a positive and significant influence on farmers' decisions to use the Internet, with a significance level of 1%. This shows that the more family members, the more

Table 1: Descriptive statistics

Variable	Definition	Percentages	Mean	Std. Dev
Internet Use	Dummy 1 if the farmer uses the Internet, 0 otherwise	69.650%		
SAP	The number of sustainable practices applied		2.074	1.716
Family Size	The total number of family members		3.179	1.185
Age	Age (years)		54.432	11.296
Education	Education (years)		7.965	3.424
Experience	Experience (years)		26.864	14.501
Land Distance	Distance to agricultural land (km)		4.560	3.841
Total Area	Total agricultural area (m^2)		7606.341	12334.490
Land status	Dummy 1 for owned land, 0 otherwise	84.436%		
Social Activity	Dummy 1 for participating in social activities, 0 otherwise	73.930%		
Organisation	Dummy 1 for participating in the agricultural organisation, 0 otherwise		0.027	0.163
Income	Total income (Indonesian Rupiah/ IDR)		2711576	5772306

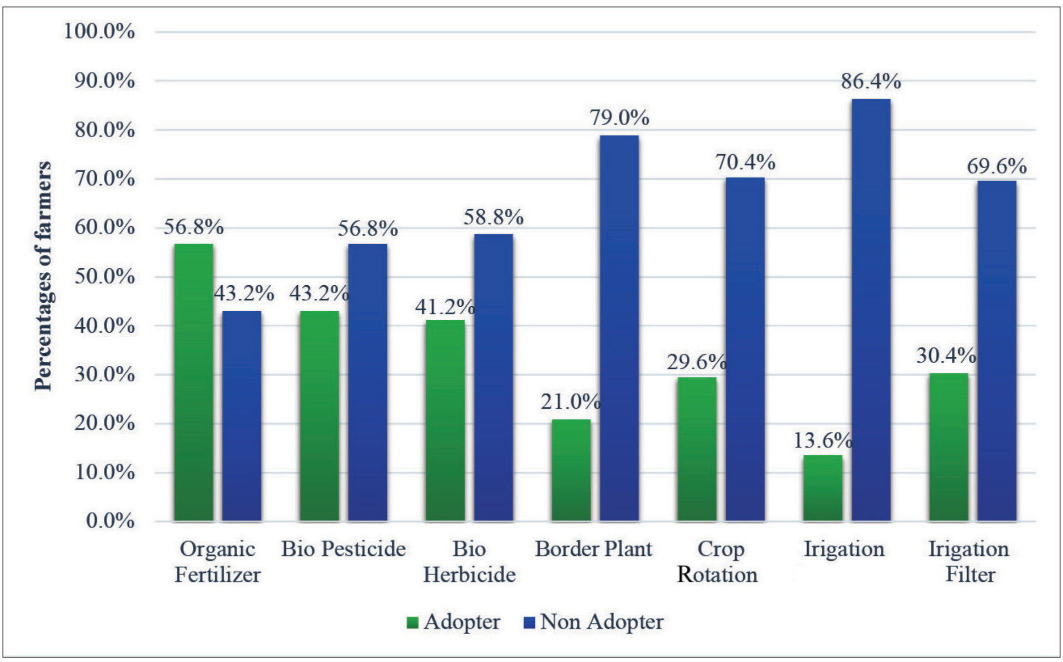

Figure 1: Sustainable agricultural practices

Table 2: Mean t-test between Internet users and non-users: A Mann-Whitney U Test

Variables	Rank Sum		z	Probability
	User	Non-User		
Family size	26367.0	6786.0	6.177	0.000***
Age	19917.5	13235.5	5.796	0.000***
Education	25921.0	7232.0	5.519	0.000***
Experience	19675.0	13478.0	6.250	0.000***
Land distance	22043.5	11109.5	1.971	0.049**
Total area	24174.5	8978.5	1.979	0.048**
Land status	22816.0	10337.0	0.799	0.424
Social activity	23176.5	9976.5	0.205	0.837
Organisation	23235.5	9917.5	0.935	0.350
Income	24876.5	8276.5	3.265	0.001

