UNIVERSITY OF THE PHILIPPINES LOS BAÑOS

Doctor of Philosophy in Agricultural Economics

TRINH QUANG THOAI

THE ECONOMIC VALUE OF AGROMETEOROLOGICAL INFORMATION IN CLIMATE CHANGE ADAPTATION IN VIETNAM

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TRINH QUANG THOAI

**SUBMITTED TO THE GRADUATE SCHOOL
UNIVERSITY OF THE PHILIPPINES LOS BAÑOS
IN PARTIAL FULLFILLMENT OF THE
REQUIMENTS FOR THE
DEGREE OF**

**DOCTOR OF PHILOSOPHY
(Agricultural Economics)**

JUNE 2017

The dissertation attached hereto, entitled **"THE ECONOMIC VALUE OF AGROMETEOROLOGICAL INFORMATION IN CLIMATE CHANGE ADAPTATION IN VIETNAM"** prepared and submitted by **TRINH QUANG THOAI** in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURAL ECONOMICS)** is hereby accepted.

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BIOGRAPHICAL SKETCH

The author was born on May 28 1978 in Yen Quang commune, Y Yen district, Nam Dinh province, Vietnam. He is youngest of eight children of Mr. Trinh Quang Kieu and Mrs. Trinh Thi Dan.

He obtained his elementary, secondary, and high school education from 1984 to 1996 in Y Yen district, Nam Dinh province, Vietnam. He graduated with Bachelor of Science degree in Agricultural Economics from Vietnam National University of Agriculture (VNUA) in October 2000. He was a marketing staff of some private companies from October 2000 to May 2001. He worked for Department of Economics and Market, Fruit and Vegetable Research Institute (FAVRI) under Vietnam Academy of Agricultural Sciences (VAAS), as a researcher from June 2001 to December 2003. He was a researcher of Department of Quantitative Analysis, Faculty of Economics and Rural Development, Vietnam National University of Agricultural (VNUA) from January 2004 to October 2004. Since January 2005, he has worked as a lecturer in Department of Economics, Faculty of Economics and Business Administration, Vietnam National University of Forestry (VNUF).

In April 2008, the Southeast Asian Regional Center for Graduate Study and Research in Agricultural (SEAMEO-SEARCA) granted him a two years scholarship to pursue a Master's degree in Agricultural Economics, Specialization in Natural Resources Economics at the University of the Philippines Los Baños (UPLB).

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He is happily married to Ms Nguyen Thi Ngoc Anh since November 2003 and they are blessed with their son, Trinh Minh Quang and daughter, Trinh Bao Ngoc.

TRINH QUANG THOAI

ACKNOWLEDGEMENTS

I wish to express my deep gratitude and heartfelt appreciation to the following people and institutions that became instrumental in the completion of my Ph.D degree:

Grateful acknowledgment is made to the all members of my advisory committee, Dr. Roberto F. Rañola, Jr., chair of advisory committee, for his intellectual insights, constant encouragement and hospitality, Dr. Jose M. Yorobe, Jr., Dr. Zenaida M. Sumalde and Dr. Leni D. Camacho, members of advisory committee, for their valuable advice, constructive suggestions, sincere concern and understanding.

I am also grateful to the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), especially to German Academic Exchange Service (DAAD) for granting me financial support. I also thank Dr. Gil C. Saguguit, Jr., Director of SEARCA; Dr. Maria Cristeta N. Cuaresma, Program Head, Graduate Education and Institutional Development Department (GEIDD)-SEARCA; and all the staffs of the GEIDD for responding to all my requests so graciously.

I likewise thank World Agroforestry Centre (ICRAF), Vietnam Office for granting me financial support for my fieldwork. Especially, I would like to thanks Dr. Delia Catacutan, ICRAF Country Representative and Dr. Elisabeth Simelton, Project Manager for their valuable advice, constructive suggestions, sincere consideration and support. I also thank Mr. Pham Duc Thanh, Office Manager, ICRAF Vietnam, Mr. Duong Minh Tuan and Ms. Le Thi Tam, member staffs of ICRAF Vietnam for their support in administrative procedure for my fieldwork and related issues.

My acknowledgment also go to the local officers and people in Ky Son commune especially Mr. Nguyen Anh Ngoc, President, Ky Son commune, Mr. Duong Van Tham, Head, My Loi village for their support and cooperation during my data collection. I also wish to thank Mr. Le Quang Trung, Rector, Ky Son Secondary School for providing me accommodation during my field survey; Mr. Dang Quoc Minh, Teacher, Ky Son Secondary School and his family's members for their logistical support. I also like thank to Ms. Nguyen Thi Linh, BS in Education and Ms. Hoang Thi Thanh Huyen, BS in

Economics for their assistance in data gathering. My special thanks go to Dr. Ernesto S. Luis for his checking and editing my dissertation.

