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The Determinants Behind Changes of Farming Systems and Adaptation to Salinity Intrusion in the Coastal Regions of Mekong Delta

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Changes of farming system in the coastal areas of the Vietnamese Mekong Delta (VMD) have been happening as an inevitable trend under the context of climate change, especially salinity intrusion. However, these changes are sometime associated with very high risks or interest conflicts. Therefore, the local government has been attempting to control and manage these changes in order to lower the unexpected risks or conflicts for farmers in the coastal regions. However, the empirical evidences hidden behind changes of farming systems in the VMD were not fully recognized. The current study aimed at investigating the factors affecting the changes of farming system in Kien Giang and Soc Trang provinces by using binary logit model. The study found that the household head' educational level was significantly and positively associated with the adoption of new farming systems. More importantly, the distance from fields to rivers or salinity level negatively affected the changes of farming systems. In case of change of farming system from sugarcane to mono–shrimp, the study also found that the number of female labor, accessing to credit, membership in organization and total agricultural land negatively affected the adoption of new farming system. In case of change of farming system from rice–shrimp to mono–shrimp, the study suggested that shrimp experience was positively associated with the adoption of new farming system.

Key words: adaptation, climate change, farming systems, salinity intrusion

INTRODUCTION

Climate change, particularly extreme weather and salinity intrusion are considered as the most severe issues in the VMD, which affects agricultural production more and more seriously (Carew–Reid, 2008; Nhan *et al*., 2011). In addition, being affected by market instability, low selling price but high prices of material inputs has directly and indirectly forced farmers to change their farming systems as a inevitable trend to adapt to new environment (Binh *et al*., 2009; Clayton, 2003). Transformation of farming systems and identification of appropriate production activities are the possible solutions to adapt to climate change, especially in the coastal regions, where is considered as the most vulnerable zones to salinity intrusion (Le Dang *et al*., 2014; Parry *et al*., 2007). However, the transition process contains many risks in terms of production technology and environmental constraints as well as policy contexts.

The VMD, where is considered as the national core agricultural region, accounts for only 12 percent of total national area but it contributes more than 50 percent of total national rice production and over 70 percent of fishery and aquaculture production (General Statistical Office [GSO], 2016). However, according to many previous assessments, the livelihoods of agricultural and aquaculture households are still in poor conditions, especially for those in the coastal areas (Binh, 2011; Can, 2011). The VMD is considered one of the three deltas in the world most severely affected by the increasingly serious context of climate change (Cosslett & Cosslett, 2014; Dinh *et al*., 2012). Therefore, the Vietnamese Prime Minister has promulgated the Decision 2139/QĐ–TTg about the National Strategy on Climate Change to figure out appropriate and sustainable farming systems for the coastal regions.

Recently, many farmers in the VMD have been changing their production activities to shrimp farming systems with the hopes of improving the economic performances and adapting to salinity intrusion, for instance a conversion from sugarcane to shrimp in Soc Trang province and rotated rice – shrimp farming system to mono–shrimp farming in Kien Giang province (Renaud *et al*., 2015; Smajgl *et al*., 2015; Tan *et al*., 2014). Consequently, these changes have led to the remarkable increase of total brackish water shrimp area. For instance, the total brackish water shrimp area in 2005 was only 551,470 hectares but this figure reached to 651,267 hectares in 2014 (Institute of Fisheries Economics and Planning [IFEP], 2015).

