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Determinants of Farmers' Climate Change Adaptation Strategies: A Case of Saltwater Intrusion and Rice Production in the Central Coastal Region of Vietnam

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Abstract: This study analyzes the factors that influence the choice of saltwater intrusion adaptation strategies of farmers living in Vietnam's Central Coastal region, using a multinomial choice model fitted to data from a cross-sectional survey of 414 farmers. The adaptation strategies identified include cultivating new varieties of rice or switching to papyrus planting, vegetable planting, shrimp production, or lotus–fish production. The results reveal that family size decreases the likelihood of applying new varieties of rice and plant papyrus but increases the probability of applying shrimp production. The level of education of the household's head negatively impacts the probability of switching to new varieties of rice and shrimp production but positively affects the odds of implementing papyrus and vegetable production. The older, more experienced farmers are more likely to cultivate new varieties of rice. Regarding the farm's characteristics, the higher the percentage of salted land and the less serious the saltwater intrusion level, the higher the probability of switching to shrimp or lotus–fish production. Access to information from the local authorities, taking part in training courses, and being a member of Vietnamese Women Union all promote adaptation to saltwater intrusion. From a policy perspective, we recommend that the government develop official media channels to promote saltwater intrusion adaptation, organize more training courses for farmers, support the activities of the Woman Union, and relax constraints on accessing public credit.

Keywords: *Saltwater Intrusion, Adaptation Strategies, Multinominal Choice Model, Central Coastal Region*

Introduction

Many reports indicate that developing countries are expected to suffer the most from the negative impacts of climate change (CC) and extreme weather events due to their high dependency levels on agriculture and the majority of their inhabitants living in rural areas, where agriculture is the main source of income (Field, Barrows, and IPCC 2014; World Bank, UNDP, and MPI 2016). It is predicted that for parts of Asia, crop yields will decline up to 10% in the 2020s and 30% in the 2050s, compared to the 1990s (Field, Barrows, and IPCC 2014). Looking at the long-term climate risk index, out of the top ten countries with the highest risks, seven are located in Asia (Eckstein et al. 2019). Vietnam ranks sixth in the list of countries that have been affected most by CC over the last twenty years in terms of deaths per inhabitant and economic losses per unit of GDP as the country has witnessed the highest number of extreme weather events of all countries (Eckstein et al. 2019). Moreover, with Vietnam being the second biggest rice exporter in the world, its agricultural sector, and its rice production in particular, will strongly be impacted by CC. For example, GFDRR (2011) warned that in the absence of

adaptation, the productivity of Vietnamese rice production would suffer a decrease by 3.4% to 6.7% in 2050 compared to the 1990s, affecting not only the livelihoods of farmers in the country but also the stability of the Vietnamese economy as a whole. Some researchers have indicated that the Central Coastal region of Vietnam is a considerably vulnerable area to CC (McElwee 2010; Minh 2019; Boateng 2012), as the region is more strongly exposed to salinity problems, droughts, and sea level rise compared to other regions in the country. Especially, saltwater intrusion (SWI) that is known as the consequence of landward intrusion into coastal aquifers (Safi et al. 2018) is expected to exceed the currently designed heights of the sea dike system more frequently in the Central Coastal region of Vietnam than in other regions (Thuc et al. 2015). In addition, it is predicted that the region may experience an increased occurrence of droughts from water shortages of 23% to 40% by 2070, while the temperature is projected to rise by around 1.15°C in inland Central Vietnam, resulting in higher evaporation rates, further increasing drought risks (Minh 2019). All of the foregoing implies further increases in SWI risks in the region. Given the urgency involved in tackling SWI issues, several studies have been conducted to scrutinize the impact of CC on agricultural production in Vietnam's Central Coastal region and to identify suitable SWI adaptation measures. Shrestha, Deb, and Bui (2016), for instance, estimate that CC will reduce rice yields in the study area by 1.29% to 23.05% during the winter season (Shrestha, Deb, and Bui 2016). In response to SWI threats, farmers in the region have initiated some autonomous and planned adaptive measures, including changing sowing dates, moving to salt-tolerant varieties of rice and switching to other crops, or aquaculture production (Minh 2019).

Piya, Maharjan, and Joshi (2013) state that a thorough understanding of the determinants underlying farmers' decisions to implement specific adaptation strategies can help policymakers to promote proper responses to the climatic change impacts (Piya, Maharjan, and Joshi 2013). While the number of studies that measure both the physical and the financial impacts of CC on Vietnamese agriculture is increasing (Smyle and Cooke 2012; FAO 2011; Parker et al. 2019; Ho 2018), we only found two studies that examine the factors that impact farmers' decisions regarding CC adaptation. It is reported that farmers in Central Vietnam were found to have been applying adaptation strategies to overcome changes in temperature and rainfall and that the determinants of adaptation decisions are different for poor and nonpoor farm households (Van et al. 2015). However, this research only focuses on a binary choice—adapting versus non-adapting, without focusing on the different adaptation measures that were implemented. Thoai et al. (2018) have carried out a more extensive analysis by applying not only a binary logit model but also estimating a multivariate probit model to examine the different factors influencing farmers' decision to adopt different CC adaptation strategies in their agricultural production (Thoai et al. 2018). However, this study focuses on agricultural production in general, and not on rice production in particular. We did not find a study focusing on the determinants of farmers' choices regarding SWI adaptation in rice production. Therefore, the purpose of this study is to identify the determinants of farmers' choices regarding the current implementation of SWI adaptation strategies in the study area. In doing so, we want

