



Munich Personal RePEc Archive

Farmers' adaptive measures to climate change induced natural shocks through past climate experiences in the Mekong River Delta, Vietnam

Ngo, Quang Thanh

Institute of Policy and Strategy for Agriculture and Rural Development

16 April 2016

Online at <https://mpra.ub.uni-muenchen.de/78055/>
MPRA Paper No. 78055, posted 01 Apr 2017 03:06 UTC

Full Length Research Paper

Farmers' adaptive measures to climate change induced natural shocks through past climate experiences in the Mekong River Delta, Vietnam

Thanh Quang Ngo

Southern Center of Agricultural Rural Policy and Strategy, Institute of Strategy for Agriculture and Rural Development (IPSARD), Hanoi, Vietnam.

Received 22 December, 2015; Accepted 1 March, 2016

This study examined farmers' adaptive measures to climate change induced natural shocks through past climate experiences in the Mekong River Delta (Vietnam) from a data set of 330 farmers. Seemingly unrelated regression model was used to identify the determinants of farmers' adaptive measures. Results showed that male household head, education of the household head, marital status of the household head, production assets, farm size, availability of credit, access to market, temperature and rainfall had significant impacts on choices of adaptation. Results also indicated that past climate experiences was the most important determinant of adaptive measures. Policy messages enhanced access to credit, to markets, and created awareness on climate change. Other policy options could also be suggested, including: strengthening education level of farmers, facilitating cheap technologies, spurring irrigation investment through public - private partner, and supporting the land reform such as farmers' cooperation in large-scale production.

Key words: Climate change induced natural shocks, adaptative measures, past climate experiences, Mekong River Delta.

INTRODUCTION

The Mekong River Delta, the major agricultural region of Vietnam, is identified as significantly vulnerable to climate change (Yusuf and Francisco, 2010; Asian Disaster Preparedness Center, 2003). Agricultural production remains the main source of livelihoods for most farmers in this area (Nguyen and Le, 2012; Le Anh et al., 2014; Asian Disaster Preparedness Center, 2003). Climate change has greater negative impacts on farm households as they have the lowest capacity to adapt to changes in

climatic conditions (Yu et al., 2010; Asian Disaster Preparedness Center, 2003).

Adaptation measures are therefore important to help farmers to better face extreme weather conditions and associated climatic variations (Valipour et al., 2015; Adger et al., 2003; Kandlinkar and Risbey, 2000).

A better understanding of current adaptation measures and their determinants will be important to inform policy for future successful adaptation. Some related studies

E-mail: thanh.ngo@scap.gov.vn. Tel: (84.8)937105567.

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](https://creativecommons.org/licenses/by/4.0/)

conducted in the last few years focused on farmers' past climate experiences. Niles et al. (2015a), using farmer survey data from New Zealand, showed that limiting factors mediated the effect of past climate experiences on the adoption of adaptation strategies differently in two regions with water acting as a limiting factor in Hawke's Bay and water and temperature as a limiting factor in Marlborough. Le Dang et al. (2014) addressed the limited understanding of how rice farmers appraise their private adaptive measures and influential factors in the Mekong River Delta of Vietnam. Authors found that belief in climate change, information and objective resources were found to influence farmers' adaptation assessments. Geoff (2014) also stressed that farmers' climate change beliefs affect adaptation to climate change.

Nicholas and Gina (2012) explored commercial farmers' perceptions of and responses to shifting climates in the Little Brak River area along South Africa's south coast and found that farmers' experience with shifting climates has played a large part in driving their adaptive decision-making. This study adds to these analyses by evaluating farmers' past climate experiences and distinguishing determinants of adaptation to climate change induced natural shocks among farmers in the Mekong River Delta. Evaluating past climate experiences of and response to climate change includes exploring what these perceptions are, how they are formed and how perception affects response (Bryant et al., 2000; Vedwan and Rhoades, 2001).

DATA AND METHODOLOGY

Research site and data

Long An, Ben Tre, Can Tho, Soc Trang, Kien Giang, and Ca Mau are the six provinces randomly selected from 13 provinces in the Mekong Delta which are defined at different agro-ecological systems which enabled representation of the Mekong Delta region. One district from each province and two communes from each district were randomly chosen. In total, there are 12 communes and commune centres in the survey. From the official household lists of the twelve communes, farm households were selected by simple random sampling. The face-to-face structured interviews were conducted in July, 2014. Four teams of 10 interviewers each had been involved in two intensive training sections, one before and one after the pre-test. The interviewers visited 335, but interviewed 330 farm households, 50 in each commune. Each interview was around two hours in duration. In this study, the farm household was the unit of analysis and the household heads or their spouses were the interviewees.

The structured questionnaire mainly covers perception of past climate change, climate change adaptation assessment, and a number of influential factors. The questionnaire was refined and finalized based on the information from three focus group discussions in provinces such as Long An, Ben Tre, Can Tho and of the questions were also tested through the pre-tests with 30 randomly chosen farm households in Ben Tre Province. The data used in this paper are specified from questions about climate change, adaptation assessment, farm characteristics, income, assets, infrastructure and institutional factors.

The principal systems in the survey areas are mono-rice, shrimp-mixed rice, fish, shrimp, cereal-root crop mixed, and fruit. Out of

330 farm households, 32% of them cultivate rice, 1% of them shrimp-mixed rice, 2.5% of them fish, 11.3% of them shrimp, 5.5% of them annual crops, and 10.5% of them fruit. Farmers have average land size of about 1.1 ha. About 70% of farming households have less than 1.2 ha. Average size of rice land, land for annual crops and land for fruit are 2.5, 2.4, and 1.9 ha, respectively. Average shrimp-mixed rice land size is 4.3 ha. Paddy yield in the study area is around 6.09 tones/ha. Average income of farmers in the study area is about 76.348 thousand Vietnam Dong (about 3.455 USD). Several Mekong River Delta related studies and reports by the (United Nations Development Programme (UNDP), 2008; EU/MWH, 2006; ADPC/GTZ, 2003) clarify the trends of climate change in terms of higher temperature, salt water intrusion, eroded shorelines, exacerbated coastal flooding, rainfall increasingly concentrated over fewer months in the rainy season, while the dry season will be more prolonged. This will lead to more frequent and intense floods and droughts simultaneously. In addition, tropical cyclone and typhoon occurrence are expected to alter and become more intense under a warmer climate as a result of higher sea-surface temperatures.