I thank the Vietnam National University of Forestry (VNUF) for granting me a study leave, especially Prof. Dr. Tran Van Chu, Rector; Asso. Prof. Dr. Tran Huu Dao, Dean, Faculty of Economics and Business Administration; and Dr. Nguyen Van Hop, Deputy Dean, Dr. Nguyen Tien Thao, Head, Department of Economics. I also thank all of my colleagues in Department of Economics, Faculty of Economics and Business Administration, VNUF, who took over my academic responsibilities during my study leave.

My thanks go to the professors and administrative staff of the Department of Agricultural and Applied Economics (DAAE), Department of Economics (DE), Department of Social Forestry and Forest Governance for their academic and administrative support. I also like thank all the staff members of Graduate School (GS) of UPLB for their great support in helping me meet all requirements. I am grateful to Vietnamese Student Association (VSA) in UPLB for their moral support throughout my stay at UPLB.

I am forever grateful to my parents, brothers and sisters, especially, my wife, Nguyen Thi Ngoc Anh, my son, Trinh Minh Quang, and my daughter, Trinh Bao Ngoc for their love, understanding, and spiritual supports. This dissertation is dedicated to my loving parents, brothers, sisters, my wife, and my children.

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ABSTRACT

TRINH QUANG THOAI, University of the Philippines Los Baños, June 2017. **The Economic Value of Agrometeorological Information in Climate Change Adaptation in Vietnam**

Major Professor: Dr. Roberto F. Rañola, Jr.

This study estimated the economic value of seasonal weather forecast and meteorological information in coping with extreme weather events in Ha Tinh province, Vietnam. It also analyzed the factors affecting farmers' adaptive and/or remedial practices to overcome the effects of extreme weather events in agricultural production in the region.

The results of the study showed that climate change exemplified by extreme weather events such as drought, typhoon, flood, hot and cold spell in Ha Tinh province had a serious effect on agricultural production. Among these events, drought had the most serious negative effect to the region. These phenomena reduced the yields of major crops such as rice, peanut, and corn of the province. The study also revealed that local farmers have increasingly considered various adaptive practices to minimize the negative effects of extreme weather events in their agricultural production. Five major adaptive practices used by the farmers include changing crop varieties, switching to new cultivar types, adjusting farming calendar, following up weather forecasts, and intercropping. Among them, following up weather forecasts and changing crop varieties were adopted by many farmers.

Factors affecting farmers' adaptive behavior to extreme weather events include the farm size, gender, training attended, educational level, farming experience, and damage level. Of these factors, farm size and training attended affected significantly all the major adaptive practices of farmers. By contrast, household's agricultural labor, access to credit and membership in local organizations had no significant effects on the farmers' adaptive strategies.

Farmers in the study area have recognized the different explicit benefits of following weather forecast news in confronting extreme weather events. Thus, many farmers use meteorological information given by the weather forecast news to schedule properly their agricultural production activities. The farmers' practices to cope with extreme weather events based on meteorological information encompass changing planting dates, adjusting application of inputs, and shifting harvesting calendar. Educational level, farming experience and training attended significantly affected the farmers' specific farm management practices based on meteorological information. By contrast, gender, damage level and household's agricultural labor have no significant influences on farmers' adjustment of agricultural production activities.

Many farmers in the study area have been aware of the importance and necessity of seasonal forecast bulletin in coping with extreme weather events in agricultural production. Thus, they were willing to pay from VND 20,000 (US$0.9) to VND 60,000 (US$2.6) per month for this bulletin. Bid level, age, gender, annual crop income and membership in local organizations affected significantly farmers' paying ability for the seasonal forecast bulletin. The mean WTP level for seasonal forecast bulletin of farmers is VND 46,700 (US$2.1) per month. Total estimated economic return derived from the seasonal forecast in Ky Son commune is VND 450 million (approximately US$20.000) per year.

The policy recommendations from this study are as follows: (1) broadening the training courses on climate change; (2) institute policies that would promote consolidation of farmlands; (3) integrate concepts of climate change adaptation into the operation of the local organizations; and (4) further downscaling weather forecast and localizing meteorological information in other areas.

CHAPTER I

INTRODUCTION

Background of the Study

Climate change has become a threat to human society (Ramirez-Villegas et al., 2012, Kibue et al., 2015), particularly in developing countries where smallholder farmers are greatly affected and are becoming increasingly more vulnerable to extreme weather events (Lotze-Campen and Schellnhuber, 2009; Altieri and Nicholls, 2013; Comoé and Siegrist, 2015). Thus, adaptation to climate variability and change is now gaining wide recognition and is a focal concern around the world (Smit and Skinner, 2002; Wilbanks et al., 2007; Thornton and Comberti, 2013). However, developing countries have lower adaptive capacity and do not have the essential technology for adaptation to climate change (Lotze-Campen and Schellnhuber, 2009).

