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# The Determinants of Rice Farmers' Adoption of Sustainable Agricultural Technologies in the Mekong Delta, Vietnam

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## Abstract

Farmers' adoption of sustainable agricultural technologies guarantees for increasing their income/profit, providing quality agricultural products for the society, and preserving tolerance limits of ecological agriculture. This study analyzes factors affecting the adoption behavior of sustainable agricultural technologies among rice farmers in the Mekong Delta, Vietnam based on the binary logit model. The result shows that factors affecting the adoption behavior are i) human capital; ii) farm size; iii) social capital; iv) extension and v) access to the market. The study also gives policy implications, which make the scientific foundation for policymakers in promoting the adoption of sustainable production.

*Keywords*: Binary logit, rice farmers, sustainable agriculture, technology adoption.
*JEL classification codes*: 013, Q01, Q15, Q16, Q55

## Introduction

Over the past three decades of agricultural renovation since 1989, Vietnam has become self-sufficient in food with an annual export of 30 billion USD, providing livelihoods for 10 million rural households and contributing nearly 22 percent of the gross domestic product and 23-35 percent of exports. However, the past agricultural growth has been excessive, utilizing natural resources intensively. The recent growth has been slowed down due to  the majority of farmers are small-scale with limited access to technology, the stagnation of expansion of arable lands, water scarcity, environmental degradation, negative impacts of climate change, competing uses of natural resources between food and bio-energy crops, rapid urbanization and declining agricultural labor force. In order to achieve sustainable agricultural production and productivity growth in the future, the advancement of agricultural research and its effective applications in farmers' fields through technology transfer and innovation are required (Luu & Nguyen, 2017). However, the smallholder farmers in Vietnam are facing many constraints in terms of limited market access, knowledge, skills, technology, innovation, new value chains, and access to other resources such as public service, financial capital, education and information. Overcoming these difficulties in pursuit of the goal of developing sustainable agriculture requires responsibility and participation of all stakeholders, including the government, businesses, farmers, scientists, banks, and most importantly the farmers. Therefore, the understanding of which determinants restrict or support farmers in the adoption of sustainable agricultural technologies are important for stakeholders in Vietnam and the Mekong Delta, one of the areas most affected by climate change.

Previous studies on the adoption of agricultural technologies began in the 1980s, which focused on the farmers' decision to adopt new technologies and sustainable production technologies (Feder & O'Mara, 1981; Feder, Just, & Zilberman, 1985; D'souza, Cyphers, & Phipps, 1993; Agbamu, 1995; Okoye, 1998; Neill & Lee, 2001; Isham, 2002; Dimara & Skuras, 2003; Carolan, 2005; Kabwe & Donovan, 2005; Bandiera & Rasul, 2006; Jansen et al., 2006; Marenya & Barrett, 2007; Isgin, Bilgic, Forster, & Batte, 2008; Kassie, Zikhali, Manjur, & Edwards, 2009; Hashemi & Damalas, 2010; Liu, Wu, Gao, & Wang, 2011; Thapa & Rattanasuteerakul, 2011; Kassie et al., 2013; Teklewold, Kassie, & Shiferaw, 2013). These studies used farm management models that provide variables for explaining farmers' adoption decision. In Vietnam, Heong, Escalada, and Mai (1994), Huan, Mai, Escalada, and Heong (1999), Huan, Thiet, Chien, and Heong (2005), Le Dang, Li, Nuberg, and Bruwer (2014) also provided variables explaining the adoption of sustainable technologies in rice production among farmers in the Mekong Delta. The technologies in the previous studies focused on two criteria of economic efficiency and ecology aspects containing i) efficient use of resources and environmental protection, ii) modern technology, iii) economic efficiency and iv) be socially acceptable or accordance with the conditions of the local agricultural production system. In this study, we also include high-tech and agriculture 4.0 technologies as farmer choices for adoption, which require a lot of capital and knowledge of adopter in comparison to conventional or existing sustainable technologies, and therefore farmers will face new constraints in adopting these technologies. Indeed, previous studies scatterly show that farmer' characteristics, economic factors, perceived risk and utility, market access and physical resources play key roles in determining the farmer behavior, but still lack theoretical models and framework to combine all these potential influences.

