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Estimating the Economic Impacts of Climate Change on Crop Production in the Coastal Provinces of the Mekong Delta, Vietnam

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August, 2015

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EXECUTIVE SUMMARY

This study used the Ricardian approach to examine the economic impacts of climate change on crop production in the coastal provinces of the Vietnam Mekong Delta. The authors conducted a regression analysis of the net farm revenue against various explanatory variables, including climate, soil, inundation, irrigation, and other socioeconomic variables in order to examine their effects on the variability of net farm revenues. The results showed that an increase in temperature has a negative effect on net farm revenues; conversely, an increase in precipitation has a positive effect on net farm revenues. The study estimated that net crop revenue per hectare would fall by approximately VND 180,000–VND 200,000 in 2050; and by VND 300,000–VND 1,600,000 by 2100.

This study also identified the major methods used by farmers in the coastal provinces of the Vietnam Mekong Delta in order to adapt to climate change and the factors that affect their choices of adaptation measures. The adaptation methods identified include using different crop varieties, changing farmers' planting schedule, intensifying irrigation, and adopting crop diversification. The results of the model indicate that level of education, gender, age, household size, minority, participating in organization, information on climate change and temperature during the rainy season influence farmers' choices.

1.0 INTRODUCTION

Climate change is a global phenomenon that can have significant effects on the national economic and social development of many countries. It is generally recognized that agriculture is the most sensitive and vulnerable to climate change (IPCC 2007). The body of scientific evidence on the seriousness of the climate change threat to agriculture is now obvious (Kaiser 1994; Seo and Mendelsohn 2007a, 2007b, 2007c; Calzadilla et al. 2013).

The Vietnam Mekong Delta is at 80^0 North latitude of the Tropic of Cancer, and is considered as one of the most vulnerable areas to global warming (Renton 2009). Agricultural yield can significantly decrease as a consequence of the loss of arable land, salt intrusion, drought, etc. resulting from climate change.

Using the results of the Intergovernmental Panel on Climate Change (2007), the Ministry of Natural Resources and Environment (MONRE) of Vietnam predicted that by the end of the century, temperature in the Mekong Delta would increase by around 1.1 ^{0}C–1.4 ^{0}C under the low-emission scenario (B1); 1.9 ^{0}C–2.0 ^{0}C under the medium-emission scenario (B2); and 2.3 ^{0}C–2.6 ^{0}C under the high-emission scenarios (A2) (MONRE 2009). Sea level is estimated to increase by 65 cm, 75 cm, and 100 cm under the B1, B2, and A2 scenarios, respectively. Yusuf and Francisco (2009) found that sea level rise would be the dominant hazard of climate change in the Mekong Delta in the next coming years. To date, salinity intrusion has been a major constraint to the irrigation-planning initiatives for crop cultivation in the delta, especially in the coastal areas (Nguyen et al. 2008).

Climate change mitigation involves those measures that help lessen the amount of anthropogenic greenhouse gases emitted to the atmosphere; it is considered as a reactive response. Meanwhile, climate change adaptation is seen to be more proactive. In the Vietnam Mekong Delta, implementing climate change adaptation measures is one of the government's priorities for the delta's long-term development. In fact, some of the adaptation projects have already been launched to help people in the Mekong Delta (MRC 2009; Renton 2009).

However, one of the crucial inputs needed to develop policies geared toward climate change mitigation and adaptation is information on the potential impacts of climate change on crop cultivation and the factors affecting the choice of the suggested adaptation method. Therefore, this study quantified the impacts of climate change on the agricultural production of the farmers in the coastal provinces of Mekong Delta and analyzed the determinants of farmers' choice of adaptation methods.

The Ricardian approach, which exploits observed differences in agricultural production and climate among different regions, can measure these impacts (Mendelsohn, Nordhaus, and Shaw 1994). The advantage of this approach is its ability to capture adaptation. However, "adaptations are a black box, never explicitly measured or identified" (Seo and Mendelsohn 2007c, p. 3). Hence, the authors relied on a multinomial logit (MNL) regression to analyze the link between the choices of adaptation, climatic variables, and other exogenous variables.

Policy makers can use the findings of this research for framing appropriate regional adaptation strategies and their associated development policies. The outputs of this research can also contribute to the knowledge regarding the short- and long-term impacts of climate change on agricultural production, which can help address the environmental and social change issues in the Vietnam Mekong Delta.

2.0 EMPIRICAL MODEL

2.1 The Ricardian Model

In recent years, many economists (Seo and Mendelsohn, 2007a, 2007b, 2007c; Manley, Kurukulasuriya, and Maddison 2007; Seo et al. 2008; Wang et al. 2008) have chosen the new economic approach—the Ricardian approach or the so-called cross-sectional approach—to study the interaction between climate, water, and other agricultural factors. The Ricardian model assumes that a farmer maximizes his net revenue to the exogenous conditions of his farm. This function can be expressed as

$$Max\pi = PQ_i\,(X, L, C, W, S) - P_xX - P_LL - P_WW \qquad \text{Equation (1)}$$

where:

π	=	net revenue per hectare;
P	=	market price of agricultural production;
Q_i	=	production function;
X	=	vector of input like seeds, pesticides, etc.;
L	=	vector of labor;
C	=	vector of climatic variables;
W	=	vectors of water;
S	=	vectors of soil characteristics;
P_x	=	vector of price for inputs;
P_L	=	vector of price of labor; and
P_W	=	vector of price for water.