to bridge this knowledge gap in order to support local policymakers in the study area in the promotion of SWI adaptation strategies. The focus of this research is rice farmers in the Central Coastal region of Vietnam, yet we believe that this research will also contribute to a wider understanding of farmers' responses to CC in developing countries. Adaptation to CC in the agricultural sector can and will take a variety of forms ranging from farm-level measures to national and global-level plans (Field, Barrows, and IPCC 2014). The adaptation on each scale has its characteristics. In this study, we focus on the adaptation at the individual farm level to understand the driving factors of farmers' adaptation choices.

Empirical Model

The most widely used approach in adaptation choice research (with multiple adaptation options) is the multinomial probit (MNP) or multinomial logit (MNL) models (Hassan and Nhemachna 2008). Both models are appropriate when the dependent variable at hand is neither binary nor continuous. This study used an MNL to analyze the various factors affecting farmers' choices in applying adaptation strategies to SWI in agricultural production. This is because (1) it is suitable for our research question—that is, examining farmers' adaptation choices involving multiple possible adaptation strategies (Sarker, Alam, and Gow 2013), (2) it allows for easier computations and more precise estimates compared to MNP (Kropko 2008; Cheng and Long 2007), (3) MNP causes difficulty in the estimation process (Cheng and Long 2007), (4) MNL has been widely and successfully applied by previous scholars (Bryan et al. 2009; Deressa et al. 2009; Hassan and Nhemachna 2008).

Farmers' choice of adaptation measures is discrete and mutually exclusive. In the context of this study, a farmer selects a measure from six alternatives (see Table 2). Let D_i denote the random variable representing the adaptation strategy chosen by farmer i. Next, we assume that the choice of adaptation measures depends on a number of factors such as weather variability, socioeconomic characteristics, and institutional and environmental attributes (referred to as X). The MNL model for adaptation choice identifies the relationship between probability of choosing one adaptation strategy and the set of factors X (Greene 2003):

$$\text{Prob}(D_i = j) = \frac{\exp^{\beta_j^i X_j}}{\sum_{k=0}^{j} \exp^{\beta_k^i X_j}}, j = 0, 1, \ldots, J \quad (1)$$

where βj is a vector of coefficients on each of the independent variables X. The MNL model builds on the assumption of independence of irrelevant alternatives (IIA)(Deressa et al. 2009; Sarker, Alam, and Gow 2013), which refers here to the fact that the probability of applying one adaptation strategy by a given farmer is to be independent of the probability of choosing another adaptation strategy—that is, P_j / P_k is independent of the attributes of any other strategy of an alternative set (Hausman and McFadden 1984).

The estimated parameters of the MNL model present only the direction of the effect of independent variables on the influential (dependent) ones, but they do not estimate either the actual magnitude of change or the probabilities (Deressa et al. 2009). By differentiating Equation 1, the marginal effects are derived to scrutinize the effects of explanatory variables on the probabilities.

$$\delta_j = \frac{\partial P_j}{\partial x_i} = \text{Prob}_j \left[\beta_j - \sum_{k=0}^{j} \text{Prob}_k \ \beta_k \right] = \text{Prob}_j [\beta_j - \bar{\beta}] \quad (2)$$

Equation 2 indicates the expected change in probability of a particular choice being caused by a unit change in an explanatory variable from the mean (Greene 2003).

An MNL model is constructed by choosing one category that is indicated as the "reference state" or "base category." In this study, the "no-adaptation" strategy is used as the base category. To check the multicollinearity among the explanatory variables, we calculate the correlation between variables. We also test the model for multicollinearity using the variance inflation factor (VIF). The VIF of all included variables is less than ten, which reflects that multicollinearity is not a serious problem in this model. In the last step before conducting the logit model, we test the independence of the IIA assumption by using the Hausman test with a null hypothesis of independence of the SWI adaptation strategies. (For the case of eliminating Apply_new_varieties of rice, χ^2 is negative, we use the SUEST test). All tests failed to reject a null hypothesis, implying that the application of MNL is appropriate to model the SWI adaptation practices of our study.

The limitations of the methodology applied in this study are mainly twofold. First, this study is based on farm-level data from only 414 farmers from a select number of communes. Therefore, caution needs to be applied to generalizing the results. Second, IIA is a restrictive assumption, while real choice problems tend to violate the IIA assumption (Jaeger and Rose 2008).

Study Area, Data Collection, and Model Variables

Study Area

The Central Coastal region of Vietnam is dominated by a subtropical humid climate with two main seasons: dry and rainy. This region has nine provinces with a population of 12.6 million[1] and accounts for 19%[2] of the total surface of Vietnam, which is 706,000 (10%) ha of paddy fields. In our study, we selected the Thua Thien Hue and Quang Nam Province because these two provinces satisfy our location criteria, including (1) leaders in rice production surface (2), a high proportion of SWI-affected areas, (3) some adaptation strategies have been applied by farmers. In the Thua Thien Hue province, 6% of the 84,400 ha of paddy land is affected by SWI. Within this province, the district of Quang Dien was selected as the first study area given its high proportion of paddy fields affected by SWI (13%) (DARD 2019). The

[1] See: https://www.gso.gov.vn/px-web-2/?pxid=V0201&theme=Dân%20số%20và%20lao%20động.