Agriculture as the major means of man for providing food sustainability is highly dependent on and strongly affected by weather and climate as well as extremely related events (Mjelde et al., 1989; Das, 2005; Motha and Murthy, 2007; Sivakumar, 2011; CIE, 2014). Therefore, global agriculture has become an extremely vulnerable industry to the impacts of climate variability and change (Verchot et al., 2007; Bryan et al., 2009; Alam et al., 2012; Arbuckle Jr. et al., 2013b; Sima et al., 2015). Climate change has adversely affected crop production and yields in important agricultural regions of the world (Almaraz et al., 2008, Riedsma et al., 2009). In addition, higher temperature due to climate change may result to lower yields of crops with significant economic importance due to higher weed and pest proliferation (Nelson et al., 2009).

Thus, increasing resilience and adaptation capacity to climate change in agriculture is a societal priority (Smit and Skinner, 2002; Verchot et al., 2007; Bryan et al., 2009; Kibue et al., 2015). Adaptation to climate change is necessary to reduce losses in agricultural production (Wilbanks et al., 2007; Hirota et al., 2011). In addition, adaptation to climate change in agriculture is also an imperative task to ensure food and livelihood security of smallholder farmers (Smit and Skinner, 2002; Verchot et al., 2007; Nelson et al., 2009; Kibue et al., 2015). This is to supplant the adverse impacts of climate change on agricultural production, which leads to high poverty level (Mendelsohn et al., 2007) and food insecurity in the world (Das, 2005; Rosenzweig and Tubiello, 2007; Nelson et al., 2009; Misra, 2013; Connoly-Boutin and Smit, 2015). However, most smallholder farmers do not have enough resources or have limited capacity to adapt to climate variability and change (Verchot et al., 2007; Nyamadzawo et al., 2013).

Weather forecast and meteorological information has increasingly become importance for countries to adapt to climate change (Rogers and Tsirkunov, 2013). Improving seasonal weather forecast could provide a valuable tool for different stakeholders to reduce the adverse impacts of climate change (Patt and Gwata, 2002;

Ziervogel and Downing, 2004; Amissah-Arthur, 2005; Klopper et al., 2006; Archer et al., 2007; Hamin and Gurran, 2009; Marshall et al., 2011). Moreover, accurate weather forecast had brought various benefits to various economic sectors including agriculture (Williamson et al., 2002; Roncoli et al., 2012). For instance, by using precise weather forecast information, farmers may attain higher farm output, productivity or profit (Macauley, 2005; Hay, 2007; Solí and Leton, 2013). In addition, farmers can use weather forecast information to change or modify their plan/program in agricultural production, which results in the reduction of losses or adaptation cost to climate change (Murphy, 1990; Keller et al., 2007; Trærup and Stephan, 2014).

Meteorological information has a crucial role not only in decision making for farm management but also in coping with natural disaster risks and uncertainties (Sivakumar et al., 1998; Sivakumar, 2011). Moreover, meteorological information also has a crucial contribution in recommending appropriate agricultural management practices to maintain sustainable production under climate change impacts (Sivakumar et al., 1998; Murthy and Stigter, 2004; Rathore et al., 2011; Fosu-Mensah et al., 2012; Roco et al., 2015). By using accurate meteorological information, farmers could adjust their production activities and therefore maintain high crop yield under changed climate conditions (Williamson et al. 2002; Amissah-Arthur, 2003; Amissah-Arthur, 2005; Keller et al., 2007; Tena and Gómez, 2009; Das, 2010; Furman et al., 2011).

Thus, the first priority in climate change adaptation is the use of extensive, homogenized series of meteorological information to analyze the climate variations

(Perarnaud et al., 2005). Moreover, to cope effectively with meteorological hazards, it is necessary to provide the public the reliable meteorological information and early warning systems (Ustrul et al., 2015). Availability of accurate meteorological information is also a dominant factor for smallholder farmers to realize and adapt to climate change (Nhemachena and Hassan, 2007; Tambo and Adoulaye, 2012; Huda, 2013; Le et al., 2014b; Kunimitsu et al., 2015). Many water resource planners in South Africa, water managers and farmers in USA have made effective climate change adaptation plans by using seasonal forecast information (Ziervogel et al., 2010; Furman et al., 2011; Templeton et al., 2014).

However, the effects of taking meteorological information to the end users is hardly felt (Murthy and Stigter, 2004). Furthermore, the significant role of providing meteorological information in establishing adaptive strategies to climate change has still not been realized (Klopper et al., 2006). There is also lack of timely meteorological information (Hallegatte, 2009). Moreover, stakeholders do not always use effectively and efficiently weather forecast and meteorological information in coping with climate change (Ziervogel et al., 2010). Another problem is how different smallholder farmers can apply meteorological information in decision making to adapt to climate change (Asplund et al., 2013). Thus, there is need of a guideline framework that recognizes how stakeholders can effectively use meteorological information to cope with climate change (Furman et al., 2011).