According to Ricardo (1817), in a competitive market, land rent can reflect the net profit; hence, "the present value of these rents would equal land value" (Seo and Mendelsohn 2007b, p. 4). Consequently, there are two ways to estimate a Ricardian model—by using land value as the dependent variable and by using the net revenue as the dependent variable. Seo and Mendelsohn (2007b) used both net revenue and land value in their research on Latin American agriculture, whereas other researchers used net revenue only (Kumar 2009; Deressa 2007). In Vietnam, it is very difficult to measure the value of the land that farmers use for crop production. Therefore, this research employed net revenue as the dependent variable.

The model further assumes that farm value or land rent value has a quadratic relationship with climate variables such as temperature and precipitation (Mendelsohn et al. 1994). Likewise, the standard Ricardian model relies on a quadratic formulation of climate, which is specified as

$$\pi = \beta_0 + \beta_1 F + \beta_2 F^2 + \beta_3 Z + \beta_4 G + \beta_5 H + u \qquad \text{Equation (2)}$$

where:

π	=	net revenue per hectare,
F	=	vector of climate variables,
Z	=	set of soil variables,
G	=	vector of socioeconomic variable,
H	=	relevant hydrology variables like irrigation, and
u	=	error term.

The most important advantage of the Ricardian model is its ability to capture adaptation. In this study, farmers adapt to climate change to maximize their profits by changing the crop mix and by changing the planting schedule. However, this model does not capture the change of carbon dioxide in fertilization, which impacts productivity. Another weakness of the Ricardian model is that it does not include price effects (Helmy, Samia, and Samiha 2007).

The Ricardian model can estimate a 1-unit marginal change in temperature and precipitation. Using the results from Equation (2), the marginal impacts of the climate coefficients can be computed by taking the first derivative of the function with respect to climatic variables (temperature and precipitation) as follows:

$$\frac{\partial \pi}{\partial F} = \beta_1 + 2\beta_2 F \,. \qquad \text{Equation (3)}$$

The authors analyzed the impact of climate change on net revenue per hectare by using a uniform rate of change in temperature and precipitation levels. These scenarios assume that only one aspect of the climate changes and that this change is uniform across the region. These scenarios (Tables 1 and 2) are based on the scenarios developed by MONRE (2009). The change in welfare ($\Delta\pi$) resulting from a climate change from C_0 to C_1 can be measured as follows:

$$\Delta\pi = \pi(C_1) - \pi(C_0) \,. \qquad \text{Equation (4)}$$

The Ricardian model has been applied to many countries, including United States (Mendelsohn, Nordhaus, and Shaw 1994); China (Wang et al. 2008); Israel (Fleischer, Lichtman, and Mendelsohn 2008); South Africa (Deressa, Hassan, and Poonhty 2005); Egypt (Helmy, Samia, and Samiha 2007); Zambia (Jain 2007); Cameroon (Molua 2007); and Africa (Seo et al. 2008). Seo and Mendelsohn (2007a) analyzed the impacts of climate change on animal husbandry in Africa by using the Ricardian approach. About 80% of African agricultural land is for grazing; thus, farmers have opportunities to develop livestock for income, food, animal products. The results of the study indicated that as temperature increases, the net revenue and the size of stock decreases for large farms. However, Seo and Mendelsohn (2007a) also cited that "the higher temperatures do not affect the size of stock and they increase the net revenue per value of stock" (p. 2). Therefore, large farms are more vulnerable to warming than small farms.

Does climate change always have a negative relationship with agriculture? Reinsborough (2003) answered this question in his research on Canada's agriculture, in which the author used temperature and precipitation as the key variables in the climate change analysis. Interestingly, Reinsborough (2003) found that under the Ricardian model, Canadian agriculture benefited from climate change. In Asia, Kumar (2009) applied the Ricardian model to study the climate sensitivity of Indian agriculture using a 20-year panel data. The study projected that climate change would decrease agricultural revenues by 9% in the base model; but incorporating spatial effects would lower this effect to 3%. Meanwhile, Wang et al. (2008) raised an interesting question in their paper "Can China Continue to Feeding Itself?" and raised concern as to whether China can meet its demand for agricultural commodities in the coming decades. Specifically, Wang et al. (2008) analyzed the effects of temperature and precipitation on net crop revenues using cross-sectional data for both rain-fed and irrigated farms in China. The results from the Ricardian analysis demonstrated that global warming is likely harmful to China in the future, but the impacts are likely to be different in each region.