[2] See: https://www.gso.gov.vn/px-web-2/?pxid=V0613&theme=Nông%2C%20lâm%20nghiệp%20và%20thủy%20sản.

province of Quang Nam has 87,396 ha of paddy land, of which 7,816 ha is saline (9%) (DARD 2019). Here, we chose the Duy Xuyen district as the second study area, since it is the district in which SWI is most problematic—affecting 2,258 ha of paddy field, or 29.1% of the total paddy land surface. In each district, three different communes were selected as representatives of three different levels of SWI impacts (high, moderate, and mild). In both districts, the majority of affected paddy fields are located alongside the coast or a tidal river. The risk of SWI is particularly high in the summer season, with large negative impacts on rice production. In some areas, the water sources used for irrigation have turned saline due to high salinity levels of the soil in combination with seawater intrusion, sometimes even in the rainy season. To cope with SWI, about half of the farmers in the study area have started to apply adaptation strategies over the last five years, and many more plan to apply adaptation strategies over the coming years.

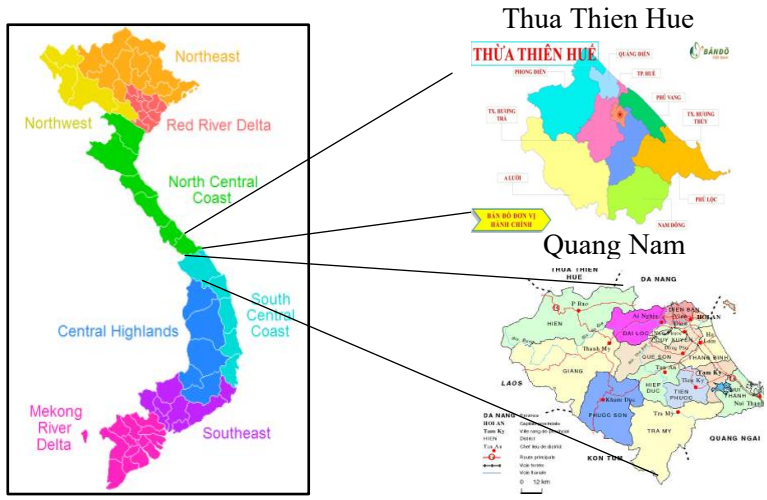

Figure 1: Study Area

Source: Bando Vietnam 2022a, 2022b; Wikiwand, n.d.

Data Collection

The data for our research were collected through farm-household surveys and Focus Group Discussions (FGDs) in both the Quang Dien and Duy Xuyen districts. Two FGDs (one per district) were organized in which members representing the Agricultural and Rural Development Department (Economic division), Cooperatives, Farmer Unions, and farmers participated FGDs were organized on two separate occasions: once before designing questionnaires and once before conducting the official survey to refine and finalize questionnaires. A pilot survey was conducted to pretest the questionnaires with a sample size of thirty in each district.

We used a multistage stratified random sampling strategy for the survey underlying this research based on the percentage of households in each district who did or did not adapt to

SWI, taking into account current implementation rates of the different adaptation strategies, to calculate the number of each household type to be included in the survey. The sample of each adaptation strategy as well as of non-adapters is divided into three levels of SWI (high, moderate, and mild) and takes into account the percentage of poor households (See Table 1). There are various ways to determine the level of SWI—testing for soil quality or checking salinity levels in irrigation water and location—but due to the lack of official information on SWI levels in our study area, we made use of the expertise of FGD participants, who indicated the levels of SWI plots. In the final stage, individual farm households were chosen randomly from the official household lists of the communes. To collect data, face-to-face interviews were conducted by twelve interviewers who had been intensively trained. The eligible interviewees are heads of household or their spouses. For the non-adaptation cases, we made sure that the farmers were still growing rice in their salted paddy fields. These farmers could have previously applied adaptation strategies but not for the last four years. For the adaptation cases, we only included farmers that had been implementing an adaptation strategy for the last two or three years before being interviewed. The total sample size for each district is 200, but we visited 220 farmers (10% for backup). The final number of valid questionnaires is 205 for the Duy Xuyen district and 209 for the Quang Dien district.

Table 1: Surveyed Area

Provinces	*Districts*	*Communes*	*Vulnerability to Climate Change*
Thua Thien Hue	Quang Dien	Quang Phuoc	High
		Quang An	Moderate
		Quang Thanh	Mild
Quang Nam	Duy Xuyen	Duy Vinh	High
		Duy Phuoc	Moderate
		Duy Nghia	Mild

Model Variables

The dependent variable in the empirical estimation is the choice for one particular SWI adaptation strategy from the list of adaptation options in Table 2. Based on field observations, we identified five adaptation strategies that farmers could potentially implement to cope with SWI in the study area. Farmers in the study area own or partly rent small plots of land and apply one agricultural production method—that is, traditional rice farming, or one of the SWI adaptation strategies listed in Table 1. In addition, we noted that in the study area, almost all farmers have small sizes of arable land in which salted plots account for the majority of the total land surface. Therefore, the "SWI situation" is a plot-related variable and might reflect the farm situation. The situation that farm households own more than one plot and combine different adaptation strategies is not the case in our study area.