The aims of this study are to determine main factors that restrict and affect farmers' adoption of sustainable agricultural technologies; and suggest policy implications for stakeholders in the agricultural production system in boosting the adoption of sustainable agricultural technologies of rice farming households in Vietnam. The structure of the article consists of five parts including i) introduction, ii) conceptual framework, iii) methodology and data, iv) results and discussions, and v) conclusion and policy implications.

## Conceptual Framework

FAO (1989) indicated sustainable agricultural technologies (SATs) must meet two criteria of economic efficiency and ecology aspects containing four components, which are i) efficient use of resources and environmental protection, ii) modern technology application, iii) economic efficiency and iv) be socially acceptable or accordance with the conditions of local agriculture production. In Vietnam, based on national situations of rice production system in the Mekong Delta, the government has promoted SATs, particularly among rice farmers, which are "One Must Do, Five Reductions", Integrated Pest Management (IPM), high-tech agriculture, and agriculture 4.0 technologies (Luu & Nguyen, 2017).

The sustainable agricultural practice package of "One Must Do, Five Reductions" was built on the 3R3G program, launched in An Giang Province, through the collaboration of IRRC and Ministry of Agriculture and Rural Development (Vietnam). The "One Must Do" is the use of certified seed, whereas the "Five Reductions" are: the amount of seed, fertilizer use, chemical pesticides, water use, and postharvest losses. Using these best rice farming practices compared to the farmers' practices resulted in the following: i) lower seed rate, ii) lower plant hopper incidence, and ii) used the least water compared to the other treatments. This initiative help reduce environmental footprint, improve rice production yield and quality, and increase the profit of farmers. Vietnam has been implementing the IPM program since 1992 in order to solve pest problems and problems related to pesticides overuse due to the lack of farmers' knowledge in managing crops and agro ecosystems. The main purpose of the IPM Program is to improve farmers' decision-making capacities by enhancing their knowledge and skills to secure more effective production conducive to human health and environment protection. IPM refers to crop protection techniques and practices which satisfy economic, ecological and toxicological requirements, while encouraging the use of natural pest control. The term Agriculture 4.0 was first used in Germany since 2010. Analogous to Industrial Revolution 4.0, the Agriculture 4.0 stands for the integrated internal and external networking of farming husbandry, fisheries, and forestry. Vietnam has been approaching the agriculture 4.0 technologies based on implementing hi-tech agriculture projects. The hi-tech agriculture model must meet criteria in four areas; technology, economy, society, and environment aspects. First, it must use modern technology to create agricultural products of superior quality and value. Then, it should be more efficient than older methods, hence more competitive in the market. Third, it should suit the climate, weather and soil conditions of the different regions in the country, and be accepted and applied by the community. Fourth, it should ensure stable production without negative impacts on biodiversity, the environment, the ecosystem and human health (Luu & Nguyen, 2017).

There is a long and rich empirical studies that seek to explain farmers' adoption of SATs. Researchers typically select a number of potential independent variables for inclusion in their analysis based on theories and literature review, then conducting statistical tests to determine which variables correlate with the adoption of SATs among farmers.

Human capital

The human capital of farmer such as the education level of household head, age, agricultural knowledge, and experience may affect decisions to adopt SATs because of the imperfect markets. The education level of farmer correlates positively with adoption decisions because of the assumed link between education and knowledge (Rahm & Huffman, 1984; Knowler & Bradshaw, 2007; Wollni & Andersson, 2014). Farmer age also has been regularly assessed on the adoption of SATs. The results are mixed showing positive signs (Feder, 1982; Warriner & Moul, 1992), the negative sign (Clay et al., 1998) and insignificant correlation (Neill & Lee, 2001). Assessments of the role of farmer experience in SATs adoption revealed positive correlations (Rahm & Huffman, 1984; Clay et al., 1998) and insignificant cases (Neill & Lee, 2001).