The changes of farming system in the VMD are widely recognized to be highly associated with salinity intrusion (Can *et al*., 2007; Nhan *et al*., 2007; Nhan *et al*., 2011; Renaud *et al*., 2015). However, the fact is that only some farmers in coastal regions changed their farming system while the others have been still maintaining their old production activities. Such situation has resulted in difficulties in terms of planning and management for local government. For instance, pro–shrimp farmers try to adopt mono–shrimp farming with the hope of achieving better economic performance. Consequently, saline water taken in for shrimp farming probably results

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in losses for rice and sugarcane production. Inversely, shrimp farming may also suffer from freshwater used for rice and sugarcane production (Nhan *et al*., 2007; White, 2002). In addition, wastewater effluents with high concentration of chemical fertilizers and pesticides discharged by rice and sugarcane farmers is then taken in for shrimp farming, which also lead to high risks. The conflict also occurs within shrimp farmers when wastewater with high nutrient concentration and hidden diseases is discharged to rivers, and then this water is reused by other shrimp farmers (Dung, 2008; Nhan *et al*., 2007). Therefore, investigating the factors behind the changes of farming system in the coastal regions is very crucial for policy makers and local authorities to manage and promote adaptive farming systems under the context of salinity intrusion.

METHODOLOGY

Conceptual framework

The general picture of changes in farming system in the study sites can be described in Figure 1. Figure 1 shows that the farming systems in the freshwater zone of the study sites are normally based on rice and sugarcane production. The adoption levels of these farming systems (rice and sugarcane) become lower as the level of salinity increases. At the intersection (rice–shrimp and sugarcane with mono–shrimp) where the interviews were conducted, the level of changes in farming system, especially shifting from rice–shrimp and sugarcane to mono–shrimp increased significantly due to the impact of salinity intrusion. In order to test this hypothesis, we considered a variable namely the distance from the field to rivers (see Tables 1 & 4 for more detailed information on this variable). In this study, we considered this variable to represent for the salinity level as farmers were unable to measure the salinity level individually. In fact, the salinity level is higher in the fields that are close to river than the fields are far from rivers.

As mentioned in the study sites, salinity intrusion has been becoming more serious, which results in the changes in farming system. Therefore, salinity intrusion is considered as the direct driver behind changes of farming system. However, only some farmers in the study sites changed their farming system while the others have been still maintaining the old production activities. It implies that many other factors, especially socio–economic and demographic characteristics are also important determinants behind these changes. Therefore, the current study would like to investigate which socio–economic and demographic characteristics affect the changes of farming system. The definitions and descriptive statistics of the variables used in the logit model are given in Table 1 and Table 4, respectively.

Analytical framework

The current study focused mainly on two changes of farming system: one is from sugarcane to mono–shrimp farming and the other is from rice–shrimp to mono–shrimp farming systems in the coastal regions of the VMD. Based on these data structures, the dependent variable (denoted by Y_i) takes on the values of 0 and 1. $Y_i = 0$ indicates non–adopters – farmers didn't change their farming systems – (i.e., sugarcane farming in case of Soc Trang province and rice–shrimp cultures in case of Kien Giang province) while $Y_i = 1$ indicating adopters – the farmers changed their farming systems to mono–shrimp culture in two study sites. Explicitly, the study contains two separate estimations: one for the case of changes from sugarcane to mono–shrimp and the other from rice–shrimp to mono–shrimp cultures. As the dependent variable is binary, the study employed binary logit model. The probability of adopting a new farming system can be written as below

$$Pr(Y_i = 1 | X_{im}) = \frac{(\exp(\beta_0 + X_1\beta_1 + X_2\beta_2 + \ldots X_k\beta_k)}{1 + [\exp(\beta_0 + X_1\beta_1 + X_2\beta_2 + \ldots X_k\beta_k)]}; m = 1,2,\ldots k \quad (1)$$