Finally, the Ricardian approach enables researchers to quantify the economic impacts of climate change on farm revenue. However, although the model can capture the adaptation that supports farmers' attempts to reduce the losses due to climate change (e.g., changes in temperature and precipitation and sea level rise), it cannot analyze the factors that affect famers' choice of adaptation methods. Accordingly, the MNL model can be used to identify the determinants of farmers' choice of climate change adaptation measures for crop production in the coastal provinces of the Vietnam Mekong Delta.

2.2 The Multinomial Logit (MNL) Model

To describe the MNL model, let *y* denote a random variable that takes on the value of the adaptation options $J = \{1, 2, 3\ldots J\}$. Let *x* denote a set of conditioning variables that contain different household, institutional, and environmental attributes. The question then is how can *ceteris paribus* changes in the elements of *x* affect the response probabilities ($P(y = j \mid x)$, $j = 1, 2, \ldots J$).

Let *x* be a 1 x *K* vector with first element utility. The MNL model has the response probability

$$(P(y = j / x) = \frac{exp\,(x\beta_j)}{1 + \sum_{h=1}^{j} exp(x\beta_h) = 1,2,\ldots J} \qquad \text{Equation (5)}$$

where:

β_j = *K* x 1, a vector of the coefficients of the model which can be estimated by the maximum likelihood method and $j = 1, 2, \ldots J$.

In this study, the farmers' choices of adaptation strategies are the dependent variables in the empirical estimation. These include changing crop varieties, intensifying irrigation, adopting crop diversification, and changing planting schedules. These adaptation options, which are based on a survey conducted by the researchers in the Mekong Delta, are similar to the other previously studied adaptation methods (Maddison 2007; Deressa et al. 2009).

The capacity of farmers to adapt is influenced by many factors such as institutional and political systems, agricultural system design, geographic area, farmer skills, local market systems, farm household characteristics, household resource endowments, and access to information (Gbetibouo 2009; Nhemachena and Hassan 2007). In this study, the explanatory variables used include household characteristics (i.e., educational level, gender, age of the household head, household size, and farm and nonfarm income) and information on climate change and climatic characteristic such as temperature and precipitation.

The parameter estimates of the MNL model provided only the director of the effect of the independent variables on the dependent (response) variable. The estimates do not present either the actual magnitude of change or the probabilities. Differentiating Equation (1) from the explanatory variables, the marginal effects of the explanatory variables can be expressed as

$$\frac{\partial P_j}{\partial X_k} = P_j(\beta_{jk} - \sum_{j=1}^{j-1} P_j\beta_{jk}). \qquad \text{Equation (6)}$$

According to Greene (2000), the marginal probabilities are the functions of the probability itself; they measure the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable from the mean. The signs of the marginal effects and respective coefficients may be different.

3.0 STUDY AREA AND DATA COLLECTION TECHNIQUE

3.1 Characteristics of the Study Area

The Vietnam Mekong Delta has a coastline of 740 km from east to west with a sea extent area of 360,000 km^2 in the downstream area of the Mekong River. This region is impacted by two types of tidal patterns: (1) the irregular half-day cycle coming from the East Sea and (2) the West Sea tide that creates the complication in the hydrological regime. In general, Mekong Delta's climate is best described as a monsoon tropical semi-equatorial climate. Hence, there are only two seasons in a year, namely, the dry season and rainy season.

The distinguishing feature of this region is that the delta is a typical wetland area; it has a flood pattern, salinity intrusion regime, and dense channel system that accounts for more than 90% of the nature area. Salt water intrusion is the main factor that limits agricultural production in this region and affects about 50% of Mekong Delta's agricultural land during the dry season.

The soil of the Mekong Delta is mainly composed of the alluvial soil carried by the Mekong River. It is composed of sand, mud, gravel, and fine debris of shell coming from the coastal area. The soil distribution in Mekong Delta is deeply associated with the land formation process and with saline intrusion. The kinds of soil in the Mekong Delta can be divided into four groups, namely, alluvial soil, acid-sulfate soil, saline soil, and old alluvial terrace.

In the coastal provinces of the Vietnam Mekong Delta, farmers have opportunities to employ different farming practices. Rice is the most important crop of the Mekong Delta farmers; in the coastal area, it is not an exception. Paddy production has increased gradually through the years due to reasons such as

1. farmers' adoption of the double-cropping system with short fallow periods using modern rice varieties that are planted in a cropping sequence tailored to avoid the annual flood cycle,
2. the expansion of the irrigation scheme in production areas, and
3. farmers' usage of additional fertilizers and pesticides.

The coconut trees in Ben Tre are very well-adapted. This kind of industrial crop is planted to about 80%–85% of the total coconut area in Vietnam; these plantations produce about 77% of the country's coconut output (GSO 2009). The coastal area in the delta is also rich in aquatic resources with high potential for aquaculture development. Accordingly, aquaculture is an important sector that continues to improve the local residents' living standards. It is often practiced in combination with other agriculture activities such as animal husbandry and rice cultivation.