Table 2: Farmer SWI Adaptation Strategies

Strategies	*Frequency*	*Percentage*	*Description*
Non-	229	55	Farmers don't apply any adaptation strategy at interview time.

Strategies adaptation	*Frequency*	*Percentage*	*Description*
Apply New Varieties of Rice	89	21	Farmers continue to produce rice but switch to new varieties that are more salt tolerant. The local cooperatives sell new rice varieties to farmers at a price below that of the market.* The main disadvantage of this strategy is that the yield is about 25% lower than that of traditional rice.**
Planting Papyrus	29	7	Farmers convert their paddy plots into papyrus fields. This crop is neither labor nor capital nor time intensive. The main limitation of this adaptation strategy is that the consumption market tends to be unstable: papyrus is the main input of the mat industry, which faces a narrowing demand as consumer preferences change.
Shrimp Production	46	11	Farmers convert their land to build ponds for shrimp cultivation. In the process, land is sometimes combined with that of their neighbors. This adaptation strategy requires high initial investments and technical support from the local agricultural extension office. Shrimp production can bring about higher profits, but farmers face many risks ranging from diseases to fluctuating selling prices.
Planting Vegetables	10	3	Farmers convert their paddy plots into vegetable fields. Revenues for farmers typically increase, yet profits may not as this strategy is labor intensive (planting, caring, and harvesting). Moreover, cultivating vegetables requires substantial amounts of irrigation, and farmers may face water shortages in the dry season.
Lotus–Fish Production	11	3	Farmers convert their paddy fields into fish ponds in which lotus plants are grown and fish are kept at the same time. Farmers get revenues from both fish and lotus products. This strategy requires lower initial investments than shrimp cultivation, and the risks involved are also lower.
Total Number of Respondents	414	100	

Notes: *The price of agricultural materials is subsidized by the government. **This result is from a key informant interview.

The set of explanatory variables is drawn from the literature, taking into consideration data availability. The most widely used model to identify the determinants of farmers' adaptation choices is the so-called socioeconomic model. This model has been applied by, among others Bryan et al. (2009); Seo and Mendelsohn (2008); Deressa et al. (2009); Hassan and Nhemachna (2008); Nyangena (2008); Anim (1999); Below et al. (2012); Sarker, Alam, and Gow (2013); Apata, Samuel, and Adeola (2009).

Based on the FGDs and key informant interviews, we recognized that specific cognitive characteristics—for example, CC awareness, perceived risks, adaptive capacity, and subjective norms—also matter for current adaptation choices, yet working with recall questions for cognitive variables is not feasible. Therefore, we decided to only use socioeconomic variables to explain the choices of farmers in the past.

In socioeconomic models, the determinants of CC adaptation choices are often combined into different groups or clusters, such as climatic factors, soil characteristics, assets (e.g., machinery, animals), inputs of agricultural production, household and head of household

characteristics, social capital and the institutional environment, and farm characteristics (Hassan and Nhemachna 2008; Thoai et al. 2018; Di Falco, Veronesi, and Yesuf 2011; Nyangena 2008). Because our research objective is to identify the determinants of farmers' choice for the actual adaptive strategy, we carefully selected the factors that either do not change over time such as farmers' characteristics or that can be targeted by recalled questions.

Previous research indicates that participating in CC training and farm size play crucial roles in explaining the probability of adapting to CC, whereas the availability of family labor and membership in local organizations is often found to not have a significant impact (Thoai et al. 2018; Di Falco, Veronesi, and Yesuf 2011). Moreover, institutional factors such as access to information on CC and access to credit enhance adaptation to CC (Van et al. 2015; Hassan and Nhemachna 2008). In addition, farmer-to-farmer extension and the number of relatives in the local area also positively impact on adaptation to CC (Di Falco, Veronesi, and Yesuf 2011). Being inspired by the foregoing studies and by the FGDs that we organized, we combine the explanatory variables in our study into three groups: household characteristics, farm characteristics, and institutional environment. Descriptive statistics of all independent variables are presented in Table 3. As the independent variables should not be impacted by the choice of adaptation to build an MNL model, we use recall data going back to the time of the farmer's choice to adopt for the variables related to the institutional environment that could have impacted this choice.