Farm size

Farm size refers to the total land available to a farmer for an agricultural production. Feder, Just, and Zilberman (1985) show that given the uncertainty, and the fixed transaction and information costs associated with technologies, there may be a critical lower limit on farm size which prevents smaller farms from adoption decision. Owners of larger farms are more willing to invest in SATs. However, given the observance of positive (Chirwa, 2005; Teklewold, Kassie, & Shiferaw, 2013), negative (Feder, Just, & Zilberman, 1985; Clay et al., 1998) and insignificant correlations (Agbamu, 1995), the impact of farm size on farmer adoption of SATs have not been investigated consistently across a range of previous studies.

Farmers' financial resources

The financial resources of farm operation include off-farm income, and financial credit accessibility. The adoption of agriculture technology requires sufficient financial well-being, especially if new equipment is required. The impact of financial capital on adoption revealed a positive correlation (Kabwe & Donovan, 2005; Teklewold, Kassie, & Shiferaw, 2013). However, the identification of a negative correlation (Okoye, 1998) and insignificant correlation (Clay et al., 1998) provided an unqualified conclusion to this correlation. Complicating this picture is the fact that the presence of off-farm income was found positively (Napier & Camboni, 1993), negatively (Okoye, 1998) and insignificantly (Smit & Smithers, 1992) correlate with the adoption in equal measure. These results are based on the hypothesis that the alternative income sources could provide additional resources for adoption or, concomitantly, these income resources may diminish the priority of farmers in agriculture participation and, thereby reducing the adoption of SATs (Knowler & Bradshaw, 2007).

Social capital

Social capital and networks of farmers can influence SATs adoption decisions (Isham, 2002; Bandiera & Rasul, 2006; Marenya & Barrett, 2007; Chirwa, 2005; Kassie et al., 2013). This represents a combination of variables, such as membership in farmers' groups or associations, the number of relatives in and outside the village that a household can rely on for critical support, and the number of traders that a farmer knows in and outside the village. Social capital literature treats social networks as a means to access information, secure a job, obtain credit, protection against unforeseen risks, information exchange market, reduce information asymmetries and enforce contracts. Social networks also reduce transaction costs and increase farmers' bargaining power, helping farmers earn higher returns when marketing their products. Farmers with a greater number of relatives are more likely to adopt SATs because they are able to experiment with technologies while spreading the risks over more people and resources. On the other hand, farmers with more relatives may have lower opportunity costs for family labor, so farmers may invest less, including in SATs. Farmers' participation in at least one rural institution or group and extension support from skilled civil servants is significant in adoption of SATs because of increased chance of interaction and access to knowledge among farmers (Kassie et al., 2009; Wollni, Lee, & Thies, 2010; Nyangena, 2011).

Extension

Information becomes especially important as the degree of complexity of agricultural technology and innovations increases (Rogers, 2003; Jansen et al., 2006; Liu, Wu, Gao, & Wang, 2011). Information sources that positively influence adoption of farmers can include other farmers in their village, media, meetings, and extension (Knowler & Bradshaw, 2007). The extension is a source of information for many farmers, either directly, through contact with extension agents, or indirectly, through farmers who have prior exposure transmitting information to other farmers.

Perceived utility and risk

In agriculture, technological innovations are generally perceived to be riskier than traditional measures. This view has received considerable support in the literature. The perception of increased risk inhibits adoptions (Feder, Just, & Zilberman, 1985). Technologies when first appears, potential users are generally uncertain of its effectiveness and tend to view its use as experimental. Feder and O'Mara (1981) shows uncertainty declines with learning and experience thus inducing more risk-averse farmers to adopt a technology, provided it is profitable.

Land tenure status

Land tenure is a descriptor differentiating self-owned land from a property which is rented from a third party. A farmer is more likely to manage self-owned land in a more favorable manner than rented land (Polson & Spencer, 1991; Nkonya & Norman, 1997; Carolan, 2005; Chirwa, 2005; Isgin, Bilgic, Forster, & Batte, 2008; Teklewold, Kassie, & Shiferaw, 2013), because of the effect of the land tenure status of the household of adoption of SATs to the fact that the benefits of long-term practices accrue over time. SATs is affected by the land tenure status of the household. This factor has been insignificant in some cases; its impact on adoption has been generally consistent across a range of studies.