In recent years, however, many scientists and international organizations have classified the Vietnam Mekong Delta—especially the coastal area—as an area vulnerable to climate change, particularly to sea level rise (IPCC 2007; Dasgupta et al. 2007).

The data for this analysis are based on a cross-sectional farm household survey (at the district level) in three provinces, namely, Bac Lieu, Ben Tre, and Ca Mau in the Mekong Delta. The study area is the coastal region of the Vietnam Mekong Delta. It covers around 1.02 million ha, which is more than 25% of the total land area of this region.

3.2 Farmers' Perception of Climate Change and Adaptation Strategies

Based on the cross-sectional household survey data collected from 320 household, 60% of the farmer respondents have observed increasing temperatures over the past 10–15 years (Table 1). In terms of precipitation, 70% of the respondents believed that rainfall has decreased over the past 15 years, while 25% thought it has increased. Meanwhile, an equal proportion of the respondents thought that the salinity level of the soil has either increased or stayed the same over time.

In response to the perceived change in climate, the respondents have adopted several adaptation strategies, which include changing their planting schedule, adopting crop diversification, improving the irrigation system, and planting new crop varieties (Table 2). The results of the survey revealed that changing the planting schedule is the most commonly adopted adaptation method, while intensifying irrigation practices is the least practiced.

Table 1. Farmers' perception of the change in climate in the past 10–15 years (n = 320)

Variable	Percentage of Respondents (%)
Temperature	
Increase	60.44
Decrease	6.50
Stay the same	33.06
Precipitation	
Increase	25.23
Decrease	69.98
Stay the same	4.79
Salinity level	
Increase	50.45
Decrease	0.00
Stay the same	49.55

Table 2. Farmers' adaptation strategies (n = 320)

Variable	Percentage of Respondents (%)
Change planting schedule	39.68
Crop diversification	13.75
Improve irrigation	5.93
Use new crop variety	15.31
No adaptation	28.33

3.3 Data Collection Technique

The research team used a structured questionnaire for the survey, which was designed to collect data that would reflect the distinct features of the provinces. The questionnaire had five sections. Sections 1–3 asked about the respondents' household characteristics and farms activities. Sections 4 and 5 investigated farmers' perceptions of climate change and their corresponding climate change adaptation strategies.

The economic surveys were then matched with climate data, which had been collected from the Ministry of Agriculture and Rural Development (MOARD) of Vietnam. To ensure a relatively good match between crop revenue, socioeconomic data, and climatic information, the sample was restricted to only those households who had been able to give complete information on the needed data. This is so that the researchers can analyze the change in net crop revenue to represent the effect of climate change on agricultural production, and determine the farmers' choice of adaptation methods. In total, the final sample had 320 households sampled from three coastal provinces in the Vietnam Mekong Delta.

The research team conducted a farm household survey to collect the needed data on crop production covering the 2010 farming season. Specifically, the survey questionnaire inquired about farmers' total revenue, total costs, total land area for crop production, and other data needed to calculate the net revenue per hectare. Likewise, the respondents' profile and household characteristics were included, such as educational level, gender, age of the household head, household size, nonfarm income and source of nonfarm income, and other socioeconomic characteristics. Questions on irrigation and climate-related data relevant to crop production (e.g., salinity levels, change in temperature, etc.) were also included in the questionnaire. The data collected on climate change were used as the explanatory variables in the analysis of the determinants of climate change adaptation measures in the Mekong Delta.

The climate data for this study was derived from MOARD in 2010. The researchers sourced three sets of climate data from three meteorological stations located in the three provinces (i.e., Bac Lieu, Ben Tre, and Ca Mau). This study presented all the climate variables for two seasons, namely, from June to November and from December to April, which corresponded to the rainy and dry seasons, respectively.

Table 3 illustrates the descriptive statistics of the variables used in the two models. In general, the average temperatures in the dry and rainy seasons were quite similar. However, the precipitation showed a completely different picture—the amount of rain during the dry season accounted for only 22 mm, as compared to 300 mm during the rainy season.

4.0 MODEL RESULTS AND DISCUSSION

4.1 Ricardian Model

Table 4 reports the results of the econometric analysis on the impact of climate change on the net revenue per hectare of the farms in Bac Lieu, Ben Tre, and Ca Mau. A total of 321 farms were included in the sample. The goodness of fit measures (adjusted R^2) for all models was 0.42, which is relatively high for a cross-sectional household data.[1] The model generated eight significant variables among the 11 variables considered. Note that the estimated coefficients in the model had levels of statistical significance at 10% or higher.

The positive quadratic terms of temperature during the dry and rainy seasons indicate that the functions are U-shaped. Hence, warmer temperatures in the next coming years may lead to decreases in crop net revenue. In case of rainfall, the responses to dry precipitation are convex, and concave for rainy precipitation. It appears that net revenues are highly sensitive to temperature and precipitation as indicated by the strong significance levels of the climatic coefficients. This is consistent with the hypothesis that the relationship between climate and net farm revenues is nonlinear.