Statement of the Problem

Generally, the value of information that focuses on estimating potential economic value of additional information is an analytic basis for decision-making under uncertainty conditions (Keisler et al., 2013). Thus, better decision making in risk assessment framework and appropriate adaptation planning to climate change should focus on estimating economic value of climatological information (Munang et al., 2010). The economic valuation of meteorological information is necessary for stakeholders to recognize how to manage climate risks and develop responsive adaptation strategies (Wang et al., 2008; Nurmi et al., 2012). Economic value of meteorological information in climate change adaptation is expressed through its effects on the decisions of information users (Murphy, 1990) or a reduction in vulnerability of information users under changed climate condition (Hansen, 2002). However, the economic value of meteorological information is difficult to determine (Klopper et al., 2006). Thus, it is still too new to generalize the value of climate prediction and meteorological information in climate change adaptation in agricultural production (Hansen, 2002).

Measuring economic value of meteorological information in the context of climate change adaptation is not only complicated but also difficult (Johnson and Holt, 1997; Williamson et al., 2002; Borisova et al., 2009). The reason is that meteorological information is normally imperfect and has characteristics of a public good (Johnson and Holt, 1997; Stiglizt, 2000; Gunasekera, 2004; Teisberg et al., 2005; Houghton, 2011;

Bernknopf and Shapiro, 2015). Valuing the benefits of meteorological information is also difficult because there are different approaches for quantifying items such as cost savings, and efficiency gains (Houghton, 2011). Furthermore, the methods of estimating economic value of meteorological information in climate change adaptation in agriculture are still very controversial. Value of meteorological information could be the gains in output, productivity or profit of a farm (Macauley, 2005; Solí and Leton, 2013), or a decrease in farmers' avoided cost (Trærup and Stephan, 2014; Häggquist and Söderholm, 2015).

Agriculture is an important sector for Vietnam since it accounts for 20% of GDP and employs over 47% of the country's labor force (GFDRR, 2011). Agriculture also provides an income source for three-quarters of country's residents (Cooke and Toda, 2008) whose livelihood depend mostly on agricultural production (Shrestha et al., 2014). Thus, the Vietnamese Government has intensively considered improving its ability to adapt to climate change in agricultural production (Trinh et al., 2013; Schmidt-Thomé et al., 2015). Furthermore, farmers have initiated a number of autonomous and planned adaptive practices, such as adjusting sowing dates, switching to drought-tolerant crops, changing crop varieties, and switching to rice-fish rotations (World Bank, 2010). However, farmers in Vietnam have limited understanding of the importance of climate change adaptation to their livelihoods (Le et al., 2014a).

Many studies have attempted to explore the adaptive strategies to climate change in Vietnam, especially in the agricultural sector. All these studies showed many adaptive strategies to climate change in different regions of the country. Specifically, Birkmann (2011) mentioned agricultural diversification while Nguyen et al. (2013) stressed maintenance and enhancement of agroforestry systems in climate change adaptation. These studies also emphasized other adaptive strategies to climate change in agricultural production in Vietnam such as improving farm infrastructure and technology (Bastakoti et al., 2014), adopting new varieties (Bastakoti et al., 2014; Shrestha and Trang, 2015), and changing planting date (Shrestha et al., 2014; Deb et al., 2015).

These studies also stressed the role of local organization in supporting farmers to adapt to climate change in agricultural production (Le et al., 2014b). They also mentioned the importance of supplementary irrigation (Shrestha et al., 2014) and climate change adaptation information (Le et al., 2014b & 2014c). However, these studies have not determined the importance of improving weather forecast for climate change adaptation in farming systems. They also did not mention the economic value of weather forecast and meteorological information in climate change adaptation in agricultural production. This implies that these studies have not provided any rationale or basis for downscaling weather forecast and localizing meteorological information for climate change adaptation in Vietnam.

Although the Vietnamese government has recognized the importance and invested much money for weather forecasting and early warning system of the country, forecasting and early warning capacities of the country are still not effective (Detalres, undated). In addition, Vietnam still has numerous shortcomings and challenges in seasonal weather forecast and early warning system (Sivakumar, 2011; World Bank et al., undated). The first of these challenges is poor communication system for timely and fast dissemination of forecasts. The second difficulty is lack of specific weather forecast and meteorological information for specific economic sector. The last issue is poor weather forecast and meteorological information at regional and local scales (World Bank et at., undated).

Localizing meteorological information in agriculture could provide climate-related information at local level for farmers to prevent, reduce and/or manage risks of extreme events (Selvaraju, 2013). In Vietnam, weather information is always available for farmers. However, it is not downscaled to the local level, is not detailed and accurate enough (Coulier, 2016). Moreover, the adaptation strategies in most farming systems "have not been implemented to account for inter-annual or inter-seasonal variation in current climate" (World Bank et al., undated).