Table 3: Description of Independent Variables

Independent Variables	*Mean*	*SD*	*Description*
Family Size	6.27	1.33	Continuous
Education of Household's Head	0.41	0.49	Dummy, takes the value of 1 if secondary school and above, 0 otherwise
Age of Household's Head	50.73	5.71	Continuous
Percentage of Salt Land	78.03	16.80	Continuous
SWI_high	0.323	0.468	Dummy, takes the value of 1 if high SWI level, 0 otherwise
SWI_mild	0.309	0.462	Dummy, takes the value of 1 if mild SWI level, 0 otherwise
Access to Information from the Government	0.67	0.46	Dummy, takes the value of 1 if yes, 0 otherwise
Member of Vietnamese Women Union	0.65	0.47	Dummy, takes the value of 1 if yes, 0 otherwise
Access to Public Credit	0.18	0.38	Dummy, takes the value of 1 if yes, 0 otherwise
Attendance in a Training Course	0.46	0.49	Dummy, takes the value of 1 if yes, 0 otherwise

Household's Characteristics

Previous studies have shown that there is a positive relationship between a higher education level and implementing adaptation techniques to CC (Lin 1990; Igodan, Ohaji, and Ekpere 1988; Maddison 2007). Hence, the level of education of the household head is expected to be positively correlated with the probability of the adaptation choices since higher-educated farmers can better absorb new knowledge and more easily implement adaptation strategies to tackle CC issues.

The age of the household head can reflect their level of experience with farming. Some empirical studies indicate that there is a positive relationship between age and the probability of adopting new techniques (Hassan and Nhemachna 2008; Deressa et al. 2009; Van et al. 2015; Anim 1999), yet others find a negative effect—for example, Shiferaw and Holden (1998) reported a negative correlation between age and the adaptation of soil conservation practices. In our study, the age of the household head can both positively or negatively impact adaptation choices, taking into consideration the technical skills required for each adaptation strategy (Shiferaw and Holden 1998). On the one hand, we expect that as older farmers are more experienced in traditional farming activities, they will more easily switch to new rice varieties or other crops such as papyrus or vegetables—adaptation strategies that demand fewer technical skills. On the other hand, we expect younger farmers to be more inclined to take up more recent adaptation strategies that require high technical skills such as shrimp or lotus–fish production. Therefore, in our study age is expected to have different impacts on different SWI adaptation choices.

Finally, when considering family size, Di Falco, Veronesi, and Yesuf (2011) found that the higher the number of people in the household, the higher the probability of adapting to CC in a case study of farm households in Ethiopia. Other studies—for example, Van et al. (2015) and Deressa et al. (2009), reported nonsignificant relations between family size and probabilities to adapt. Looking at the specific CC adaptation strategies, Hassan and Nhemachena (2008) reported that a larger family size leads to a focus on more labor-intensive adaptation measures. However, in the study on CC adaptation in South American farms, Seo and Mendelsohn (2008) demonstrate that larger families are less likely to switch to other crops when adapting to CC. In our study, however, we expect the sign of family size to be positive because labor still plays a crucial role in agricultural activities in the rural areas of Vietnam.

Farm's Characteristics

We expect that households that face more pressing challenges from SWI, either through (1) a higher percentage of salted land (compared to total farmland) or (2) higher salt levels on their affected plots, are more likely to adapt to SWI. These independent variables are new compared to the literature as our study is the first to focus on SWI adaptation strategies.

Looking at the set of specific SWI adaptation strategies in this study, we anticipate different impacts from the SWI level on the plots for different adaptation strategies. Some of the SWI adaptation strategies can only be implemented at certain levels of SWI—for example, shrimp, lotus–fish, and vegetable production cannot be implemented on plots that suffer severe SWI impacts. New rice varieties and papyrus production can be applied to all types of plots. For this reason, we expect different signs for the level of SWI situation that farmers are facing in the models for the different adaptation strategies.

We also expected that farm size could be an important variable that impacts farmers' choices regarding the implementation of different adaptation strategies, but we do not have recall data for this variable. Given that some of the adaptation strategies potentially lead to

an accumulation of plots (e.g., for aquaculture), using farm size data at the time of our data collection might be misleading—so we chose not to include this variable in the models that we report. We did, however, estimate an MNL model with the farm size at the time of the interviews and found that this variable only has marginal effects on the outcome of one adaptation strategy (shrimp production).

Institutional Environment

Access to credit is a variable that describes a situation in which farmers have used money from the financial organizations to purchase inputs for conducting adaptation strategies. Vietnamese rural farmers can borrow money from a state bank (at a low interest rate), an NGO project (at a low interest rate), or on the black market (at a high interest rate). Thoai et al. (2018), Van et al. (2015), Di Falco, Veronesi, and Yesuf (2011), and Hassan and Nhemachena (2008) report that households who have access to credit are more likely to adapt to CC. Deressa et al. (2009) find that access to credit has a positive and significant impact on the likelihood of implementing soil conservation techniques. Thoai et al. (2018) and Van et al. (2015) confirmed that the more farmers can access credit services, the higher the chances of adapting to CC in Vietnam. In this study, we assume that access to credit has a positive impact on farmers' choices to adapt to SWI. In our model, we focus explicitly on public credit—that is, loans from the Vietnam Bank of Social Policies—because this is the only official credit channel that offers low interest rates to farmers.

Access to information on CC and its impacts is also found to be an important determinant in most adaptation strategies. Thoai et al. (2018), Van et al. (2015), Di Falco, Veronesi, and Yesuf (2011), Hassan and Nhemachena (2008) and Deressa et al. (2009) show that having information on climatic variability positively impacts the likelihood of implementing adaptation strategies. Hence, in our study, it is expected that if a farmer can access information related to the government's policies on CC and—in our case—SWI, the probability of implementing adaptation strategy increases.