The results shown in Table 5, which illustrates the marginal effects, were calculated using the coefficients from Table 4. The marginal impact of net revenue for an increase (if an infinitesimal rises) in mean temperature during the dry season would be approximately –VND 15,585. This implies that if the temperature rises at the beginning of the cropping season when the plants are germinating, then this would have a negative effect on the crop; the amount of damage during the dry season would be VND 15,585. Similarly, during the rainy season, a hill-shaped relationship between net revenue and temperature imply that a further increase in temperature by a unit during the rainy season would reduce a farming household's net revenues by about VND 4,783/ha. For the whole year, the marginal net revenue per hectare of each household would decrease by VND 4,782 as temperature increases. The marginal results confirm the research hypothesis that an increase in temperature would decrease net crop revenue.

[1] The adjusted R^2 of this research are also similar to that applied to other countries. For example, the research of Seo and Mendelsohn (2007a) on African agriculture had an adjusted R^2 of 0.36; the study of Wang et al. (2008) on China had an R^2 of 0.26; Eid, El-Marsafawy, and Ouda (2006) on Egypt had 0.21.

Table 3. Statistical data used in the Ricardian and MNL models

Variables	Minimum	Maximum	Mean	SD	Description
Net revenue per hectare (VND/ha)	−32,721.00	36,1667.00	50,097.90	57,683.10	Continuous
Temperature in dry season (^0C)	27.37	28.23	27.73	0.34	Continuous
Temperature in dry season square ($^0C^2$)	748.93	797.12	769.36	19.16	Continuous
Temperature in rainy season ($^0C^2$)	27.12	27.53	27.35	0.18	Continuous
Temperature in rainy season square ($^0C^2$)	735.31	758.08	748.15	10.16	Continuous
Precipitation in dry season (mm)	21.83	23.33	22.68	0.68	Continuous
Precipitation in dry season square (mm^2)	476.69	544.44	514.92	30.92	Continuous
Precipitation in rainy season (mm)	229.00	380.17	304.74	65.37	Continuous
Precipitation in rainy season square (mm^2)	52,441.00	14,4527.00	97,131.30	39,788.00	Continuous
Age of the head of household (years)	27.00	93.00	51.93	11.15	Continuous
Gender of the head of household (1 = M, 0 = F)	0.00	1.00	0.11	0.31	Dummy takes the value of 1 if male and 0 otherwise
Years of education (years)	0.00	16.00	6.09	3.19	Continuous
Irrigation (1 = irrigated, 0 = non-irrigated)	0.00	1.00	0.67	0.46	Dummy takes the value of 1 if there is and 0 otherwise
Salinity (g NaCl/l)	0.00	7.00	4.32	2.00	Continuous
Size of household (individuals)	1.00	11.00	4.86	1.59	Continuous
Participation in any organization	0.00	1.00	0.71	0.45	Dummy take the value of 1 if there is and 0 otherwise
Farm income ('000 VND)	−24,700.00	2,370,000.00	55,714.70	177,626.00	Continuous
Nonfarm income ('000 VND)	−502,800.00	1.4E+08	2,789,983.00	1.5E+07	Continuous
Information on climate change	0.00	1.00	0.52	0.50	Dummy take the value of 1 if there is and 0 otherwise

Note: SD = standard deviation

Table 4. Parameter estimates of the net crop revenue (per hectare) model, three coastal provinces, Vietnam Mekong Delta

Variables	Coefficients	Significant
Temperature in dry season square	–7,792.50	2.63E-18
Temperature in rainy season square	–2,391.40	0.02167
Precipitation in dry season square	452.00	0.05397
Precipitation in rainy season	31,228.00	4.41E-19
Precipitation in rainy season square	–48.34	3.24E-18
Age of the head of household	–229.21	0.32169
Gender of the head of household	–3,014.60	0.70389
Years of education	–822.72	0.30615
Irrigation	16,386.20	0.00753
Salinity	–4,038.40	0.04760
(Constant)	2,804,544.00	1.21E-06
Number of observation	320.00	
F- test	24.11	
R-square	0.42	

Table 5. Marginal impacts of climate on net crop revenue (per hectare)

Season	Temperature (VND/ha/^{0}C)	Precipitation (VND/ha/mm)
Dry season	–15,585.02	903.8
Rainy season	–4,782.80	31,191.4
Annual	–20,367.82	32,095.2

Aside from the climatic variables, the other variables would also influence crop net revenue. In the model, the irrigation and salinity variables (included in the model to capture the spatial heterogeneity across the sampled households) were statistically significant in explaining the variability in net revenue across households. The irrigation coefficient was significant and positive in explaining the variability of net farm revenue per hectare. The result further emphasizes the importance of irrigation as a factor affecting net revenue, whereas the salinity variable was negatively related to net revenue per hectare for the whole farm sample. This could be attributed to the fact that higher levels of salinity reduce crop productivity. However, the relationship between the household characteristics variables (i.e., age, education level, and gender of the household head) and the dependent variable were insignificant.