Public recognition of economic value of meteorological information is very important for localizing such information in the context of climate change adaptation. It is because local people will not pay or use climatological information if they do not see or recognize the value of this information (GFDRR, undated). Up to now, however, relatively few studies have estimated the economic value of existing weather forecast systems and meteorological information or the incremental benefits of improvement such systems and information (Katz and Murphy, 1997; Rogers and Tsirkunov, 2013; Lee et al., 2014). Furthermore, although weather forecast and meteorological information plays an important role in improving country's capacity to cope with climate change, this contribution is still rarely quantified or remains as an understudied issue (Belinfante et al., 2012; Rogers and Tsirkunov, 2013).

Objectives of the Study

The general objective of this study is to estimate the economic value of agrometeorological information in climate change adaptation in Vietnam. Specifically, the study aims to:

1. describe the weather and climatic status and impacts of extreme climate events on agricultural production in the study site;
2. describe adaptive strategies and factors affecting adaptive strategies employed by farmers in study areas as influenced by extreme climate events;
3. determine the extent of the farmer's utilization of meteorological information and the factors affecting the farmers' access to such information in coping with extreme weather events as it affects agricultural production;
4. estimate the economic value of seasonal forecast and agrometeorological information on climate change adaptation in the study areas; and
5. propose policy recommendations to strengthen farmers' adaptive capacity to climate change and increase economic value of meteorological information in climate change adaptation.

Scope and Significance of the Study

Scope of the Study

Meteorological information is essential to all sectors of the world. In other words, the well-being of humanity depends on weather and climatic conditions. However, this study focused only on estimating the economic value of meteorological information in the context of climate change in relation to agricultural production. In addition, in economic valuation process in this study, meteorological information is considered as a public good.

Significance of the Study

Economic value of meteorological in formation from this study will be the basis and justification for downscaling weather forecast and localizing meteorological information. Thus, it may provide positive support for making adaptive programs and policies to climate change adaptation in Vietnam. Stakeholders can apply the process of economic valuation in this study to estimate the intangible economic value of climatological information in other sectors in Vietnam. Policy makers can also apply this process to calculate the economic value of meteorological information for other sectors depending on climatic condition such as transportation and tourism industries of the country.

CHAPTER II

REVIEW OF LITERATURE

Prevalent Adaptation Options to Climate Change in Agricultural Production

There are several definitions of climate change adaptation. Generally, adaptation could be the coping strategies (UNDP, 2004), a process of reducing harm or risk (Levina and Tirpak, 2006; Mann and Gaudet, 2015; European Commission, 2016), or an adjustment in response to adverse effects of actual or expected climate change (IPCC, 2007). In summary, adaptation is the people's strategies or actions that focus mainly on the prevention or reduction of risks and vulnerability to climate variability and change.

Climate change induced extreme climate events have many negative effects on all economic sectors, particularly agriculture. Thus, adaptation to climate change has been increasingly considered by most of the countries, organizations and individuals (Smit and Skinner, 2002; Wilbanks et al., 2007; Thornton and Comberti, 2013). Up to now, many studies have mentioned different categories of adaptive strategies to climate change.

There are many types of adaptive strategies to climate change in agricultural production. Smith and Skinner (2002) divided adaptive strategies to climate change into four different categories, including (1) technological developments; (2) government programs and insurances; (3) farming production practices; and (4) farm financial management. Adaptation options may also involve agricultural systems, location, and climate change scenario (Rosenzweig and Tubiello, 2007). This also includes crop management, land management, irrigation management, income diversification, and rituals (Esham and Graforth 2013).

Generally, an adaptive strategy to climate change is considered successful if it results in the reduction of the risks or vulnerability to climate change impacts without compromising the economic, social, and environmental sustainability (Doria et al., 2009). Therefore, the adaptive strategies to climate change could be classified into four different broad groups, namely technical, social, economic and financial adaptive strategies.

Technical Adaptation Strategies

Technical or agronomic adaptive strategies include different adjustments related to farming technique, irrigation infrastructure/technology improvement, soil conservation, land and water management, and other related issues (Rosenzweig and Tubiello, 2007; Below et al., 2014). Improving farming techniques had significant effect on farmers' adaptation to climate change in many countries and regions such as Middle East (Iglesias et al., 2011), North America (Grasso and Feola, 2012), and Vietnam (Bastakoti et al., 2014).