Input and product market access

Access to market can influence the farmers' decision making of SATs in various ways. Access to market is directly associated with the transaction costs that occur when households participate in input and output marketing activities. Transaction costs are barriers to market participation by smallholder rice farmers and are factors responsible for significant market failures in developing countries (Neill & Lee, 2001; Dimara & Skuras, 2003; Pretty, Toulmin, & Williams, 2011; Kassie et al., 2013).

**Methodology and Data**

The quantitative models used in previous studies include the multivariate logit, probit, tobit, poisson, ordered logit/probit and multinomial logit models (McNamara, Wetzstein, & Douce, 1991; D'souza, Cyphers, & Phipps, 1993; Marenya & Barrett, 2007; Moser, Pertot, Elad, & Raffaelli, 2008; Hashemi & Damalas, 2010; Thapa & Rattanasuteerakul, 2011; Teklewold, Kassie, & Shiferaw, 2013; Kassie et al., 2013; Wollni & Andersson, 2014). This study employs the binary logit model. The logit model used in adoption behavior studies is based on the theory of Maximum Likelihood suggested by Ben-Akiva and Lerman (1985). It uses maximum likelihood estimation to evaluate the probability of categorical membership and assumes that the error terms are independently and identically distributed (Greene, 2003).

The model employed in this study involves a dependent variable, the technology adoption decision variable and a set of explanatory/independent variables that might influence the final probability, $P_1$, of farmers' adoption of the SATs, are presented in Table 1. The explanatory variables include human capital (age, agricultural knowledge and education level of household head), farm size, farmers' capital resources (off-farm income, access to credit), social capital (membership in a rural cooperative, number of traders that farmer knows), extension (number of times that farmer contacts with extension officers), perceived utility, land tenure status, access to agricultural input/product markets.

The adoption decision by farmers is specified as, Y = f (X, e) where e is the stochastic disturbance term assumed to follow a logistic distribution (Greene, 2003). The logit model is generally specified as follows:

$$\mathrm{Ln}\left[\frac{p=1}{p=0}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_{12} X_{12} + e \qquad (1)$$

Where:

P (Y=1) = Probability of farmer adoption SATs

P (Y = 0) = 1- P(Y=1): Probability of farmer non-adoption of SATs

Xi = Independent variables (i: from 1 - 12); Ln: Log of e (e = 2.714).

$\beta$ = a scalar of parameters as defined in equation (1)

Odds ratio ($O_0$):

$$O_0 = \frac{P0}{1-P0} = \frac{P(Adopter)}{P(Non\_Adopter)}$$

Replace $O_0$ intoequation (1):

$$LnO_0 = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots + \beta 12X12 + e \qquad (2)$$

The log of the Odds ratio is a linear function with independent variables Xi (Cox, 1970).

Agresti (2007) indicated the prediction function of the binary logit model is:

$$E\,(Y/Xi) = \frac{e^{LnOdds}}{1 + e^{LnOdds}}$$

E (Y/Xi): Probability of Y = 1, when X equal Xi (i = 1,2,3, …, 12)

$$LnOdds = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_{12} X_{12}\ (2) + e$$

$$E\,(Y/Xi) = \frac{e^{\beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \cdots + \beta 12X12}}{1 + e^{\beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \cdots + \beta 12X12}}$$