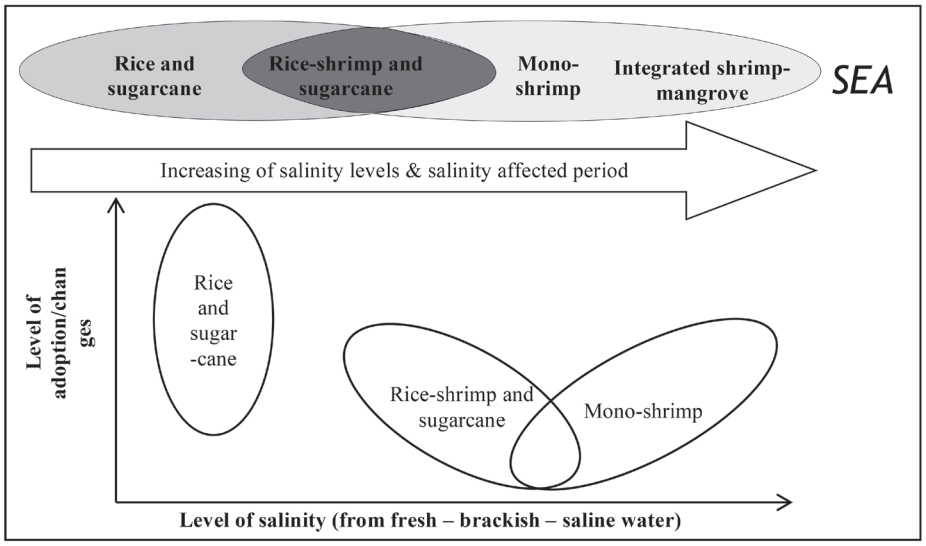

Fig. 1. Changes of farming systems in Kien Giang and Soc Trang.

From equation (3), in order to predict the probability, we need to model a function that presents the relationship between dependent variable (Y_i) and the independent variables (X_{im}). The empirical model showing the relationship is given by

$$Y_i = \alpha_0 + \alpha_1 AGE + \alpha_2 EDUCATION + \alpha_3 LABOR + \alpha_4 FEMALE + \alpha_5 EDUCATION + \alpha_6 ORGANIZATION + \alpha_7 CREDIT + \alpha_8 AGRILAND + \alpha_9 DISTANCE + \alpha_{10} EXPERIENCE \quad (2)$$

DATA COLLECTION

The study selected two coastal provinces in the VMD with the highest conversion rate to shrimp culture: Soc Trang and Kien Giang with the former being affected by the West Sea and the latter being affected by the East Sea. In the period 2011–2015, the production of shrimp in Soc Trang province increased by 13.3 percent, showing the highest rate compared to other coastal provinces (GSO, 2016). Kien Giang province was selected because it is the only coastal province of the VMD affected by the West Sea. Such selection was expected to provide a comprehensive picture of changes in farming system in the VMD.

From two selected provinces, the study continued to select three districts with the highest conversion rate to shrimp: U Minh Thuong and An Bien districts of Kien Giang province and Cu Lao Dung district of Soc Trang province. An Bien and U Minh Thuong are two districts that had the largest rice–shrimp area and the highest conversion rate from rice–shrimp to mono–shrimp in Kien Giang, with the total area of shrimp farming in two districts in 2017 of 22,384 ha (Department Agriculture and Rural Development Kien Giang [DARDKG], 2017b). According to Soc Trang Statistical Office (STSO, 2016), the total sugarcane area of Cu Lao Dung decreased significantly from 8,400 in 2013 to 7,157 hectares in 2015.

In the selected districts, we conducted face–to–face interviews with 314 farmers, in which 161 farmers were in Soc Trang province and 153 farmers in Kien Giang province. In Soc Trang, the survey was conducted with sixty–seven farmers who are cultivating sugarcane and ninety farmers who shifted from sugarcane to mono–shrimp. In Kien Giang, seventy rice–shrimp farmers and eighty–three farmers changed from rice–shrimp to mono–shrimp were interviewed. Because the study only considered the changes of farming systems from sugarcane and rice–shrimp to mono–shrimp, the observations represented nearly the entire population for each of the geographic target locations. The most important criterion for selecting non–adopters (sugarcane and rice–shrimp farmers) was geographic proximity to adopters (mono–shrimp farmers). The reason for this decision came from our assumption that non–adopters had known well about mono–shrimp culture but they had refused to change. Such selection also ensured homogeneity in terms of natural conditions (soil, water, rain, etc.) as well as cultural characteristics for both adopters and non–adopters. The dependent and explanatory variables used in the binary logit analysis are described in Table 1.