At present, adaptive strategies related to cultural practices (Table 1) such as adjusting agricultural calendar, changing cultivar varieties and types, and crop rotation and diversification have been widely adopted in climate change adaptation (Rosenzweig and Tubiello, 2007; Lotze-Campen and Schellnhuber, 2009; Esham and Graforth, 2013; Keshavarz et al., 2013; Below et al., 2014). Among these adaptive practices, adjusting farming calendar is mentioned in many studies (Table 1). Adjusting farming calendar relates to changing planting and harvesting dates. Changing planting date was an effective strategy for farmers to cope with climate change in agricultural production (Rosenzweig and Tubiello, 2007; Barbier et al., 2009). Meza et al. (2008) found that double cropping that is also a farming technique could help farmers adapt effectively to climate change in agricultural production.

The usefulness of changing crop systems and varieties, switching to new cultivars, and production diversification in climate change adaptation was revealed by many people such as Bradshaw et al. (2004), Rosenzweig and Tubiello (2007), Riedsma et al. (2010), Birkmann (2011), Arbuckle Jr. et al., (2013a), Jamir et al. (2013), Bonzanigo et al., 2014), and Westengen and Brysting (2014). However, several authors (e.g., Bradshaw et al., 2004; Seo and Mendelsohn, 2008; Tingem and Rivington, 2009; Qiu and Prato, 2011; Brooks, 2014; Kassie et al., 2015; Srivastava et al., 2015) indicated the inefficiency of these cultural practices for farmers in coping with climate change in their agricultural production.

Table 1. Common cultural practices used as technical adaptive strategies

CULTURAL PRACTICES	REFERENCES
Adjusting farming calendar	Yang et al., 2007; Sultana et al., 2009; Moriondo et al., 2010; Jalota et al., 2012; Kassie et al., 2013; Kumar et al., 2014; Omoyo et al., 2015
Changing crop system/Crop pattern	Yang et al., 2007; Joyce et al., 2011; Gioli et al., 2014; Keshavarz et al., 2014; Banerjee, 2015
Adopting to new crop variety	Yang 2007; Lotze-Campen and Schellnhuber, 2009; Tao and Zhang, 2010; Yaro, 2013; Westengen and Brysting, 2014; Fisher et al., 2015
Changing crop/cultivar type	Yang et al, 2007; Kurukulasuriya and Mendelsohn, 2008; Bryan et al., 2009; Byjest et al., 2010; Olesen et al., 2011; Li et al., 2013; Moradi et al., 2014
Crop diversification	Reidsma et al., 2010; Steffen et al., 2011; Anik and Khan, 2012; Antwi-Agyei et al., 2014
Crop rotation	Barbier et al., 2009; Lotze-Campen and Schellnhuber, 2009; Esham and Garforth, 2013; Klein et al., 2013

Soil conservation and land management were also efficient technical strategies for smallholder farmers to minimize negative impacts of climate change in their agricultural production (Rosenzweig and Tubiello, 2007; Eakin et al., 2014; Aleksandrova et al., 2015). This is also found in the studies of Ebi et al. (2011) in Mali, Bonzanigo et al. (2014) in Italia, and Klein et al. (2013&2014) in Switzerland. Improving irrigation infrastructure and water management practices have also benefited farmers in confronting climate change (Yang et al., 2007; Wantanabe and Kume, 2009; Sowers et al., 2011; Sissoko et al., 2011; Dono et al., 2013; Sima et al., 2015). This was justified in several countries such as Ethiopia (Demeke et al., 2011), Mali (Ebi et al., 2011), India (Jamir et al., 2013), Itali (Bonzanigo et al., 2014), and Thailand (Koontanakulvong et al., 2014).

Other technical adaptation strategies such as agroforestry techniques and climate-smart agriculture techniques were also recognized as effective adaptive strategies by several studies. Agroforestry could maintain agricultural production activities (Verchot et al., 2007; Nguyen et al., 2013) and provide food during shortage or cash source for weather-related crop failure under changed climate conditions (Fisher et al., 2010). This is similar to findings of Thorlakson and Neufeldt (2012) in Kenya, and Rahn et al. (2014) in Nicaragua. Climate-smart agriculture that is a new terminology that was coined by FAO in 2009 (Msangi, 2014) could also facilitate climate change adaptation or provide the basis for development of the capacity for farmers to cope with climate change (Kenny, 2011; Scherr et al., 2012; Zhang et al., 2015). The importance of climate-smart agriculture technique for farmers in coping with climate change was explained in the studies of Wantanabe and Kume (2009) in Japan, Murungweni et al. (2015) in Zimbabwe, and Zhang et al. (2015) in China.

In summary, technical adaptive strategies have played an important role in coping with climate change (Yang et al., 2007; Krysanova et al., 2010; Asseng and Pannell, 2013). Thus, public intervention on climate change adaptation in developing countries should enhance farmers' understanding of technical knowledge (Eakin et al., 2011; Faysse et al., 2014). However, technical adaptive strategies were not always effective for farmers to cope with future change in climate variability (Rosenzweig and Tubiello, 2007; Marshall et al., 2011; Qiu and Prato, 2012; Trærup and Stephan, 2014).