To illustrate what the regressions imply for the coastal area of the Mekong Delta agriculture, the researchers also tested for the uniform climate scenarios, in which only one climate factor changes at a time across the region. The assumption that climate change will be uniform across the Mekong Delta region is realistic because the climate in Southern Vietnam is considered uniform. In the scenario analysis, this study employed the climate change project for Vietnam reported by MONRE (2009). In that particular project, three scenarios with three emission levels were used, namely, low emission (B1), medium emission (B2), and high emission (A2) (Tables 6 and 7).

Table 6. Mean temperature change (^{o}C) in South Vietnam, 1980–1999, by emission scenarios

Scenarios	Month Periods	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low emission (B1)	Dec – Feb	0.3	0.5	0.6	0.8	0.9	1.1	1.1	1.1	1.1
	Mar – May	0.4	0.6	0.8	0.9	1.0	1.2	1.2	1.3	1.3
	Jun – Aug	0.5	0.7	0.9	1.1	1.3	1.4	1.5	1.5	1.5
	Sep – Nov	0.5	0.6	0.9	1.2	1.2	1.4	1.5	1.5	1.5
Medium emission (B2)	Dec – Feb	0.3	0.5	0.6	0.8	1.0	1.3	1.5	1.5	1.7
	Mar – May	0.4	0.6	0.8	0.9	1.2	1.4	1.7	1.8	1.9
	Jun – Aug	0.5	0.7	0.9	1.2	1.5	1.8	2.0	2.1	2.1
	Sep – Nov	0.5	0.6	0.9	1.2	1.4	1.8	1.9	2.1	2.3

Table 6 continued

Scenarios	Month Periods	2020	2030	2040	2050	2060	2070	2080	2090	2100
High emission (A2)	Dec – Feb	0.3	0.5	0.7	0.8	1.0	1.3	1.3	1.8	2.1
	Mar – May	0.4	0.6	0.8	0.9	1.2	1.5	1.9	2.1	2.7
	Jun – Aug	0.6	0.7	0.9	1.2	1.5	1.8	2.2	2.6	2.9
	Sep – Nov	0.5	0.7	1.0	1.2	1.5	1.8	2.1	2.5	2.9

Source: MONRE. (2009)

Table 7. Rainfall change (%), South Vietnam, 1980–1999, by emission scenarios

Scenarios	Month Periods	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low emission (B1)	Dec – Feb	–2.7	–4.4	–6.2	–7.7	–7.7	–9.4	–9.1	–10.1	–10.1
	Mar – May	–2.6	–3.6	–5.8	–7.2	–8.1	–8.7	–9.2	–9.4	–9.4
	Jun – Aug	0.3	0.5	0.6	0.8	0.9	1.0	1.1	1.1	1.1
	Sep – Nov	2.6	3.8	5.0	6.3	7.3	8.1	8.3	8.5	8.5
Medium emission (B2)	Dec – Feb	–3.0	–4.4	–6.2	–8.1	–8.7	–11.4	–12.8	–14.2	–15.4
	Mar – May	–2.8	–4.1	–5.8	–7.5	–9.1	–10.6	12.0	–13.2	–14.3
	Jun – Aug	0.3	0.5	0.6	0.9	1.1	1.2	1.4	1.5	1.6
	Sep – Nov	2.6	3.8	5.3	6.8	8.3	9.6	10.9	11.9	13.0
High emission (A2)	Dec – Feb	–3.3	–4.5	–5.9	–7.4	–9.7	–12.0	–14.4	–16.9	–19.6
	Mar – May	–3.0	–4.2	–5.5	–7.2	–9.0	–11.1	–13.3	–15.7	–18.2
	Jun – Aug	0.4	0.5	0.6	0.8	1.0	1.3	1.5	1.8	2.1
	Sep – Nov	2.8	3.8	5.0	6.5	8.2	9.3	12.1	14.3	16.5

Source: MONRE. (2009)

4.2 Likely Effects of Climate Change on Future Net Farm Revenues Based on Uniform Scenarios

To calculate future climate, the value changes were added to the existing mean temperature of Mekong Delta. Precipitation changes were also multiplied by rainfall. Then, the authors predicted the change in net revenues per farm at the current and each new climate by subtracting the two net revenue values. Table 8 presents the changes in the net revenue per hectare per household that was predicted from the three climate scenarios for the years 2020 and 2100.

The simulation shows that by the middle of 2050, net revenue per hectare in the three scenarios would decrease by around VND 180 million to VND 200 million. This number would be significantly different in Year 2100, and the loss range would be from VND 330 million to VND 1.63 billion.