RESULTS AND DISCUSSIONS

Prior to investigating the factors affecting the changes of farming systems in the study sites, it is necessary to provide the background information on economic analysis of all farming systems so that policy makers can come up with comprehensive decisions.

Economic analysis and comparisons among farming systems

By making the economic comparisons among farm-

Table 1. Definition of variables used in binary logit model

Variables	Explanation	Description
	Dependent variable	
ADOPTION	Adoption of new farming system	0=non–adopters; 1= adopters
	Independent variables	
SEX	Sex of household head	Dummy, 1 if male, 0 otherwise
AGE	Age of the family head	Continuous variable, years
LABOR	Number of family labors	Continuous variable, members
FEMALE	Numbers of female labors	Continuous variable, members
EDUCATION	Education of the family head	Continuous variable, schooling years
ORGANIZATION	Membership in organizations	Dummy, 1 if participate, 0 otherwise
CREDIT	Accessing credit	Dummy, 1 if yes, 0 otherwise
AGRILAND	Total area of farm land	Continuous variable, 1,000 m^2
DISTANCE	Distance from the field to river	Continuous variable, meter
EXPERIENCE	Experiences in shrimp culture	Continuous variable, years

Source: Own estimates; data appendix available from authors.

Table 2. Economic comparison between sugarcane and shrimp farming

Indicator	Unit	Sugarcane	Shrimp	Difference
Yield	Tons/ha	108.96	23.44	
Cost	Million VND /ha	64.91	1,490.69	1,425.78***
Revenue	Million VND /ha	100.93	2,518.17	2,417.24***
Benefit	Million VND /ha	24.85	1,027.48	1,002.63***

*Note: *** indicates the significance of 1% by using t–test*

Table 3. Economic comparison between rice–shrimp and mono–shrimp farming

Indicator	Unit	Rice–Shrimp	Mono–shrimp	Difference
Yield	Tons/ha			
Cost	Million VND /ha	11.61	67.39	55.78***
Revenue	Million VND /ha	45.87	129.07	83.20***
Benefit	Million VND /ha	34.26	61.67	27.41**

*Note: *** indicates the significance of 1% by using t–test*

Table 4. Descriptive statistics of variables used in binary logit model

Variables	Soc Trang		Kien Giang	
	Mean	S.D	Mean	S.D
Dependent variable				
ADOPTION	0.559	0.498	0.542	0.499
Independent variables				
SEX	0.863	0.344	0.915	0.279
AGE	50.341	11.047	47.823	12.109
LABOR	1.993	1.045	2.091	1.034
FEMALE	0.527	0.613	0.746	0.667
EDUCATION	6.826	3.664	6.758	3.274
ORGANIZATION	0.136	0.344	0.098	0.298
CREDIT	0.490	0.501	0.215	0.412
AGRILAND	8.889	10.196	25.01	16.966
DISTANCE	202.61	340.00	201.392	351.461
EXPERIENCE			7.934	4.709

Source: Own estimates; data appendix available from authors.

ing systems, the study found that the destination or new farming systems had far higher economic performances compared to the old ones. The higher economic performances are considered as an important factor affecting the changes of farming systems in the coastal areas of the VMD. For instance, Table 2 shows that the total benefit of mono–shrimp farming (the destination or new farming system) was 1,027 million VND per ha, which is 41 times higher than sugarcane farming – the old farming is affected seriously by salinity intrusion.

In addition, in case of changes from rice–shrimp farming to mono–shrimp, Table 3 indicates that the total benefit of mono–shrimp farming was approximately 2 times higher than the old rice–shrimp farming, 61.67 versus 34.26 million VND per ha, respectively.