Model specification

Common approach uses a univariate technique such as probit/logit analysis for discrete choice dependent variables to model each of the adaptation measures individually as functions of the common set of explanatory variables. The shortfall of this approach is that it is prone to biases caused by ignoring common factors that might be unobserved and unmeasured and affect the different adaptation measures. In addition, independent estimation of individual discrete choice models fails to take into account the relationships between adoptions of different adaptation measures. Farmers might consider some combinations of adaptation measures as complementary and others as competing. By neglecting these common factors the univariate technique ignores potential correlations among the unobserved disturbances in adaptation measures, and this may lead to statistical bias and inefficiency in the estimates (Lin et al., 2005; Belderbos et al., 2004; Golob and Regan, 2002).

A multinomial (MNL) discrete choice model is another alternative to the multivariate model with more than two endogenous discrete choice variables. In the multinomial discrete choice model the choice set is made up of all combinations of adaptation measures. The shortfall of this technique is that interpretation of the influence of the explanatory variables on choices of each of the original separate adaptation measures is very difficult. The shortfall of this technique is that all multinomial replications of a multivariate choice system have problems in interpreting the influence of explanatory variables on the original separate adaptation measures (Golob and Regan, 2002).

This study follows Zellner's Iterative Seemingly Unrelated Regressions (ISUR) to overcome the shortfalls of using the univariate and multinomial discrete choice techniques. The ISUR technique provides parameter estimates that converge to unique maximum likelihood parameter estimates. The resulting model has stimulated countless theoretical and empirical results in econometrics and other areas (Zellner, 1962; Srivastava and Giles, 1987). The benefit of this model is that the ISUR estimators utilize the information present in the cross regression (or equations) error correlation and hence it is more efficient than other estimation methods such as the univariate and multinomial discrete choice techniques.

The methodology used in this paper for misspecification testing follows Godfrey (1988) and Shukur (2002). White (1980) test was used (including cross products of the explanatory variables) to test for heteroscedasticity and Ramsey's (1969) RESET test to test for functional misspecification (Ramsey, 1969) Table 1. Definition of variables. Table 2 provides the variables hypothesized to determine

Table 1. Definition of variables.

Variable	Description	Value	Expected sign
Household characteristics			
Age	Age of the household head	Years	Cannot be signed a priori (+ or -)
Education	Number of years of formal schooling attained by the household head	Years	Positive
Gender	Gender of the household head	1= male, 0= female	Cannot be signed a priori (+ or -)
Household size	Number of family members	years	Positive
Wealth	An index of production assets was constructed using production assets including tractor, pesticide sprayers, grain harvesting machine, rice milling machine, feed grinding machine, plough	Numbers	Positive
Farm characteristics			
Farm size	Land area	Numbers	Positive
Institutional factors			
Credit	If household has access to credit from any sources	1=yes, 0= no	Positive
Off-farm employment	Income from off-farm activities during the survey year		Cannot be signed a priori (+ or -)
Tenure	Proportion of land use with Land Right Certificate or	Numbers	Positive
Climate conditions			
Sunshine	Total hours of sunshine	hours	Cannot be signed a priori (+ or -)
Rainfall	Total level of rainfall	mm	Cannot be signed a priori (+ or -)
Climate change induced natural shocks' perception			
Wind storm	Perceived by wind storm	1=yes, 0= no	Cannot be signed a priori (+ or -)
Drought	Perceived by drought	1=yes, 0= no	Cannot be signed a priori (+ or -)
Flood	Perceived by flood	1=yes, 0= no	Cannot be signed a priori (+ or -)
Untimely rain	Perceived by untimely rain	1=yes, 0= no	Cannot be signed a priori (+ or -)
Pestilent insect	Perceived by pestilent insect	1=yes, 0= no	Cannot be signed a priori (+ or -)
Water shortages	Perceived by water shortages	1=yes, 0= no	Cannot be signed a priori (+ or -)

Source: Author's compilation

adaptation behaviour, a brief description of each variable, its value, and expected sign. Following Filmer and Pritchett (2001), principal

component analysis (PCA) was used to assign weights to each asset. The overall wealth index is calculated by applying the

Table 2. Adaptation measure to climate change induced natural shocks in the Mekong River Delta, 2014.

Code	Category	Adaptation measure (%)
A	Water use management (n)	44
01	Build/repair cistern	0.05
02	Build/repair well	0.08
03	Water saving technology	0.03
B	Adjustments of crops and varieties (n)	162
04	Change varieties	0.39
05	Change crops/livestock	0.08
06	Change crop structure	0.07
C	Adjustments of planting techniques (n)	175
07	Change crop cultivation	0.14
08	Change fertilizer/stimulus	0.16
09	Change pesticides/herbicides	0.30
10	Change crops quantity	0.13
11	Change farmyard manure	0.04
D	Adjustments of planting calendar (n)	48
12	Change irrigation schedule	0.07
13	Change crop rotation	0.07
E	No adaptation (n)	43

Source: Climate change survey in the Mekong River Delta (2014).

following formula:

$$w_j = \sum_{i=1}^k [b_i(a_{ji} - x_i)]/s_i$$

Where w is the wealth index, b is the weights from PCA, a is the asset value, x is the mean asset value, and s is the standard deviation of the assets.

Dependent variables

Intergovernmental Panel on Climate Change (IPCC's) report, which is based on the social sciences, states that "adaptation refers both to the *process* of adapting and to the *condition* of being adapted" (Smit and Pilifosova, 2001). Specifically, adaptation is the process of improving society's ability to cope with changes in climatic conditions across time scales, from short term (for example, seasonal to annual) to the long term (for example, decades to centuries). The IPCC (2007) defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The goal of an adaptation measure should be to increase the capacity of a system to survive external shocks or change.

Important adaptation options in the agricultural sector include: crop diversification, mixed crop-livestock farming systems, using different crop varieties, changing planting and harvesting dates, mixing less productive, drought-resistant varieties and high-yield water sensitive crops (Adger et al., 2003; Bradshaw et al., 2004). Agricultural adaptation involves two types of modifications in

production systems. The first is increased diversification that involves engaging in production activities that are drought tolerant and or resistant to temperature stresses as well as activities that make efficient use and take full advantage of the prevailing water and temperature conditions, among other factors. Crop diversification can serve as insurance against rainfall variability as different crops are affected differently by climate events (Orindi and Eriksen, 2005; Adger et al., 2003). The second strategy focuses on crop management practices geared towards ensuring that critical crop growth stages do not coincide with very harsh climatic conditions such as mid-season droughts. Crop management practices that can be used include modifying the length of the growing period and changing planting and harvesting dates (Orindi and Eriksen, 2005). Use of irrigation has the potential to improve agricultural productivity through supplementing rainwater during dry spells and lengthening the growing season (Baethgen et al., 2003; Orindi and Eriksen, 2005). It is important to note that irrigation water is also subject to impacts from climate change. Use of irrigation technologies need to be accompanied by other crop management practices such as use of crops that can use water more efficiently. Important management practices that can be used include: efficient management of irrigation systems, growing crops that require less water, and optimizing of irrigation scheduling and other management techniques that help reduce wastage (Loë et al., 2001).