Attendance in training courses to get acquainted with new techniques in agricultural activities is similarly expected to have a positive impact on adaptation choices. Based on the FGDs we organized, training courses in the study area are conducted by the agricultural extension office. Therefore, in this study, we consider attendance in such training courses as one of the ways that farmers access agricultural extension services. Thoai et al. (2018), Van et al. (2015), Di Falco, Veronesi, and Yesuf (2011), Hassan and Nhemachena (2008), Deressa et al. (2009), and Van et al. (2015) reveal that access to agricultural extension services plays an important role in farmers' decisions to adapt. As a result, we hypothesize that attendance in training courses raises the probability of implementing adaptation options to tackle SWI.

Finally, as noted by Nyangena (2008), being a member of an association is considered to be an important indicator of social capital that could facilitate adaptation processes. However, Thoai et al. (2018) conclude in their study that there is no significant relationship between membership in local organizations and farmers' chances of adapting to changes in climatic

conditions in the case of North Central Vietnam. In this study, we will assess social capital through membership of the Vietnamese Women's Union[3] (either the female household head or the wife of the male household head) rather than membership of the Farmer Union because (1) almost all local farmers are members of the Farmer Union and (2) the Vietnamese Women's Union usually offers small credits to farmers that might increase the probability of implementing an SWI adaptation strategy.

All of the foregoing variables related to the institutional environment were collected through recall questions in the survey, so the interviewed household head responded to each about the time when the choice to adapt was made.

Results

The estimated coefficients of the MNL model, along with their levels of significance are presented in Table 4. Likelihood ratio statistics, as indicated by χ^2 statistics, are highly significant ($p < 0.0001$), confirming that the model has a strong explanatory power.

As mentioned previously, the estimated coefficients of MNL indicate only the direction of the impact of explanatory variables on the dependent variables but do not show the actual magnitude of change or probabilities (Greene 2003). Hence, we also check the marginal effect from MNL to showcase how the probabilities change when farmers make choices with respect to changes in independent variables.

Table 4: Parameter Estimates of the Multinomial Logit SWI Adaptation Strategies

Explanatory Variables	*Apply New Varieties of Rice*	*Plant Papyrus*	*Shrimp Production*	*Vegetable Production*	*Lotus–Fish Production*
	Coefficients	*Coefficients*	*Coefficients*	*Coefficients*	*Coefficients*
Family Size	0.648***	0.488*	0.450**	–0.446	–0.634**
Edu.of.head's.hh	–0.885**	–1.078*	–1.703**	0.910	–0.763
Age of hh's Head	0.100**	0.109*	0.022	0.048	0.079
SWI_high	–0.283	0.442**	–0.988**	–14.838*	–0.897
SWI_mild	–0.024	–2.850*	0.631	–0.097	1.123**
Per.of.salt.land	–0.039***	0.002	0.078***	0.020**	0.089***
Access information_Gov	0.743**	0.840	1.455***	–0.468	1.400
Member of VWU	2.110***	1.934**	2.258**	2.570*	2.621**
Access Public Credit	0.116	–0.124	–0.907**	1.183	0.313
Attendance in a Training Course	2.276***	2.438**	2.309**	2.390***	3.018***
Diagnostics					
Base Category	Non-adaptation				
Number of Observations	414				
LR χ^2	388.62***				
Log Likelihood	–333.41813				
Pseudo R^2	0.3682				

Note: ***, **, and * are significant at 1%, 5%, and 10% probability levels, respectively.

[3] We did not consider if farmers belong to Farmer Union because almost all farmers in rural areas are already members of this organization.

Table 5 represents the marginal effects with the respective levels of statistical significance.

Family size decreases the probability of adapting to SWI except for shrimp production. As can be seen in Table 4, family size significantly decreases the likelihood of applying new varieties of rice and plant papyrus. A unit increase in a household size would yield 9% and a 1.2% decrease in the probability of applying new varieties and plant papyrus to adapt to SWI in the study area. These results can be explained by the fact that (1) papyrus production requires less labor and (2) for new rice varieties, farmers prefer to invest labor in off-farm activities to compensate for the lower financial benefits associated with it. By contrast, increasing household size did significantly increase (by 1.9%) the probability of shrimp production. This result is coincident with the findings of Van et al. (2015).

The education level of the household head has both positive and negative impacts on the probabilities of the SWI adaptation strategies. Farmers with a degree from secondary school or higher tend not to choose to apply new varieties (–11.6%) or take up shrimp production (–4.9%). This can be explained by the fact that farmers with higher education levels tend to prefer off-farm activities to farm activities. In contrast, having a higher degree increases the probability of planting papyrus by 6.5%.

The older farmers are more likely to adopt new varieties of rice or plant papyrus. One unit increase in farmers' age results in a 1.3% and 0.3% increase in the probability of applying new varieties of rice and planting papyrus, respectively. This result can be explained by the fact that older farmers have spent most of their lives producing rice and papyrus, which is noted as the first SWI adaptation strategy that farmers applied, and as a consequence, they do not want to move to other crops or other agricultural activities. We did try to take into account age squared in our model to see whether there is a quadratic relation between age and adaptation choices, but we did not find evidence for it.