Social Adaptation Strategies

Along with technical solutions, social adaptation strategies or soft strategies are also efficient in addressing adverse impacts of climate change (Hallegatte, 2009; Krysanova et al., 2010). Social adaptive strategies relates directly to improving household's social capital (Sowers et al., 2011; Esham and Garforth, 2013; Kassie et al., 2013). Improving household's social capital could help farmers in many countries such as Australian (Marshall et al., 2011), Ghana (Antwi-Agyei et al., 2013), Kenya (Jalón ét al., 2015), and Tanzania (Mutabazi et al., 2015) cope effectively with climate change in their agricultural production.

Social adaptation strategies include improving human recognition and knowledge on climate change, strengthening social network and institutional capacity, providing information and extension services, and building capacity for farmers (Sowers et al., 2011; Esham and Garforth, 2013; Kassie et al., 2013). According to Challinor et al. (2007), accessing knowledge on climate change could be a key to improve farmers' ability in confronting climate change. The efficiency of improving farmers' recognition and knowledge in coping with climate change was recognized by different authors such as Reidsma et al. (2010), Marshall et al. (2011), Newsham and Thomas (2011), and Pennesi et al. (2012).

Training is a suitable way to improve people's recognition and knowledge on climate change. Thus, training also has an important role for climate change adaptation in different countries. According to Alam et al. (2012), training has enabled farmers in

Malaysia to adapt effectively to the negative effects of extreme climate events in agriculture. Moreover, Szlafsztein (2014) also revealed that training was the most important adaptation strategy in the agricultural sector of Brazil. Mutual learning across stakeholder groups were also helpful in enhancing adaptive plan to address climate change in Canada, Finland, Germany, UK and the US (Bizikova et al., 2014a).

Improving human recognition and knowledge on climate change is also associated with enhancing local or indigenous knowledge. Enhancing local or indigenous knowledge regarding the climate change has been an important approach for farmers to cope with the negative impacts of future climate change (Nyong et al., 2007; Manandhar et al., 2011; Anik and Khan, 2012; Campos et al., 2014). Kassie et al. (2013) pointed out that integrating local knowledge into government policies would significantly assist farmers to cope with the adverse impacts of current and future climate change. Hiwasaki et al. (2014) concluded that there is need for integration between indigenous knowledge and science to improve farmers' adaptive capacities. Omoyo et al. (2015) also indicated that enriching the awareness of climate change is imperative in Eastern Kenya to help farmers counter climate variability and change.

Strengthening social network, institutional capacity and community's participation is also another significant strategy for farmers to cope with climate change (Acosta-Michlike and Espaldon, 2008). This is consistent with the findings of several studies in different countries and regions such as India (Prabhakar and Shaw, 2008), African countries (Westerhoff and Smit, 2009; Batisani and Yarnal, 2010; Antwi-Agyei et al., 2013 & 2014; Yaro, 2013; Brooks, 2014), the Mesoamerica (Eakin et al., 2011), the Europe (Bizikova et al., 2014b), and Nicaragua (Rahn et al., 2014). However, Sowers et al. (2011) pointed out that community participation in several countries in the Middle East and North Africa was not effective in enhancing climate change adaptation because of political issues. Seo (2011) also concluded that public adaptation to climate change was likely inefficient because of the high transaction cost needed to coordinate for public provision, and lack of public information dissemination.

Capacity building has also an important role in helping farmers cope with climate change in agricultural production in several African countries. According to Yaro (2013), capacity building was more effective for Ghanaian farmers in coping with climate change in agricultural production compared to risk aversion strategies. Brooks (2014) indicated that in setting up adaptive strategies to climate change in Malawi and Kenya, policy makers should prioritize capacity building from the bottom. Rahn et al. (2014) also showed that capacity building was also effective in helping coffee farmers in the Northern Nicaragua to counter adverse impacts of climate change.

Economic and Financial Adaptation Strategies

Economic and financial adaptive strategies that related to income diversification and access to market and credit are also useful for farmers in climate change adaptation. Income or livelihood diversification (off-farm employment, leased cropping land, etc.) is an effective solution for smallholder farmers in climate change adaptation (Thomas et al., 2007; Esham and Garforth 2013; Keshavarz et al., 2014). This was justified in several countries such as Canada (Bradshaw et al., 2004), Tanzania (Paavola, 2008), India (Jamir et al., 2013), and Ghana (Antwi-Agyei et al., 2013 & 2014). However, Thomas et al. (2007) argued that livelihood diversification is not always effective for farmers to cope with climate change. Eakin et al. (2014) also pointed out that farmers in Mesoamerica did not use new economic activities or livelihood diversification as adaptive strategy to climate change.