The adaptation measures in this study are based on asking farmers about their perceptions of past climate change induced natural shocks and the actions they take to counteract the negative impacts of these shocks. We follow Maddison (2006) and Hassan and Nhemachena (2008) by assuming that farmers' adaptation actions are driven by climatic factors.

A list of private adaptive measures to climate change was initially developed from the literature (Bradshaw et al., 2004; Bryan et al.,

2009; Deressa et al., 2009; Hassan and Nhemachena, 2008; Thomas et al., 2007). To ensure the appropriateness, these measures were raised for discussion in focused group discussions. Typical farmers, participants of the focus grouped discussions, were asked to choose the measures that have been used or available in their areas. The same request was given to agricultural province-level officers interviewed. The adaptive measures had finally been refined by the pre-tests before they were actually included in the questionnaire. Those 14 adaptive measures in table were considered as farmers' adaptive responses to climate change induced natural shocks. These adaptive measures were grouped into five groups: (A) Water use management, (B) Adjustments of crops and varieties, (C) Adjustments of planting techniques, (D) Adjustments of planting calendar, and (E) No adaptation. Most of previous studies considered "no adaptation" as lacking of information on climate change and dropped from analysis. In this paper, we treated "no adaptation" as one of choices by farmers since climate change can also bring positive effects on agriculture production.

In general, measures such as "Build/repair cistern" (5%), "Build/repair well" (8%), and "Water saving technology" (3%) in water use management were not very commonly used. The limited use of these adaptations could be attributed to need for more capital.

While a high proportion of farmers used measure of "Change varieties" (39%) as an adjustment of crops and varieties, a lower proportion of farmers use "Change crops/livestocks" (8%), "Change crop structure" (7%) in response to climate change. Local farmers may be lacking skills, motivation and opportunities for other crops and/or livestock. While a high proportion of farmers used measure of "Change pesticide/herbicides" (30%) as an adjustment of planting techniques, a lower proportion of farmers use "Change crop cultivation" (14%), "Change fertilizer input/stimulus" (16%), "Change crop quantity" (13%), and "Change farmyard manure" in response to climate change. These adaptations could be associated with the less expense and ease of access by farmers than that of adjustments of crops and varieties.

Less proportion of farmers use "Change irrigation schedule" (7%), and "Change crop rotation" (7%) in response to climate change. This is probably because farmers access to climate change information is rather limit. No farmer bought insurance as an adaptive measure to climate change and only 1 percent of farmers combined agriculture and forestry. Those numbers implied a lacking of suitable mechanism that can secure farmers from extreme climate events associated with climate change in the Mekong River Delta. Moreover, about 13% of the surveyed farmers reported not to have taken any adaptation method above.

Explanatory variables

With respect to household characteristics such as household head's gender, on the one hand, various studies have shown that gender is an important variable affecting adoption decisions at the farm level. According to Bayard et al. (2007) female farmers are more likely to adopt natural resource management and conservation practices. It was also emphasized by Burton et al. (1999) that female farmers are indeed important in the choice of agricultural practices to adopt, particularly in regard to conservation or sustainable technology. According to Nhemachena and Hassan (2007) the possible reason for female to adapt is that in most rural smallholder farming communities, men are more often based in towns, and much of the agricultural work is done by women. Therefore, women have more farming experience and information on various management practices and how to change them, based on available information (Anim, 1999). On the other hand, according to Asfaw and Admassie (2004), male-headed households are more likely to get information about new technologies and

undertake risky businesses than female-headed households. Moreover, Tenge and Hella (2004) argue that having a female head of household may have negative effects on the adoption of soil and water conservation measures, because women may have limited access to information, land, and other resources due to traditional social barriers. There is a line of argument in between by Bekele and Drake (2003) who believe that gender has no significant factor in influencing farmers' decision to adopt climate change adaptation measures. They stressed that there is a significant difference in farmer's ability to adapt to climate change due to major differences between them in terms of access to assets, education, credit, technology and input supply.

Many research works have shown that education increases one's ability to receive, decode, and understand information relevant to making innovative decisions (Maddison, 2006; Lin, 1991; Igoden et al., 1990). On the contrary, Clay et al. (1998) found that education was an insignificant determinant of adoption decisions. The influence of age on adaptation has been mixed in the literature. For example, Bekele and Drake (2003) in their study of Eastern highlands of Ethiopia found that age had no influence on farmer's decision to participate in soil and water conservation activities. Others such as Nyangena (2008) and Dolisca et al. (2006), however, found that age is significantly and negatively related to farmers' decisions to adopt in soil and water conservation and forestry management programs, respectively. Studies by Maddison (2006) and Nhemachena and Hassan (2007) indicate that experience in farming increases the probability of uptake of adaptation measures to climate change.

Regarding farm characteristics, according to Nhemachena and Hassan (2007) the empirical literature shows that household size has mixed impacts on farmers' adoption of agricultural technologies. Larger family size is expected to enable farmers to take up labour intensive adaptation measures. Alternatively, a large family might be forced to divert part of its labour force into non-farm activities to generate more income and reduce consumption demands.

Farm and nonfarm income and assets represent wealth. It is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial wellbeing (Knowler and Bradshaw, 2007). Other studies that investigate the impact of income on adoption found a positive correlation (Franzel, 1999). The occupation of the farmer is an indication of the total amount of time available for farming activities. Off-farm employment may present a constraint to adoption of technology because it competes for on-farm managerial time (McNamara et al., 1991).

Among institutional factors, access to credit is an important factor affecting adoption of measures. Access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to take (Nhemachena and Hassan, 2007). Similarly, land tenure can contribute to adaptation, because landowners tend to adopt new technologies more frequently than tenants, an argument that has justified numerous efforts to reduce tenure insecurity (Lutz et al., 1994; Shultz et al., 1997). Land ownership is widely believed to encourage the adoption of technologies linked to land such as irrigation equipment or drainage structures. Land ownership is likely to influence adoption if the innovation requires investments tied to land.

Among infrastructure factors, it is hypothesized that as distance to output and input markets increases, adaptation to climate change decreases. Proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Maddison, 2006). Perceived change in climate variables and access to climatic change information are also important pre-conditions to take up adaptation measures (Niles et al., 2015a; Geoff, 2014; Nicholas and Gina, 2012; Nhemachena and Hassan, 2007; Maddison, 2006). Accordingly, it is hypothesized that farmers that perceive change in

Table 3. Summary statistics of independent variables in models.