Table 8. Likely effects of climate change on future net farm revenues (in '000 VND) based on uniform scenarios

Year	Low Emission (B1)	Medium Emission (B2)	High Emission (A2)
2020	–46,537	–47,662	–50,285
2030	–77,085	–79,570	–82,023
2040	–127,075	–127,076	–127,036
2050	–186,356	–199,752	–183,040
2060	–214,103	–275,394	–298,662
2070	–285,592	–431,617	–477,121
2080	–293,418	–201,797	–725,735
2090	–329,481	–712,302	–1,100,085
2100	–329,481	–867,745	–1,629,906

4.3 Choices of Adaptation

Table 9 illustrates the parameter estimates used in the MNL model of this study. However, “the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable” (Deressa et al. 2009, p. 8). It was not possible to calculate the probability and the actual magnitude of change; thus, this study estimated the marginal effects instead.

Table 10 presents the marginal effects of the various explanatory variables on the decision to adopt climate change adaptation measures along with their levels of statistical significance. The results showed that in all of the adaptation measures, household size would not significantly increase the probability of adaptation. The age of the household head would increase the farm household’s probability of changing its planting schedule. A unit increase in the age of the household head would increase the probability that a household would intensify their irrigation practice and change their planting schedules by 0.2%.

Interestingly, having a male-headed household would have a positive and significant impact on that household’s decision to use new crop variety; it would have a negative effect on that household’s decision to adopt crop diversification as an adaptation method. The variable is also expected to decrease the probability of that household’s decision to adopt crop diversification by 9.9%, but it would increase the household’s probability of using new crop by 25%.

As expected, having a household head with higher education would increase the probability that the household would choose to adapt to climate change. The variable would also increase the probability that a farm household would intensify its irrigation practice, change its planting schedule, and adopt crop diversification as adaptation methods. A unit increase in schooling year could increase the probability that a farm household would improve its irrigation system by 2%; adopt crop diversification by 4%; and change its planting schedule by 7%.

A farm household’s participation in any kind of organization could increase the likelihood that the household would use new crop varieties by 77% and adopt crop diversification by 8.5%. The implication of this result is that social networks increase farm household’s awareness and use of climate change adaptation options. Having information on climate change would have significant and positive impact on the likelihood that a farm household would adopt crop diversification by 3.5%. A unit increase in temperature would increase the probability that a farm household would intensify its irrigation practices by 9.3% during the dry season, and would increase the probability that a household farmer would change its planting schedule during the rainy season by 21.14%.

Although numerous explanatory variables in the MNL model showed significant relationships with a farmer’s decision to adopt climate change adaptation measures, there were also variables that would not significantly impact on the farmer’s decision. These variables were household size, income from farm and nonfarm activities, and precipitation.

Table 9. Parameter estimates of the MNL climate change adaptation model

Explanatory Variables	Change Planting Date		Crop Diversification		Irrigation		Use New Crop Variety	
	Coef	Sig	Coef	Sig	Coef	Sig	Coef	Sig
Size of household	0.422	0.625	0.913	0.530	0.597	0.303	0.577	0.000
Age of the head of household	0.007	0.001	0.004	0.007	0.025	0.003	0.001	0.640
Gender of the head of household	−1.608	0.003	−2.739	0.013	−33.312	0.256	−0.129	0.797
Years of education	0.045	0.008	0.069	0.341	−0.058	0.014	0.013	0.043
Participate in any organization	−0.437	0.256	0.741	0.058	−0.507	0.392	0.152	0.752
Farm income	1.42E-06	0.172	−1.12E-06	0.783	8.77E-07	0.818	−7.49E-06	0.093
Nonfarm income	−5.68E-08	0.003	−1.66E-07	0.455	−1.42E-07	0.754	−5.77E-06	0.143
Information on climate change	0.873	0.010	0.938	0.034	0.523	0.319	0.290	0.467
Temperature in dry season	2.727	0.182	6.766	0.080	−3.282	0.193	0.285	0.904
Temperature in rainy season	−1.745	0.639	−10.206	0.282	3.277	0.414	−0.651	0.069
Precipitation in dry season	−0.712	0.044	−1.059	0.297	−0.411	0.781	−0.165	0.886
Precipitation in rainy season	0	0.995	−0.001	0.955	0.001	0.968	0.006	0.066
const	−13.004	0.842	109.473	0.498	5.971	0.951	8.973	0.905
Best Category			**No Adaptation**					
Number of observations			320.0000					
Log likelihood			−684.8900					
Pseudo-R^2			0.1788					

Note: Coef = coefficient; Sig = significance

Table 10. Marginal effects of the variables on the decision to adopt climate change adaptation measures