Table 1. Definition of variables

| Variable | Definition | Expected sign |
|---|---|---|
| Dependent variable | | |
| Y | Sustainable agriculture technologies adopted by farmers: 1 = yes, if household adopted SATs (Among “One Must Do, Five Reductions”, IPM, high-tech agriculture, agriculture 4.0 technologies); 0 = otherwise | |
| Independent variables | | |
| Age | Continuous, Age of household head (years) | - |
| Education | Continuous, The number of formal education year of household head, year(s) | + |
| Knowledge | Continuous, The number of agricultural knowledge sources that farmer accesses per annum (other farmer, television-radio, agricultural paper-book, smartphone, extension officer, extension-education courses), source(s) | + |
| Farmsize | Continuous, Total farm land (1,000 $m^2$) | + |
| Income | Dummy, Off-farm income of household: 1= yes, 0 = otherwise | + |
| Credit | Dummy, Access to credit of household: 1= yes, 0 = otherwise | + |
| Membership | Dummy, Membership in a rural cooperative: 1= yes, 0= otherwise | + |
| Trade | Continuous, The number of traders that farmer contact per annum, person(s) | + |
| Extension | Continuous, The number of times that farmer contacts for extension officer per annum, time(s) | + |
| Utility | Dummy, Perceived utility: 1=yes, 0 = otherwise | + |
| Tenure | Dummy, Land tenure status: 1=secure, 0 = otherwise | + |
| Market | Continuous, Access to markets (Distance to input/product market), km | - |

According to Yamane (1967), the minimum sample size in the study should be:

$$n = \frac{Z^2 p(1-p)}{e^2} = \frac{(1.96)^2 0.5(1-0.5)}{0.05^2} = 384.16$$

Where:

Z = The significance of 95%, the value of the distribution table Z = 1.96

P = The estimate of correct prediction of n for p = 0.5

E = Sampling error allowed with + -0.05 (5%).

The Mekong Delta is the largest rice production area in Vietnam, located in the Southwestern of Vietnam. The Delta covers 39,000 km$^2$ with about 600 km of coastline and is divided into 12 provinces (Long An, Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Dong Thap, An Giang, Kien Giang, Hau Giang, Soc Trang, Bac Lieu and Ca Mau) and 1 central city, Can Tho. The sample size in this study is 420 farmers, which is selected by the non-probability method based on the quota and convenience sampling techniques. The sample areas include 7 communes among 7 provinces, including An Giang, Dong Thap, Long An, Kien Giang, Tien Giang, Can Tho, and Soc Trang which represents three zones based on the depth and extent of flooding in the Delta: deep flood area (most of Long Xuyen Quadrangle, Plain of Reeds and An Giang, Dong Thap and Long An); average flood area (most of Hau Giang, Vinh Long, Tien Giang and Can Tho; part of the Trans-bassac depression and freshwater alluvial zone); shallow or no flood area (most of the coastal area and Kien Giang, Ha Tien, Soc Trang, Bac Lieu, Ben Tre and Tra Vinh) (Huynh, 2015). In each selected commune, the author interviewed 60 farmers based on supports from extension officers and farmers' cooperatives.

The results of the survey show that 260 cases (61.9 percent) are SATs adopters while 160 cases (38.1 percent) were non-adopters. About  94 percent of the smallholder farm households, both SATs adopters and non-adopters are male headed. Other characteristics of the adopters and non-adopters in the sample are shown in Table 2 and Table 3.

The results of t-test presented in Table 2 show that the farmers likely to adopt SATs were those who have better resources, including human capital, totalfarmland, the number of traders that farmer knows, the number of times that farmer contacts extension officer, and access to markets. These factors are all statistically significant at the 5 percent level, except farmer age.

Table 2. T-test analysis

| | | Adopted decision | | Levene's test | t-test |
|---|---|---|---|---|---|
| | | Mean | Mean Difference | Sig. | Sig. (2-tailed) |
| Age | Adopters | 40.2 | -0.6 | 0.955 | 0.621 |
| | Non-adopters | 40.8 | | | |
| Education | Adopters | 9.8 | 2.8 | 0.001 | 0.000 |
| | Non-adopters | 6.9 | | | |
| Knowledge | Adopters | 2.9 | 0.7 | 0.000 | 0.000 |
| | Non-adopters | 2.2 | | | |
| Farmsize | Adopters | 5.0 | 2.0 | 0.000 | 0.000 |
| | Non-adopters | 3.0 | | | |
| Trade | Adopters | 3.5 | 0.6 | 0.000 | 0.000 |
| | Non-adopters | 2.9 | | | |
| Extension | Adopters | 2.9 | 0.6 | 0.000 | 0.000 |
| | Non-adopters | 2.2 | | | |
| Market | Adopters | 3.9 | -1.2 | 0.013 | 0.000 |
| | Non-adopters | 5.1 | | | |

The chi-square test results in Table 3 indicate that households who own better resources, including access to credit, off-farm income, membership in a rural cooperative, perceived utility and land tenure status are more likely to adopt SATs than non-adopted cases, which is statistically significant at the 5 percent level.