Variable	Mean	Std. Dev.	Min	Max
Male-headed household (male: 1; female: 0)	0.89	0.31	0	1
Years of education by household head (years)	6.23	3.34	0	16
Marital status of household head (married: 1; other: 0)	0.90	0.30	0	1
Household size (persons)	4.19	1.40	1	8
Production asset index	0.01	1.32	-0.52	10.30
Proportion of cultivation income in total income (%)	0.27	2.31	-39.93	3.64
Proportion of aquaculture income in total income (%)	0.20	0.44	-1.75	2.5
Proportion of non-agriculture income in total income (%)	0.24	0.44	-1.29	3.35
Land area (log)	0.45	1.22	-4.42	4.03
Access to loan (1: Yes; 0: No)	0.21	0.41	0	1
Proportion of land with long-term use right	0.95	0.18	0	1
Distance from plot(s) to house (km)	0.69	1.69	0	20
Distance from plots(s) to nearest commune road (km)	2.97	3.92	0	35
Total hours of sunshine	2313.83	237.32	1952.6	2592
Total level of rainfall	1503.56	450.83	1018.4	2262
Climate change induced natural shocks perceived				
Through wind storm (1: Yes; 0: No)	0.15	0.35	0	1
Through drought (1: Yes; 0: No)	0.23	0.42	0	1
Through higher temperature (1: Yes; 0: No)	0.25	0.43	0	1
Through flood (1: Yes; 0: No)	0.19	0.39	0	1
Through untimely rain (1: Yes; 0: No)	0.23	0.42	0	1
Through salt water intrusion (1: Yes; 0: No)	0.04	0.19	0	1
Through eroded shorelines (1: Yes; 0: No)	0.02	0.12	0	1
Through pestilent insect (1: Yes; 0: No)	0.70	0.46	0	1
Through water shortages (1: Yes; 0: No)	0.08	0.27	0	1

Source: Author's estimation; N=329.

climatic conditions and farmers who have access to climate change information have higher chances of taking adaptive measures in response to observable changes (Nhemachena and Hassan, 2007). The explanatory variables in this study include household characteristics such as education, gender, age of the household head, household size. Farm characteristics include farm size, farm and nonfarm income; institutional factor such as access to credit; infrastructure includes distance to input and output markets, climate conditions, and past climate experiences (Le Dang et al., 2014; Nicholas and Gina, 2012; Patrick and Richard, 2012; Nhemachena and Hassan, 2007; Maddison, 2006). In the empirical model, each explanatory variable is included in all four equations to help test if the impacts of variables differ from one adaptation option to another. Table 3 gives the descriptive statistics of variables in the models.

RESULTS OF ANALYSIS AND DISCUSSION

Farmers' past experiences of climate change induced natural shocks

Farmers' past climate experiences and variability is a prerequisite for devising subsequent adaptation strategies. Therefore, it is important to understand how farmers perceive climate change and variability in the context of

agriculture production in the Mekong River Delta. Studies in Mekong River Delta have found that farmers' perception of climate change corresponds with local climate data (Le Dang et al., 2014; Nguyen and Le, 2012; Nguyen, 2007; UNDP, 2008, EU/MWH, 2006; ADPC/GTZ, 2003). In this study, farmers' perceptions of the changes were considered in terms of nine past climate experiences - wind storm, drought, flood, higher temperature, untimely rains, salt water intrusion, eroded shorelines, pestilent insect, and water shortages. The key informants were asked to assess the frequencies of the main climate changes they have seen/observed over the last 5 years. A list of options was provided with 5 levels of occurrences. From Figure 1, recurrent droughts, flood, changes in temperature, and pestilent insect have been confirmed by their often frequencies annually in the Mekong River Delta. Higher temperature and pestilent insect are the two most often past climate change phenomena.

Past climate change induced natural shocks' impacts

The respondents were asked to rank from "very severe"

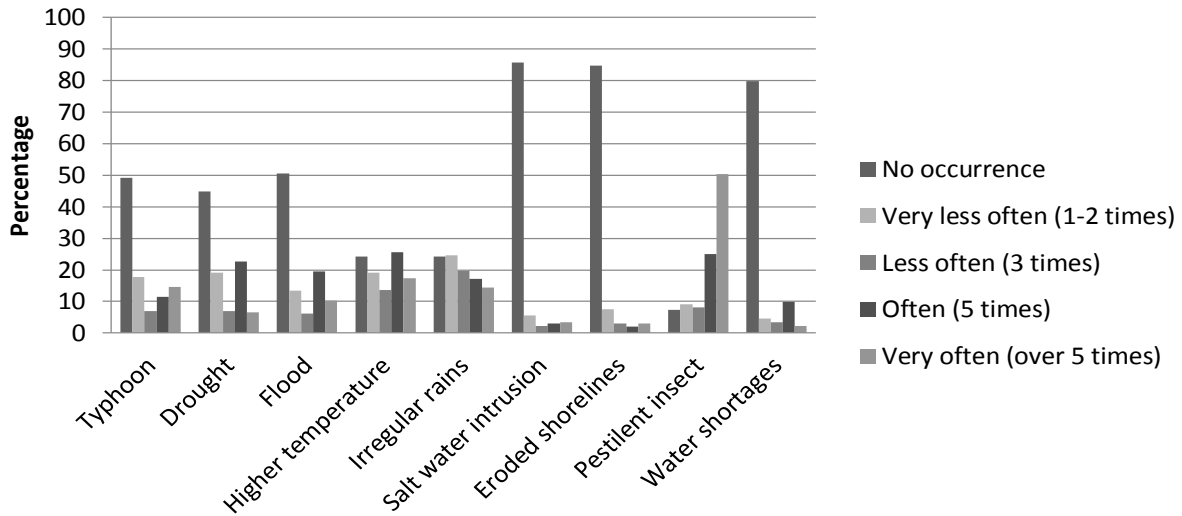


Figure 1. Climate change induced natural shocks (frequencies in 5 recent years). Source: Author’s estimation.