The factors affecting the changes of farming systems

Table 4 shows that in general the majority of the household heads in the study sites are male, accounting more than 86 percent in Soc Trang (both sugarcane and shrimp farmers) and 91 percent in Kien Giang (both rice–shrimp and mono–shrimp farmers). Like other farming activities, the household heads who have been cultivating shrimp, rice–shrimp and sugarcane in the study sites are the elderly at around 50. The numbers of family labor are almost identical between Soc Trang and Kien Giang at two persons per household. However, there were more female laborers in Kien Giang province than in Soc Trang. Table 2 also shows that the educational levels of farmers in both Kien Giang and Soc Trang are almost identical at grade 7. Another striking result is that the farmers in Kien Giang provincce have had quite big agricultural land of 2.5 hectares per household while this figure was only 1 hectare on the average in Soc Trang.

In order to investigate the relationship between the change of farming system and the influencing factors, the results from the binary logit model are shown in Table 5 below.

In case of Soc Trang province (change of farming system from sugarcane to mono–shrimp), Table 5 show that the variables of *FEMALE*, *CREDIT*, *ORGANIZATION*, *AGRILAND* and *DISTANCE* negatively affect while the only *EDUCATION* has a significantly positive impact on the dependent variable of *ADOPTION*. At the significant level of 10 percent, the study found that the households with more number of female labors are unlikely to adopt or change their farming system. This result is consistent with many previous studies as the female labors are normally averse to risks, so they often do not accept changes (Zamasiya *et al.*, 2017). This result explicitly suggests that the policy makers could manage or control the situation via female labors of shrimp households. The study also found that the membership in organization (*ORGANIZATION*) affect negatively the adoption at the significant level of 10 percent. The marginal effect for *ORGANIZATION* at –0.3682 indicates that the predicted probability of change is 0.3682 smaller for the households with membership in organization than for those without membership. The households with financial constraints (*CREDIT*) normally did not change their farming system. This result was consistent with the real situation that change of farming system requires a great amount of money to invest, so these households had not enough money to invest or change the farming system. As opposed to the case of change from rice–shrimp to mono–shrimp in Kien Giang, the access to credit was a significantly important factor affecting the change decision from sugarcane to shrimp. It can be explained that the sugarcane farmers have to redesign their fields (i.e., making shrimp ponds), which requires a lot of monetary investment while the rice–shrimp farmers do not need to change the field design. Therefore, the policy makers

Table 5. Logit results considering the determinants behind changes of farming systems

Variables	Soc Trang province (Sugarcane → mono–shrimp)			Kien Giang province (Rice–shrimp → mono–shrimp)		
	A	s.e	dy/dx	A	s.e	dy/dx
SEX	0.132	0.863	0.0329	0.441	0.772	0.1093
AGE	–0.027	0.029	–0.0066	0.013	0.019	0.0033
LABOR	0.016	0.416	0.0039	0.260	0.348	0.0650
FEMALE	–0.994*	0.592	–0.2483	0.429	0.499	0.1074
EDUCATION	0.153*	0.081	0.0382	0.124*	0.073	0.0309
ORGANIZATION	–1.650*	0.887	–0.3682	–1.209	0.853	–0.2807
CREDIT	–2.682***	0.608	–0.5853	0.158	0.526	0.0395
AGRILAND	–0.168***	0.053	–0.0422	–0.015	0.012	–0.0038
DISTANCE	–0.004***	0.001	–0.0012	–0.004***	0.001	–0.0009
EXPERIENCE				0.253***	0.056	0.0633
Intercept	4.731**	2.026		–3.476**	1.503	
Log–likelihood						

Note: * indicates the significant level; *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$
s.e stands for standard error; dy/dx indicates marginal effects.
Source: Own estimates; data appendix available from authors.