The percentage of salted land has a strong positive impact on the probability of adopting all adaptation measures except for applying new varieties of rice (negative impact) and planting papyrus (no impact). One unit increase in the percentage of salted land on the farmer's plot leads to a 0.2%, 0.03%, and 0.08% increase in the probability of adopting shrimp, vegetables, and lotus–fish production, respectively. At the same time, such a unit increase leads to a 0.6% decrease in the probability of applying new varieties of rice. This could potentially be explained by the fact that shrimp, vegetables, and lotus–fish production require larger surfaces, and, therefore, if the proportion of salted land rises, farmers tend to convert their paddy from rice cultivation to any of these three adaptation strategies.

The current SWI impact on the farmer's plot is found to have both negative and positive impacts on the probability of applying adaptation strategies in the study area. Being confronted with a higher SWI level on their plot leads to a 7.4% increase in the probability of applying papyrus and a 2.5% and 2.9% decrease in the probability of applying shrimp and vegetables production, respectively. Farmers facing mild SWI conditions are more inclined to switch to lotus–fish production (+0.6%). This reflects the fact that shrimp, lotus–fish, and

vegetable production have limitations in their levels of salt tolerance: if the SWI level passes a specific threshold, farmers are not able to apply either adaptation strategy to cope with SWI.

Better access to CC and SWI information from the government is found to promote the implementation of applying new varieties of rice (+8.5%) and shrimp production (+3.6%).

Households in which the female household head or the wife of the male household head is a member of Vietnamese Woman Union are more likely to implement all of the adaptation strategies under consideration. We find that being a member of the Women Union results in 21.6%, 4.1%, 4.9%, 0.04%, and 1.3% increases in the probability of applying new rice varieties, shrimp, planting papyrus, switching to vegetable production, and lotus–fish production, respectively. Despite the dominance of male household heads in rural areas of Vietnam, the role of female family members is strengthened thanks to the support from the Vietnamese Women Union. Having a woman in the household who is a member of the Vietnamese Woman Union also increases the chances of having access to small credits sponsored by this organization or by NGOs.

Access to public credit is found to only influence the probability of adopting shrimp production. When deciding about implementing an SWI adaptation strategy, farmers consider the availability of different kinds of credit, and especially their access to public credit lines that typically have a lower interest rate. We find that farmers who get a loan from the Vietnam Bank of Social Policy are 2.7% more likely to apply for shrimp production. Our data show that only 18% of the interviewed farmers have accessed public credit. This might explain why the impact of this variable is not significant in the models for other adaptation strategies.

Taking part in training courses strongly promotes switching to all SWI adaptation strategies except vegetable production. Farmers who take part in training courses are 26.9%, 7.5%, 5.7%, and 2.0% more likely to apply the new rice varieties, papyrus, shrimp, and lotus–fish production, respectively. This finding might be explained by the fact that producing on saline soils requires more updated technical knowledge that can only be taken up through training courses.

Table 5: Marginal Effects from the Multinomial Logit SWI Adaptation Strategies

Explanatory Variables	*Apply New Varieties of Rice*	*Plant Papyrus*	*Shrimp Production*	*Vegetable Production*	*Lotus–Fish Production*
	Coefficients	*Coefficients*	*Coefficients*	*Coefficients*	*Coefficients*
Family Size	–0.09***	–0.012*	0.019**	–0.00008	–0.004
Education of Household's Head	–0.116**	0.065*	–0.049**	0.003	–0.004
Age of Household's Head	0.013**	0.003*	0.0003	0.0002	0.0004
SWI_high	–0.025	0.074**	–0.025**	–0.029*	–0.005
SWI_mild	0.014	–0.010	0.017	0.017	0.006**
Percentage of salt land	–0.006***	0.0002	0.002***	0.025**	0.0007***
Access to Information from Government	0.085**	0.020	0.036**	–0.001	0.008
Member of VWU	0.216***	0.041**	0.049**	0.0004*	0.013**
Access to Public Credit	0.021	–0.004	0.027**	0.004	0.002
Attendance in a Training Course	0.289***	0.066**	0.059**	0.022***	0.022***

Note: ***, **, and * are significant at 1%, 5%, and 10% probability levels, respectively.

Discussion and Conclusion

This study analyzes the determinants of farmers' choices related to SWI adaptation strategies on cross-sectional survey data collected in the Central Coastal region of Vietnam. An MNL model is estimated to identify the factors impacting farmers' choices. The different values that the dependent variable can take relate to the different production activities of farm households that either produce traditional rice or any of the five different SWI adaptation strategies that have been identified in the study area. The independent variables in the model include factors related to household characteristics, farm characteristics, and the institutional environment at the time of the adaptation choice. Before running the MNL model, the IIA assumption is tested by the Hausman and SUEST test. The results indicate that there is no evidence that the IIA assumption is violated, justifying the application of an MNL model. Marginal effects from MNL are used to evaluate the change in the probability of a certain choice being picked (compared to the base category of sticking to traditional rice production) with respect to a unit change in any given explanatory variable.