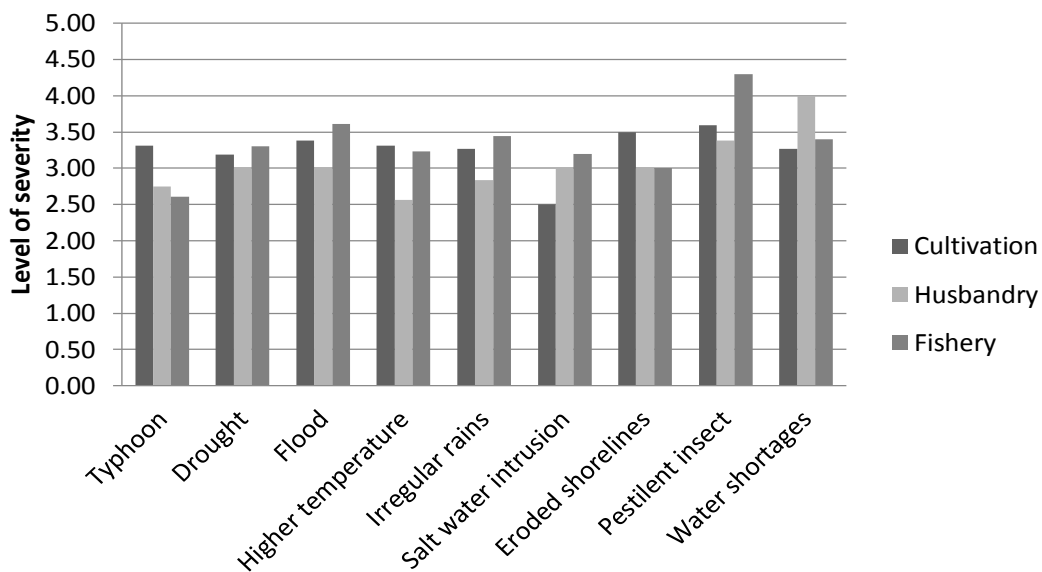


Figure 2. Climate change induced natural shocks’ impacts on agricultural activities. Source: Author’s estimation.

(5) to “not severe at all” (1) from options provided by the impacts they have noticed on different agricultural activities. From Figure 2, typhoon, drought, flood, higher temperature, untimely rain, eroded shoreline, pestilent insect, and water shortages are the most severe climate change phenomena in cultivation (average points of above 3.0). Pestilent insect and water shortages are the most severe climate change phenomena in husbandry (average points of above 3.0). Drought, flood, higher temperature, untimely rain, pestilent insect, and water shortages are

the most severe climate change phenomena in fishery (average points of above 3.0).

Regression results

Despite the fact that the majority of the farmers interviewed claimed that they have perceived at least one change in climatic attributes, some of the farmers who perceived climate change did not respond by taking adaptation measures. Here it is argued that farmers who perceive and responded (or did not respond) share some common characteristics, which assist in better understanding the reasons underlying their response

Table 4. Model summary.

Parameter	Adjustments of crops and varieties	Adjustments of planting techniques	Adjustments of planting calendar	No adaptation
R squared	0.14	0.16	0.20	0.19
Breusch-Pagan test for independent equations (Chi squared and p value)	54.61 (0.0001)	63.47 (0.0000)	84.47 (0.0000)	76.03 (0.0000)
Goodness-of-fit test (Pearson chi-square and p value)	323.55 (0.25)	323.01 (0.25)	325.15 (0.23)	299.04 (0.62)
Test for multicollinearity (mean VIF)	1.32	1.32	1.32	1.32
Test for model specification -Ramsey test (p value of squared coefficient)	0.27	0.89	0.09	0.74

Source: Author's estimation.

in Table 4 (Note that one choice of adaptation - Water use management - was not significant and dropped from the results). Four models with alternative choices are in columns, namely: (1) Adjustments of crops and varieties, (2) Adjustment of planning techniques, (3) Adjustments of planting calendar, and (4) No adaptation.

The R² for all models indicated that the statistically significant explanatory variables can explain around 14 to 20% of the variation of farmers' adaptation assessments. Breusch-Pagan test for independent equations were highly significant with values less than 0.001, implying that equations are correlated. Goodness-of-fit test indicates that four models fit the data well. No multi-collinearity problems were detected as the variance inflation factor (VIF) for all explanatory variables were less than 1.4. Tests for model specification (Ramsey test) pass for all four models. The regression coefficients in the four ISUR regression models are presented in Table 5. Bootstrap estimates were conducted. We used bias corrected bootstrapped (n =1000) results because they have been shown to perform the best with regards to power and Type I error results (Briggs, 2006), particularly for smaller sample sizes (Preacher and Hayes, 2008).

DISCUSSION

With respect to household characteristics, the estimated coefficients for the household head's gender, years of education by household head, and marital status of household head were statistically significant. Male headed households have more probability of specifically adapting to climate change which is revealed by the fact that a unit change from being headed by a female household to male increases the probability of adapting adjustments of planting techniques to climate change by 23.0%, *ceteris paribus*. This result is in line with the argument that male-headed households are often

considered to be more likely to get information about new technologies and take risky businesses than female headed households (Asfaw and Admassie, 2004). However, male headed households have less probability of choosing no adaptation to climate change by 22.3%, *Ceteris paribus*.

A unit increase in the education of the head of the household will have the impact of raising the probability of making adjustments of planting techniques to climate change by 2.2%, *ceteris paribus*. This is in line with studies of Maddison (2006), Lin (1991) and Igoden et al. (1990). Although a series of adaptive measures has been used by many households, the above findings may imply causes of inefficient adaptation in local areas. Poor education can be one possible cause. Our estimation also showed that education level of household head has less probability of choosing no adaptation to climate change by 1.7%, *Ceteris paribus*.

With respect to farming characteristics, farm size was statistically significant and positively related to adaptation. Farm households who owned more land conducted adjustments of crops and varieties more by 5.8%, *Ceteris paribus*. The probable reason for the positive relationship between adaptation and farm size could be due to the fact that adaptation is subject to economies of scale. The result is in accordance with study by Nhemachena and Hassan (2007). If large-scale cultivation is an advantaged in conducting adaptation measures, in general, government should support some implementations of the land reform such as farmers' cooperation in cultivating in large-scale fields. In the Mekong River Delta in recent years, this trend has turned to be common. It was also found that more land households have less probability of choosing no adaptation to climate change by 3.9%, *Ceteris paribus*.

Households with higher production assets (but may not necessarily have most land) increases the probability of adjustments of planting calendar to climate change by

4.3%, *Ceteris paribus*. This is in line with Nhemachena and Hassan (2007), Knowler and Bradshaw (2007) and

Table 5. Results of ISUR probit analysis of determinants of adaptation measures.