could control and manage changes of farming systems via restriction/promotion of access to credit, particularly for the changes with high investment. Another striking result from the study is that those households with the greatest agricultural land (*AGRILAND*) were unlikely to adopt or change the farming system from sugarcane to shrimp at the significant level of 1 percent. The possible explanation is that if these households converted a small piece of land to mono–shrimp, the remaining land (sugarcane production) would be affected by saline water used for shrimp culture. The distance from sugarcane fields to river (*DISTANCE*) had a negative effect on the decision of change at 1 percent of significant level. This result indicates that those who have sugarcane fields far from rivers are unlikely to change their farming system. This result again confirms that the salinity level is positively correlated with the changes of farming systems. Based on the marginal effect of –0.0012, it suggests that if the distance of sugarcane fields to rivers decreases (increases) one meter, the probability of adoption of the new farming system increase (decrease) about 0.12 percent. The positive coefficient of household head' education (*EDUCATION*) at 10 percent of significant level means that if the educational level of household head increases (decreases) one schooling year, the probability of adoption increase (decrease) about 3.82 percent (Table 5).

In case of Kien Giang province (change of farming system from rice–shrimp to mono–shrimp), Table 5 shows that *DISTANCE* also negatively affects while *EDUCATION* and *EXPERIENCE* have significantly positive impacts on *ADOPTION*. Similar to the case of Soc Trang province, the significantly positive coefficient of household head' education (*EDUCATION*) at 10 percent level of significance indicates that if the educational level of household head increases (decreases) one schooling year, the probability of adoption of the new farming system increase (decrease) about 3.09 percent (Table 5). However, the marginal effect of this variable is smaller in Soc Trang than that in Kien Giang province. The most striking feature is that the distance from fields to river (*DISTANCE*) had a negative effect on the adoption at the significant level of 1 percent. This result indicates that those who have land far from river are unlikely to change their farming system. Based on the marginal effect of –0.0009, it suggests that if the distance of fields to river increases (decreases) one meter, the probability of adoption of the new farming system decreases (increases) about 0.09 percent. The possible explanation for this result is that the rice–shrimp fields with geographic proximity to river are highly exposed to salinity intrusion so they had to change their farming system to adapt to salinity intrusion. Finally, the study also found that the shrimp experience (*EXPERIENCE*) has a positive impact on change of farming system at the significant level of 1 percent. With one more year increase of shrimp experience, the probability of adoption increase 6.33 percent, keeping the other variables at means.

CONCLUSIONS

The findings of this study contribute to the limited body of research on socio–economic and physical factors affecting the changes of farming systems in the VMD under the context of salinity intrusion. The changes of farming system have been occurring as an inevitable trend under the effects of salinity intrusion. The economic performances of destination or new farming systems were much higher than the old ones. The higher economic performance is considered as an important determinant of farming system changes.

Based on the logit model, the study found that the household head' educational level is significantly and positively associated with the adoptions in two cases.

More importantly, the distance from fields to rivers or salinity level is considered as an important factor affecting negatively the changes of farming systems in the coastal areas. In case of change from sugarcane to mono–shrimp, the study found that the number of female labor, accessing to credit, membership in organization, distance from sugarcane to rivers and total agricultural land negatively affect the adoption. In case of change from rice–shrimp to mono–shrimp, the study found that the distance of rice–shrimp fields to river negatively effects while shrimp experience is positively correlated with the adoption of new farming system. The current study also suggests further research on investigating the differences in technical, economic efficiency and market opportunities among farming systems in order to provide comprehensive adaptation options for farmers in the coastal areas of the Mekong Delta.

AUTHOR CONTRIBUTIONS

Nguyen Thuy Trang designed the study questionnaire, collected and analyzed the data, and drafted the manuscript; Vo Hong Tu and Huynh Viet Khai analyzed the data, and drafted the manuscript; and Mitsuyasu Yabe supervised the research and made critical revisions to the manuscript under the Technical Cooperation Project "Building capacity for Can Tho University to be an excellent institution of education, scientific research and technology transfer" of JICA. All authors read and approved the final manuscript.

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