Table 3. Chi-square test analysis

| | Adopted decision | | | |
|---|---|---|---|---|
| (percent) | | Non-adopters | Adopters | Asymp. Sig. (2-sided) |
| Credit | No | 32.5 | 11.2 | 0.000 |
| | Yes | 67.5 | 88.8 | 0.000 |
| Off-farm income | No | 66.2 | 28.5 | 0.000 |
| | Yes | 33.8 | 71.5 | 0.000 |
| Membership | No | 44.4 | 15.4 | 0.000 |
| | Yes | 55.6 | 84.6 | 0.000 |
| Utility | No | 40.6 | 18.1 | 0.000 |
| | Yes | 59.4 | 81.9 | 0.000 |
| Tenure | No | 33.8 | 12.7 | 0.000 |
| | Yes | 66.2 | 87.3 | 0.000 |

## Results and Discussions

Table 4 shows maximum likelihood estimates of the logistic regression models, all of the twelve estimated coefficients in the Mekong Delta adoption model exhibit the expected signs and six among them are significant at the 5% level or higher level. The $R^2$ is 0.445, an upper bound $R^2$ for binary-choice models. The likelihood ratio test is significant at 1-percent level, indicating the model has good explanatory power. The ratio of correct prediction is 77.6 percent.

**Table 4. Maximum Likelihood Estimates, Goodness-of-Fit Measures, and Change in Probability for significant Coefficients**

| | B | S.E. | Wald | Sig. | Exp(B) | Change in Probability for significant Coefficients ($P_0$ = 10%) |
|---|---|---|---|---|---|---|
| Age | -0.005 | 0.011 | 0.202 | 0.653 | 0.995 | - |
| Education | 0.106 | 0.034 | 9.806 | 0.002 | 1.112 | 0.997 |
| Knowledge | 0.428 | 0.180 | 5.663 | 0.017 | 1.534 | 4.562 |
| Farmsize | 0.235 | 0.077 | 9.393 | 0.002 | 1.266 | 2.332 |
| Income | 0.149 | 0.281 | 0.280 | 0.596 | 1.161 | - |
| Credit | 0.021 | 0.333 | 0.004 | 0.951 | 1.021 | - |
| Membership | 0.635 | 0.300 | 4.480 | 0.034 | 1.887 | 7.333 |
| Trade | 0.116 | 0.167 | 0.487 | 0.485 | 1.123 | - |
| Extension | 0.722 | 0.186 | 15.019 | 0.000 | 2.058 | 8.611 |
| Utility | 0.056 | 0.297 | 0.036 | 0.850 | 1.058 | - |
| Tenure | 0.105 | 0.326 | 0.104 | 0.747 | 1.111 | - |
| Market | -0.173 | 0.077 | 5.086 | 0.024 | 0.841 | -1.454 |
| Constant | -4.332 | 0.978 | 19.628 | 0.000 | 0.013 | - |
| Observations: 420.<br>Omnibus testing: Chi-Square: 166,635; Significance: 0.000.<br>Nagelkerke R Square: 0.445.<br>Correct prediction: 0.776%. | | | | | | |

The probabilities presented in Table 4 show the effects of changes in the individual explanatory variables on the likelihood of SATs adoption assuming that all other explanatory variables are set to zero. The likelihood of SATs adoption increases by 0.997 percent if the farmer gets one more year formal education. The likelihood of SATs adoption increases by 4.562 percent if the farmer has one more agricultural knowledge source. If the farmer has one more 1,000 $m^2$ of farmland there is a 2.332 percent increase in the likelihood of adoption. If the farmer has at least a membership in a rural cooperative there is a 7.333 percent increase in the likelihood of adoption. The likelihood of adoption of SATs increases by 8.611 percent if the farmer has one more time contact with extension officers. And, if the distance from the household to the central market increase one more km, there is 1.454 percent less likely to adopt SATs.