Variable	Adjustments of crops and varieties	Adjustments of planting techniques	Adjustments of planting calendar	No adaptation
Male-headed household (male: 1; female: 0)	0.070 (0.097)	0.220** (0.097)	0.064 (0.071)	-0.223** (0.087)
Years of education by household head (years)	0.005 (0.009)	0.022*** (0.008)	0.001 (0.005)	-0.017** (0.007)
Marital status of household head (married: 1; other: 0)	0.008 (0.099)	-0.169 (0.105)	-0.0323 (0.074)	0.193*** (0.066)
Household size (persons)	-0.022 (0.021)	-0.029 (0.020)	-0.011 (0.015)	0.005 (0.014)
Production asset index	0.002 (0.023)	0.043** (0.018)	-0.003 (0.013)	-0.016** (0.008)
Proportion of cultivation income in total income (%)	-0.018 (0.032)	0.007 (0.036)	0.001 (0.024)	0.009 (0.023)
Proportion of aquaculture income in total income (%)	-0.285*** (0.075)	-0.067 (0.077)	-0.056 (0.036)	0.087* (0.048)
Land area (log)	0.058* (0.029)	0.006 (0.028)	0.004 (0.019)	-0.039* (0.021)
Access to loan (1: Yes; 0: No)	0.031 (0.072)	0.109 (0.069)	0.109** (0.055)	-0.0557 (0.040)
Proportion of non-agriculture income in total income (%)	0.015 (0.066)	-0.081 (0.067)	0.039 (0.045)	0.083 (0.052)
Proportion of land with long-term use right	0.143 (0.159)	0.112 (0.174)	-0.0619 (0.129)	-0.0453 (0.124)
Distance from plot(s) to house (km)	-0.033** (0.016)	-0.006 (0.020)	-0.001 (0.012)	0.036** (0.015)
Distance from plots(s) to nearest commune road (km)	0.014* (0.008)	-0.001 (0.008)	-0.001 (0.004)	-0.006 (0.004)
Total hours of sunshine	0.00003 (0.000)	0.001*** (0.000)	0.00003 (0.000)	-0.001** (0.000)
Total level of rainfall	0.0001 (0.00007)	-0.0001* (0.00007)	-0.0001*** (0.00005)	0.0001 (0.00004)
Climate change induced natural shocks				
Perceived through wind storm (1: Yes; 0: No)	0.001 (0.079)	0.054 (0.076)	-0.091 (0.058)	0.038 (0.051)
Perceived through drought (1: Yes; 0: No)	-0.038 (0.069)	-0.012 (0.073)	0.177*** (0.059)	-0.040 (0.038)
Perceived through flood (1: Yes; 0: No)	-0.065 (0.072)	-0.034 (0.069)	0.072 (0.052)	0.059 (0.049)
Perceived through untimely rain (1: Yes; 0: No)	0.266*** (0.064)	0.112* (0.066)	0.066 (0.051)	-0.082** (0.033)
Perceived through pestilent insect(1: Yes; 0: No)	-0.005 (0.063)	0.046 (0.073)	-0.006 (0.039)	-0.022 (0.046)
Perceived through water shortages (1: Yes; 0: No)	-0.083 (0.102)	0.105 (0.106)	0.218** (0.091)	-0.020 (0.072)

Bootstrap standard errors in parentheses;*** p<0.01, ** p<0.05, * p<0.1; N = 329. Source: Author's estimation.

Franzel (1999). As mentioned in Nhemachena and Hassan (2007), with access to technology farmers are able to vary their planting dates, switch to new crops, diversify their crop options and use more irrigation, apply water conservation techniques. However, production assets requires large capital stock that can be a constraint and thus ensuring availability of cheap technologies for farmers, especially smallholders, can

significantly increase their use of other adaptation options. Our estimation finds that households with higher production assets decrease the probability of choosing no adaptation to climate change by 1.6%, *Ceteris paribus*.

Our results indicate that farm system types alone may not determine climate change's responses; these systems are also imbedded with institutional factors, infrastructure, climate

conditions and varying climate experiences as well. With respect to institutional factors, farmers with access to credit have higher chances of adapting to changing climatic conditions as found in Nicholas and Gina (2012) and Nhemachena and Hassan (2007). Household with access to credit will have the impact of raising the probability of making adjustments of planting calendar to climate change by 10.9%, *Ceteris paribus*.

According to Nhemachena and Hassan (2007), access to affordable credit increases financial resources of farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take. With more financial and other resources at their disposal farmers are able to change their management practices in response to changing climatic and other factors. Farmers with limiting access to market have higher probability of adjustments of crops and varieties to changing climatic conditions by 1.4%, *Ceteris paribus*. With access to markets farmers are able to buy new crop varieties, new irrigation technologies, and other important inputs they may need to change their practices to suit the forecasted and prevailing climatic conditions (Nhemachena and Hassan, 2007). However, household with plots in longer distance from house will have the less probability of making adjustments of crops and varieties to climate change by 3.3%, *Ceteris paribus*. In addition, household with plots in longer distance from house will have the more probability of choosing no adaptation to climate change by 3.6%, *Ceteris paribus*. Overall, the improvement of both the accessibility and usefulness of local services is deemed a necessity for adaptation strategies.

With respect to climate conditions, increasing temperature increases the probability of adapting adjustments of planting techniques to climate change by 0.1%, *Ceteris paribus*. The fact that adaptation to climate change increases with increasing temperature is in line with the expectation that increasing temperature is damaging to agriculture and farmers respond to this through the adoption of different adaptation methods (Nguyen and Le, 2012; Nhemachena and Hassan, 2007). It was also found that increasing temperature also decreases the probability of choosing no adaptation to climate change by 0.1%, *Ceteris paribus*.

Annual average precipitation is negatively related to adaptation. Increasing rainfall decreases the probability of adapting adjustments of planting techniques and adjustments of planting calendar to climate change by 0.01%, *Ceteris paribus*. The probable reason for the negative relationship between average annual precipitation and adaptation could be due to the fact that agriculture in the Mekong River Delta is water scarce and faces high temperature and increasing precipitation will not constrain agricultural production or does not promote the need to adapt (at least using the main adaptation options considered in this study).

ISUR estimates show that past climate experiences increases the probability of uptake of adaptation measures (Niles et al., 2015b; Nicholas and Gina, 2012; Maddison, 2006). Farmers who are aware of changes in climatic conditions have higher chances of taking adaptive measures in response to observed changes. Specifically, increasing drought increases the probability of farmers to respond to changes in terms of adjustments of planting calendar (Niles et al., 2015b and Patrick and

Richard, 2012) by 17.7%, *Ceteris paribus*.

Increasing untimely rain increases the probability of farmers changing their management practices, in particular, adjustments of crops and varieties (including changes in varieties, crops/livestocks, and crop structure) by 26.6%, *Ceteris paribus*, and adjustments of planting techniques (including changes in crop cultivation, fertilizer/stimulus, pesticides/herbicides, crop quantity, and farmyard manure) by 11.2%, *Ceteris paribus*. Resulting water shortages leads to adjustments of planting calendar, including changes in irrigation schedule, and crop rotation (Niles et al., 2015b) by 21.8%, *Ceteris paribus*. However, increasing untimely rain decreases the probability of farmers making no adaptation by 8.2%, *Ceteris paribus*. This can be explained that farmers' experiences of climate change induced natural shocks lead their choice of no adaptation since this kind of shock benefits their agriculture production (Geoff, 2014). Generally, if perception of climate change induced natural shocks are the most salient for farmers, it likely has significant implications for assessing how short-term responses can influence long-term adaptations and the subsequent policies that may be needed to accompany such actions (Carlo et al., 2015; Le Dang et al., 2014; Park et al., 2012). In addition, because climate variability in higher temperature and accompanied by drought and water shortages, irrigation investment needs from the viewpoint of Public - Private Partner (PPP) should be reconsidered to allow farmers increased water control to counteract adverse impacts from climate variability and change.