The results reveal that household characteristics do not have a clear impact on the choice of adaptation strategies. While Van et al. (2015) did not find any impacts of family size and educational level of household head on farmers' CC adaptation decisions, we find that family size and the education level of the household head both negatively and positively impact the farmers' choices of implementing specific SWI adaptation strategies. These results could be explained by the differences among the adaptation strategies in terms of technical and labor requirements. For example, farmers with a degree from secondary school or above are more likely to cultivate vegetables as these agricultural products require a more hands-on approach in the selling phase (i.e., reaching out to customers). Moreover, for the last ten years at least, young and well-educated farmers have been moving away from farm activities to off-farm activities due to decreasing revenues from agricultural production. Hence, the number of family members and the education level of the household head are found to have a negative impact on the probability of farmers choosing new rice varieties as an SWI adaptation strategy. We expected the age of the household head to have different impacts on different adaptation strategies, but our results show that this variable is either nonsignificant or positively impacting on the probability of switching to certain adaptation strategies (new rice varieties and papyrus). These results are consistent with the findings of Hassan and Nhemachena (2008).

In contrast, the impact of farm characteristics on the probability of adopting SWI adaptation strategies is very clear. The results of our empirical analyses confirm that the higher the percentage of salted land, the higher the probability of switching to shrimp, vegetable, or lotus–fish production. However, if the percentage of salted land increases, farmers are less likely to adopt new varieties of rice as an SWI adaptation strategy. Based on the FGD, we noted that when facing SWI problems, farmers have two options: (1) sticking to traditional rice production with lower costs at the beginning but a proportion of paddy plants that die or (2) switching to new rice varieties with higher upfront costs but a lower death rate of paddy plants. Different factors—for example, risk aversion and financial

constraints—can explain why some farm households continue to produce traditional rice even if the percentage of salted land is big. The results of our survey show that the percentage of salted land for non-adapters is 78.4%, while this percentage for the adapters is 77.5%.

Another important finding in our study is the weak and insignificant impact of accessing public credit. This is not consistent with the findings of Di Falco, Veronesi, and Yesuf (2011) in the case of Ethiopia, yet it is consistent with the conclusion of Thoai et al. (2018) in the case of Central Vietnam. This finding can potentially be explained by the fact that although farmers prefer to make use of public credit, only very few can access it due to specific conditions or requirements: (1) the amount of money is often much less than what farmers need,[4] (2) the administrative procedures involved are complicated and time-consuming, (3) the number of potential borrowers is limited.[5] Therefore, farmers have to choose other kinds of credit that are more flexible and more easily accessible, despite the higher interest rate to be paid. Access to public credit was expected to have a strong and positive impact on the probability of implementing adaptation strategies, yet our results show otherwise as only the odds of implementing shrimp production are marginally influenced by this variable. The unclear and weak impact of the public credit variable can be linked to the fact that only 18% of the total sample has accessed this kind of credit in our study, and, therefore, it might be that for some SWI adaptation strategies only a small number of farmers or even no farmers can access public credit. Further research is necessary to examine the impact of this variable on farmers' choices with respect to SWI adaptation.

In our study area, the farmers are the ultimate decision-makers when it comes to adapting or not adapting to a changing SWI situation. However, there is an important role for policy interventions because local authorities shape the environment in which these decisions are taken (Renaud et al. 2015). In our study, the role of the government is reflected through the institutional factors included in the models. Our results show that CC and SWI information and policies from the government and the ability to participate in training courses strongly enhance SWI adaptation. At the moment, local authorities in the study are subsidizing the purchase of salt-tolerant varieties of rice for farmers who want to move away from traditional rice production. Therefore, farmers who plan on switching to new rice varieties methods need to update information about subsidizing schemes to know who can receive government's subsidy and when. As the lotus–fish production is a new adaptation strategy in the Central Coastal region of Vietnam, distributing official information related to the techniques involved and the market potential of the production is very important to farmers when deciding to implement this strategy. Hence, policymakers have to focus on setting up official channels that can provide updated information related to CC, SWI and new adaptation strategies, and techniques. Moreover, local authorities need to organize more

[4] The average amount of money at any single time is 10 million VND = around 430 USD.

[5] Only poor households or farmers who are investing in the project that receives approval from local authorities can borrow money.

training courses where farmers can learn how to adapt to SWI. Finally, our results indicate that being a member of the Vietnamese Women Union positively affects SWI adaptation. Policy interventions that encourage women to participate more in this organization can further promote adaptation to SWI in the study area.

In conclusion, local authorities in the study area are recommended to increase public investments in technical support and demonstrations of different SWI strategies, to develop reliable information channels for CC and SWI information, to promote equal chances for women, and to support effective microcredit services. In the context of rising sea levels and increasing impacts of CC, SWI is an inevitable consequence that many areas in the Central Coastal region of Vietnam will face shortly. Therefore, farmers in the study area should no longer delay adapting to SWI. The results of our study can help local authorities to develop a suitable set of policies that effectively encourage farmers to adapt to SWI.

Almost all the data in this study are primary cross-sectional data for measuring the economic and social indicators as well as identifying the determinants of farmers' choice-making. However, because all the data were collected at a certain time, the time-temporal effects have not been taken into account. Hence, we did not capture the effect of weather conditions, disease dynamics, or fluctuation of prices of input and outputs, and so on. Moreover, recalling methods in interviewing might cause some bias, especially for the old interviewees' case.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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