Note: ** sig at 5% level; *** sig at 1% level

Table 3: Determinants of Internet use among farmers

Internet	Coef.	Std.	z	*p*-value
Family size	0.332	0.091	3.640	0.000***
Age	0.003	0.012	0.280	0.782
Education	0.108	0.034	3.170	0.002***
Experience	-0.028	0.009	-2.930	0.003***
Land distance	-0.041	0.026	-1.570	0.117
Total area	0.000	0.000	1.090	0.276
Land status	-0.243	0.286	-0.850	0.396
Social activity	0.075	0.220	0.340	0.733
Organisation	0.393	0.699	0.560	0.574
Income	0.000	0.000	-0.310	0.753
_cons	-0.414	0.800	-0.520	0.604
Log-likelihood	-119.85021			
LR chi2	75.79			
Prob > Chi2	0.000			
Pseudo R2	0.2402			
Obs	275			

Note: *** sig at 1% level

probable it was for farmers to use the Internet in their farming activities. A possible explanation is that the more household members, the more information about Internet use circulates among the members. This finding aligns with the study by Zhu *et al.* (2021), which revealed a positive and significant relationship between family size and information, technology adoption.

Meanwhile, education positively and significantly influences farmers' Internet decisions. The higher the farmers' education, the more likely they use the Internet. This finding is unsurprising because educated farmers are equipped with more knowledge, especially in using technology such as the Internet, in line with a previous study by Leng *et al.* (2020). Farming experience negatively and significantly impacts farmers' decisions to use the Internet. A possible explanation is that experienced farmers trust their accumulated practical knowledge, and experience more than any information on the Internet.

The Impact of Internet Use on the Adoption of Sustainable Agricultural Practices

The main objective of this research is to analyse the impact of Internet use on SAP adoption. The results of ATT estimation using the PSM approach are shown in Table 4. The four matching algorithms are neighbour matching, radius matching, kernel matching, and stratification. The results showed positive ATT values of 1,547, 1,379, 1,432, and 1,629 for the respective matching algorithms, with 5% and 1% significance levels. These results indicate that Internet use in farming activities can increase SAP adoption rates. Farmers can obtain relevant information on farming via the Internet, including information on sustainable practices.

The Government of Indonesia has been promoting sustainable agriculture practices, such as organic farming. Farmers have also been educated on the negative impact of chemicals in farming. However, pest attacks, disease and land degradation are still common problems among farmers in Indonesia. The Internet can help farmers find information and solutions to these problems, and they are often directed to information about sustainable farming practices in Indonesia. As such, Internet use in agricultural activities significantly increases SAP adoption rates. This finding is in line with research by Ma and Wang (2020), which reveals a positive and significant relationship between the adoption of information technology and sustainable practices.

Conclusion

Based on the results and discussion of this study, we concluded that Internet use in the agricultural sector is positively and significantly influenced by family size and education level but is significantly and negatively influenced by farming experience. Meanwhile, the main findings of this study indicate that Internet use in the agricultural sector has a positive and significant impact on farmers' decisions to adopt SAP. The practical implication of this study is that the government needs to increase farmers' digital literacy and skills, especially as it relates to farming activities. The government can provide counselling and training to farmers, especially those with low levels of education.

Table 4: The impact of Internet use on the adoption of SAP

Matching Method	User	Contr.	ATT	Std. Err.	T-value
Neighbour matching method	179	42	1.547	0.420	3.687**
Radius matching method	179	74	1.379	0.223	6.198***
Kernel matching method	179	74	1.432	0.114	12.539***
Stratification method	179	74	1.629	0.216	7.534***

Note: ** sig at 5% level; *** sig at 1% level

At the same time, the government also needs to increase the dissemination of information relating to SAP via the Internet. One way to do this is by providing an integrated, farmer-friendly website or an online platform for SAP.

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