CONCLUSION AND IMPLICATIONS

A better understanding of current adaptation measures and their determinants will be important to inform policy for future successful adaptation. This study was based on farm-level analysis of farmers' past climate experiences and distinguished determinants of adaptation to climate change induced natural shocks in the Mekong River Delta of Vietnam. This research has shown that the majority of farmers used adaptive measures that mostly related to their farming practices such as adjustments of crops and varieties (including changes in varieties, crops/livestocks, and crop structure), adjusting planting techniques (such as changes in crop cultivation, fertilizer/stimulus, pesticides/herbicides, crop quantity, and farmyard manure) and adjusting planting calendar (such as changes in irrigation schedule, and crop rotation). On top of that, no adaptation is also considered as a choice of adaptation. The adaptive measures farmers followed were those that they perceived climate change induced natural shocks such as wind storm (typhoon), drought, flood, higher temperature, untimely rain, salt water intrusion, eroded shorelines, pestilent insect, and water shortages.

This paper further explored the determinants of different adaptive measures using an ISUR probit model. The model allows for the simultaneous identification of the determinants of all adaptation options, thus limiting potential problems of correlation between the error terms. Correlation results between error terms of different equations were significant (positive) indicating that various adaptation options tend to be used by farmers in a complementary fashion, although this could also be due to unobserved farm-level socioeconomic and other factors. ISUR probit results confirm gender of the farm head being male, education of the farm head, marital status of the farm head, production assets, firm size, availability of credit, access to market, and temperature and rainfall have significant impact on choices of adaptation to climate change. Results also indicate that awareness of past climate experiences is the most important determinants of farm-level adaptation.

The findings suggest some directions for adaptation policies. Sources and quality of information can be of important consideration due to the potential influences on farmers' past climate experiences and their adaptation assessments. Additionally, awareness creation on climate change and adaptation methods should be focused. On top of that, improvement of both the accessibility and usefulness of local services, such as credit and infrastructure, are deemed a necessity for successful adaptation strategies in the Mekong River Delta. Other policy options could also be suggested, including: strengthening education level of farmers, facilitating cheap technologies for farmers, spurring irrigation investment through public – private partner. Last but not least, government should support some implementations of the land reform such as farmers' cooperation in large-scale production.

Conflict of Interests

The author certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

ACKNOWLEDGMENTS

Sincere gratitude to the Departments of Agriculture and Rural Development of 6 districts: Duc Hoa (Long An Province), Thanh Phu (Ben Tre Province), Chau Phu (An Giang Province), Hon Dat (Kieng Giang Province), Phong Dien (Can Tho Province), and Dam Doi (Ca Mau

Province) for their great help and support in organising farmer interviews. Thanks also to the Southern Center of Agricultural Rural Policy and Strategy (SCAP) staff and 20 undergraduate students of Nong Lam University, local guides and 335 farm households in the Mekong Delta in helping and supporting the interviews conducted on July, 2014.

This paper is made possible under the sponsor of The National Foundation for Science and Technology Development of Vietnam (NAFOSTED) under the Project No II.6.1-2012.14.

REFERENCES

- Adger WN, Huq S, Brown K, Conway D, Hulme M (2003). Adaptation to climate change in the developing world. *Prog. Dev. Stud.* 3:179-195.
- ADPC/GTZ (2003). *Climate Change and Development in Vietnam: Agriculture and Adaptation for the Mekong Delta Region.*
- Anim FDK (1999). A note on the adoption of soil conservation measures in the Northern Province of South Africa. *J. Agric. Econ.* 50:336-345.
- Asfaw A, Admassie A (2004). The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agric. Econ.* 30:215-228.
- Asian Disaster Preparedness Center (2003). *Climate Change and Development in Vietnam: Agriculture and Adaptation for the Mekong Delta Region.* In: *Climate Protection Programme Bangkok: Asian Disaster Preparedness Center.*
- Baethgen WE, Meinke H, Gimenez A (2003). Adaptation of agricultural production systems to climate variability and climate change: lessons learned and proposed research approach. In: *Climate Adaptation net conference "Insights and Tools for Adaptation: Learning from Climate Variability,* pp. 18-20.
- Bayard B, Jolly CM, Shannon DA (2007). The economics of adoption and management of alley cropping in Haiti. *J. Environ. Manag.* 84:62-70.
- Bekele W, Drake L (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecol. Econ.* 46:437-451.
- Belderbos R, Carree M, Diederer B, Lokshin B, Veugelers R (2004). Heterogeneity in R&D cooperation strategies. *Int. J. Ind. Organ.* 22:1237-1263.
- Bradshaw B, Dolan H, Smit B (2004). Farm-Level Adaptation to Climatic Variability and Change: Crop Diversification in the Canadian Prairies. *Clim. Change* 67:119-141.
- Briggs NE (2006). Estimation of the standard error and confidence interval of the indirect effect in multiple mediator models. Doctoral dissertation: The Ohio State University.
- Bryan E, Deressa TT, Gbetibouo GA, Ringer C (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environ. Soc. Policy* 12:413-426.
- Bryant CR, Smit B, Brklacich M, Johnston TR, Smithers J, Chiotti Q, Singh B (2000). Adaptation in Canadian agriculture to climatic variability and change. *Clim. Change* 45:181-201.
- Burton M, Rigby D, Young T (1999). Analysis of the determinants of adoption of organic horticultural techniques in the UK. *J. Agric. Econ.* 50:47-63.
- Carlo A, Sirkku J, Grete KH (2015). Local climate change adaptation: moving from adjustments to transformation? *Local Environ.* 20:401-407.
- Clay D, Reardon T, Kangasniemi J (1998). Sustainable intensification in the highland tropics: Rwandan farmers' investments in land conservation and soil fertility. *Econ. Dev. Cult. Change* 46:351-378.
- Deressa TT, Hassan RM, Ringer C, Alemu T, Yesuf M (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Change* 19:248-255.
- Doliska F, Carter RD, McDaniel JM, Shannon DA, Jolly CM (2006).