Explanatory Variables	Change Planting Dates		Crop Diversification		Irrigation		Use New Crop Variety		No Adaptation	
	Coef	Sig	Coef	Sig	Coef	Sig	Coef	Sig	Coef	Sig
Size of household	0.045	0.666	0.061	0.213	0.0000	0.412	0.302000	0.291	−0.1060	0.497
Age of the head of household	0.002	0.001	0.001	0.184	0.0000	0.125	0.022000	0.749	0.0010	0.001
Gender of the head of household	−0.265	0.034	−0.099	0.107	−0.0580	0.411	0.252000	0.147	0.4220	0.000
Years of education	0.007	0.002	0.004	0.069	0.0020	0.075	−0.690000	0.181	−0.0100	0.317
Participate in any organization	−0.143	0.743	0.085	0.100	−0.0010	0.221	0.771000	0.049	0.0590	0.699
Farm income	−1.42E-06	0.393	−1.96E-07	0.346	2.79E-10	0.761	9.24E-07	0.513	−2.18E-07	0.695
Nonfarm income	−3.27E-09	0.256	−1.23E-08	0.145	1.51E-10	0.113	2.54E-06	0.417	1.57E-08	0.299
Information on climate change	1.53E-01	0.091	0.0349	0.075	0.0001	0.146	0.576000	0.251	−0.1870	0.269
Temperature in dry season	0.2426	0.712	0.4776	0.197	0.0930	0.021	0.023000	0.141	−0.7110	0.001
Temperature in rainy season	0.2114	0.033	−0.8684	0.718	0.0089	0.241	0.240000	0.271	0.6480	0.000
Precipitation in dry season	−0.1061	0.598	−0.0568	0.159	0.0002	0.361	−0.623000	0.156	0.1630	0.012
Precipitation in rainy season	0.004	0.198	0.001	0.711	9.37E-07	0.123	0.000132	0.448	0.0001	0.167

Note: Coef = coefficient; Sig = significance

5.0 CONCLUSION

This study assessed the impact of climate change on the crop farming activities of farmers in the Vietnam Mekong Delta by using the Ricardian model in the economic assessment. The study also identified the major climate change adaptation methods used by farmers by using the multinomial logit (MNL) model.

The Ricardian approach used in this study enabled the researchers to capture farmers' adaptation response to varying environmental factors and to determine the economic impacts of adaptation on crop production. Specifically, the researchers examined the vulnerability of the agricultural production in the Vietnam Mekong Delta to climate change by analyzing how the long-term farm profitability of a Mekong Delta farmer can change given the changes in temperature and precipitation (which represent climate change), while controlling for other variables. This was done by forming climate scenarios that predicted the extent by which the projected climate change could affect net farm revenue covering the period 2020–2100.

Accordingly, the results indicate that climate impacts have a nonlinear relationship with net revenue. The results further show that net crop revenue would decrease as temperature increases and that the increase in the amount of rainfall would be beneficial to crop production. Agricultural production in the Mekong Delta would be vulnerable to climate change when temperature increases and when the amount of precipitation decreases in the next coming years. The results of the analysis further emphasize the negative effect of the level of inundation and the importance of irrigation on crop production.

The estimated marginal impacts of the climate variables on net crop revenues also indicated different results for temperature and precipitation and for the different farming systems. An infinitesimal rise in mean temperature would negatively impact annual net crop revenue by VND 20,000/ha. Meanwhile, a decrease in the amount of rainfall would cause a marginal decrease of VND 32,000/ha per annum.

The study also examined three climate scenarios to determine how crop production in the coastal provinces of the Mekong Delta region would respond to future climate changes. The uniform scenario showed that if temperature increases by 1^{0}C and if precipitation decreases by 2%, net crop revenue per hectare in the coastal regions of Mekong Delta would decrease by VND 180,000–VND 200,000 in 2050. Using this estimation, the authors predicted that net crop revenue per hectare would fall by as much as VND 329,000 by 2100 when the temperature is expected to rise by 1.4^{0}C and precipitation is expected to decrease by 2.5%. In the medium-emission (B2) and high-emission (A2) climate scenarios, in which climate changes are predicted to be more serious, the loss in crop net revenue in the Mekong Delta would significantly increase to over VND 867,000 and VND 1.63 million by 2100, respectively.

Although the results predicted that global warming would be harmful to agricultural production in the Mekong Delta, the economic analysis shows that the economic impact would not be as high as expected. The optimistic results is because the study assumed and considered that farmers would adopt climate change adaptation measures such as planting new crop varieties, intensifying irrigation practices, adopting crop diversification, and changing their planting schedules.

The Ricardian model was able to capture implicitly these adaptation measures; however, it did not allow for a microlevel analysis of these adaptation strategies. Hence, the authors used the MNL model to capture how farmers choose their adaptation strategies in response to the threats posed by climate change. Specifically, the MNL model measured the probability that a farmer would decide to adopt a particular adaptation strategy. Accordingly, this study estimated the marginal effects with respect to a unit change in a particular independent variable.

The results of the marginal analysis indicate that household characteristics such as age, gender, and level of education of the household head would have a significant impact on the household's decision to adapt to climate change. These variables could be enhanced through policy interventions such that more farm households would adapt to climate change. The results also showed that two institutional factors (i.e., households' information on climate change and participation in organization) significantly influence farm household's decision to adapt to climate change. As such, policies that would promote climate change adaptation need to emphasize the crucial role of providing the right information on climate change and of enhancing the quality of organizations in order to encourage farmers in the Mekong Delta to adapt to the phenomenon.

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