In Vietnam, approximately 42 million farmers engage in the agricultural sector, the proportion of skilled workers is very small. In 2016, 84.55 percent of the labor force are under-trained, causing low labor productivity and posing constraints to the application of technology in agricultural production. The scale of land for agricultural production is very small and fragmented. A small-scale production base accounts for more than 9 million households. Vietnam is in the group of 7 ranked countries in terms of agricultural land size per capita (147th of 204 countries ranked in 2011), only about 0.11 ha/person or on average only 0.46 ha/household. Thesesmall pieces of land are often scattering and non-adjacent, which cause difficulties when applying technology in agriculture that requires large areas. Economic and social organizations in rural areas such as cooperatives, farmers' associations, women's unions, and the Vietnamese Fatherland Front are supporting and playing an increasingly important role in the implementation of economic and social objectives in general and promoting sustainable agriculture in particular. Along with that, 1,740 agricultural enterprises and 6,464 agricultural cooperatives, accounting for 86,16 percent of communes with agricultural processing facilities will assist households in accessing the input and output markets, new knowledge and technology in agriculture. The agricultural extension system in Vietnam is well organized with 91.36 percent of communes having representative extension staff and 97.32 percent having representative veterinary staff. Farmers can easily access new knowledge, skills and technologies from official sources and thus reduce risks and increase the level of application of new technologies. However, extension services are facing many difficulties because of lack of funding for R&D, poor human resources, top-down approach, and limited participation of the private sector. The market system, traffic and irrigation system in rural areas of Vietnam is well organized, with 79.04 percent of communes having access to the markets, 193.035 km of irrigation canals, and concretized roads. The infrastructure is constantly being improved under the new rural program, with a system of agro-enterprises and agro-processing enterprises that facilitate farmers' access to markets, reduce transaction costs, access to information on output and input markets, thereby promoting the application of new technologies in production. However, infrastructure in rural areas is still poor and under-treated due to slow local infrastructure projects , scattered infrastructure and low efficiency (GSO, 2017 Results of the 2016 Rural, Agricultural and Fishery Census).

## Conclusion and Policy Implications

The results of this article show that human capital, farm size, social capital, extension and access to the market significantly affect adoption of SATs of the rice farmers in the Mekong Delta, Vietnam. Therefore, in order to promote the farmers' adoption of SATs, policies should focus on five issues: *First*, improving the quality of human capital in order to improve the quality of growth, productivity, and income for producers. The government needs to focus on vocational training for farmers emphasizing innovative farming techniques, equipment, and products. This may be crucial for smallholder farmers to adopt new technology based on learning knowledge and skills. Breaking old habits may be made easier if these farming techniques and products prove effective in establishing leaner operations. *Second*, revising policies on the management and use of agricultural land. The government needs to address land issues and accelerate the implementation of administrative procedure reform. In order to encourage land accumulation for large-scale agricultural development, it is necessary to revise the 2013 Land Law by removing or loosening quotas on agricultural land.

The government can pool lands for large-scale production to enable application of technology in agriculture. Under this model, the land accumulation model has three different types: farmers gathering their land together and planting the same crops with the same inputs, enterprises negotiating with each farming household individually to buy or lease their land, and local authorities leasing land from farmers and then sub-leasing the land to enterprises. Focusing on building partnerships between enterprises and farmers, help create a consensus to pool land for large-scale production that have same cultivation models and apply scientific and technological advances in agricultural production. This cooperation will increase productivity, ensure quality, and improve value addition. *Third*, investments for improving the quality of social capital as a new dynamic factor for the growth on the basis of strengthening the role and efficiency of rural cooperatives such as cooperatives, farmers' associations, women's unions, and the Vietnamese Fatherland Front. *Fourth*, improving the quality of extension system based on strengthening agricultural extension socialization according to a demand-based extension service, human resources training and building up regional agriculture extension network. *Fifth*, strengthen the input and product markets on the basis of development in the supply chain of the agricultural production system.

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