- Factors influencing farmers' participation in forestry management programs: A case study from Haiti. *For. Ecol. Manag.* 236:324-331.
- EU/MWH (2006). *Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction: Vietnam Country Study.*
- Filmer D, Pritchett LH (2001). Estimating wealth effects without expenditure Data-Or tears: An application to educational enrollments in states of India. *Demography* 38:115-132.
- Franzel S (1999). Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. *Agroforestry Syst.* 47:305-321.
- Geoff K (2014). How Do Farmers' Climate Change Beliefs Affect Adaptation to Climate Change? *Soc. Nat. Resour.* 27:492-506.
- Godfrey LG (1988). *Misspecification Tests in Econometrics.* Cambridge: Cambridge University Press.
- Golob TF, Regan AC (2002). Trucking industry adoption of information technology: a multivariate discrete choice model. *Transp. Res. Part C* 10:2005-2228.
- Hassan R, Nhemachena C (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *Afr. J. Agric. Resour. Econ.* 2:83-104.
- Igoden C, Ohoji P, Ekpare J (1990). Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. *Agric. Adm. Ext.* 29:149-156.
- IPCC (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability.* In: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge, UK.
- Kandlinkar M, Risbey J (2000). Agricultural impacts of Climate Change; if adaptation is the answer, what is the question?. *Clim. Change* 45:529-539.
- Knowler D, Bradshaw B (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food policy* 32:25-48.
- Le Anh T, Hoang TT, Van VN (2014). The impact of climate change on farmers' livelihoods in the Mekong Delta. In: *The Sixth Forum on Conservation of Nature and Culture for the Sustainable Development of the Mekong Delta.*
- Le Dang H, Li E, Nuberg I, Bruwer J (2014). Farmers' assessments of private adaptive measures to climate change and influential factors: a study in the Mekong Delta, Vietnam. *Nat. Hazards* 71:385-401.
- Lin CTJ, Jensen KL, Yen ST (2005). Awareness of foodborne pathogens among US consumers. *Food Qual. Prefer.* 16:401-412.
- Lin J (1991). Education and innovation adoption in agriculture: evidence from hybrid rice in China. *Am. J. Agric. Econ.* 73:713-723.
- Loë R, Kreutzwiser R, Moraru L (2001). Adaptation options for the near term: climate change and the Canadian water sector. *Glob. Environ. Change* 11:231-245.
- Lutz E, Pagiola S, Reiche C (1994). The Costs and Benefits of Soil Conservation: The Farmer's Viewpoint. *World Bank Res. Obs.* 9:273-295.
- Maddison D (2006). The perception of and adaptation to climate change in Africa. In: *CEPPA Discussion Paper, vol. 10: Centre for Environmental Economics and Policy in Africa, University of Pretoria.*
- McNamara KT, Wetzstein ME, Douce GK (1991). Factors affecting peanut producer adoption of integrated pest management. *Rev. Agric. Econ.* 13:129-139.
- Nguyen HD, Le TDP (2012). How severe is the impact of climate change on crop production in the Mekong Delta Vietnam? *J. Int. Bus. Res.* P 11.
- Nguyen HN (2007). *Flooding in Mekong River Delta, Viet Nam.* In: *Human Development Report 2007/2008.*
- Nhemachena C, Hassan R (2007). Micro - level Analysis of Farmers' Adaptation to climate Change in Southern Africa In: *IFPRI Discussion paper 00714.*
- Nicholas W, Gina Z (2012). Adapting to climate change in South Africa: commercial farmers' perception of and response to changing climate. *S. Afr. Geogr. J.* 94:152-173.
- Niles MT, Lubell M, Brown M (2015a). How limiting factors drive agricultural adaptation to climate change. *Agric. Ecosyst. Environ.* 200:178-185.
- Niles MT, Lubell M, Brown M (2015b). How limiting factors drive agricultural adaptation to climate change. *Agric. Ecosyst. Environ.* 200.
- Nyangena W (2008). Social determinants of soil and water conservation in rural Kenya. *Environ. Dev. Sustain.* 10(6):745-767.
- Orindi VA, Eriksen S (2005). Mainstreaming Adaptation to Climate Change in the Development Process in Uganda. In: *Ecopolity Series vol. 15 Kenya, Nairobi: African Centre for Technology Studies.*
- Park SE, Marshall NA, Jakku E, Dowd AM, Howden SM, Mendham E, Fleming A (2012). Informing adaptation responses to climate change through theories of transformation. *Glob. Environ. Change* 22:115-126.
- Patrick M, Richard AG (2012). Climate Change Impacts and Adaptation Strategies in Kenya. *Chin. J. Popul. Resour. Environ.* 10:22-29.
- Preacher KJ, Hayes AF (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behav. Res. Methods* 40(3):879-891.
- Ramsey JB (1969). Test for Specification error in Classical Linear Least Squares Regression Analysis. *J. R. Stat. Soc. Series B Stat. Methodol.* 350-371.
- Shukur G (2002). Dynamic Specification and Misspecification in Systems of Demand Equations: A Testing Strategy for Model Selection. *Appl. Econ.* 34:709-725.
- Shultz S, Faustino J, Melgar D (1997). *Agroforestry and Soil Conservation: Adoption and Profitability in El Salvador.* Agroforestry Today 9.
- Smit B, Pilifosova O (2001). Adaptation to climate change in the context of sustainable development and equity. In: *Climate Change 2001: Impacts, Adaptation and Vulnerability (McCarthy JJ ed.) Cambridge: Cambridge University Press.* pp. 877-912.
- Srivastava V, Giles D (1987). *Seemingly Unrelated Regression Equations Models.* New York: Marcel Dekker.
- Tenge JDG, Hella JP (2004). Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. *Land Degradation and Development* 15:99-114.
- Thomas DSG, Chasca T, Henny O, Bruce H (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. *Clim. Change* 83:301-322.
- UNDP (2008). *Climate Change Country Profile Vietnam.*
- Valipour M, Gholami Sefidkouhi MA, Eslamian S (2015). Surface irrigation simulation models: a review. *Int. J. Hydrol. Sci. Technol.* 5:51-70.
- Vedwan N, Rhoades RE (2001). Climate change in the Western Himalayas of India: A study of local perception and response. *Clim. Res.* 19.
- White H (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica* 48:817-838.
- Yu B, Zhu T, Breisinger C, Hai NM (2010). Impacts of climate change on agriculture and policy options for adaptation. In: *IFPRI Discussion Paper 01015: International Food Policy Research Institute (IFPRI).*
- Yusuf AA, Francisco H (2010). Hotspots! Mapping climate change vulnerability in Southeast Asia. In: *Economy and Environment Program for Southeast Asia, 2011.*
- Zellner A (1962). An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *J. Am. Stat. Assoc.* 57:348-368.