Better access to market could help farmers cope effectively with climate change in their agricultural production. This supports for findings of Hassan and Nhemachena (2008) in the Africa, Steffen et al. (2011) in Australia, Eakin et al. (2011) in the Mesoamerica, Tambo and Abdoulaye (2012) in Nigeria, Kassie et al. (2013 & 2015) in Ethiopia, and Koopman et al. (2015) in Netherland. Facilitating access to credit could also help farmers adapt more efficiently to climate change in agricultural production (Yang et al., 2007; Hassan and Nhemachena, 2008; Deressa et al., 2009; Krysanova et al, 2010; Ebi et al., 2011). This was similarly found in many countries and regions such as the Mesoamerica (Eakin et al., 2011), Kenya (Tambo and Abdoulaye, 2012), Uganda (Hisali et al., 2011), Nigeria (Tambo and Abdoulaye, 2013), Ethiopia (Falco et al., 2011; Kassie et al., 2013), Ghana (Fosu-Mensah et al., 2012; Yaro, 2013), and Tanzania (Mutabazi et al., 2015). However, Jalón et al. (2015) revealed opposite finding, that access to credit did not affect behavior towards adoption of climate change actions of farmers in Kenya.

Factors Affecting Farmers' Adaptation to Climate Change

Practically, many studies have analyzed factors affecting farmers' adaptive strategies to climate change in agricultural production. The factors affecting relate mostly to household's livelihood assets. The livelihood assets of households include human capital, natural capital, physical capital, financial capital, and social capital (DIFID, 1999). Nhemachena and Hassan (2007) used multivariate probit (MVP) model to analyze the factors affecting farmers' adaptive options to climate change in the Southern Africa. The factors affecting farmers' adaptive options included gender, farming experience, access to extension services, access to credit and market, property right, and other elements related to climate information. This supports for major findings of Piya et al. (2013) in Nepal and Ashraf et al. (2014) in Pakistan. However, Mu et al. (2015) also used MVP model and oppositely found that farming experience, extension frequency, land ownership, and access to climate information did not significantly affect farmers' adaptive options.

Fosu-Mensah et al. (2012) used binary logit model to study factors affecting farmer's decision on adaptation to climate change in Ghana. The results of this study indicated that the access to extension services, credit, and land tenure are the most important factors influencing farmer's adaptation. Comoé and Siegrist (2015) also applied binary logit model to study farmers' adaptive behavior to climate change in Côte d'Ivoire. The authors concluded that extending information has positive influence on adaptive strategies of farmers. This is on line with findings of Jalón et al. (2015) in

Kenya, that receiving climate information, farming experience, and educational attainment influenced significantly the farmers' probability of adaptation to climate change. The importance of educational level and farming experience were also mentioned by Jin et al. (2016) who also used binary logit model to determine factors affecting farmers' adaptation choices in China.

In China, Kibue et al. (2016) found that key factors influencing farmers' decision on adaptation included extension services, frequency of seeking information, household's head education, and climate variability perception. The significant role of extension services for farmers' adaptation to climate change was found by several researchers such as Falco et al. (2012) in Ethiopia, Comoé et al. (2014) in Côte d'Ivoire, Westengen and Brysting (2014) in Tanzania, and Prokopy et al. (2015) in the US.

Role of Information, Meteorological Information and Weather Forecasts in Climate Change Adaptation

Providing information could benefit farmers in coping with climate change in agricultural production. This was justified in the studies of Tarnoczi and Berkes (2010) in Canada, Kassie et al. (2013) in Ethiopia, Yaro (2013) in Ghana, Monterroso et al. (2014) in Mexico, and Fisher et al. (2015) in sub-Saharan Africa. Providing information on climate change has also been a core adaptive strategy for smallholder farmers in agricultural production (Smit and Skinner, 2002). This supports for findings of Falco et al. (2011) in Ethiopia, Tambo and Abdoulaye (2012, 2013) in Nigeria, and Le et al. (2014c) in Mekong Delta, Vietnam. These concluded that the key driver of climate change adaptation of smallholder farmers was access to quality and timely information on future climate change. Moreover, Bonzanigo et al. (2014) identified that information on climate change had a significant and positive impact on adaptive plans to climate change of farmers. This is similar to conclusion of Acosta-Michlik and Espaldon (2008), Deressa et al. (2009), Fosu-Mensah et al. (2012), and Gebrehiwot and Veen (2013) that lack of reliable information on climate change would be a barrier to farmers in coping with climate change in agricultural production. However, Patt and Schröter (2008) revealed opposite finding that in Mozambique farmers' adaptive behavior did not change although they receive information on climate change.

Providing timely and accurate meteorological information could help farmers cope effectively with the adverse effects of climate change in agricultural production (Das, 2005; Guerreiro, 2005; Batisani and Yarnal, 2010; Goddard et al., 2010). This was found in many countries and regions such as South Africa (Klopper et al., 2006), Uganda (Roncoli et al., 2011), West African Sahel (Sissoko et al., 2011), Bangladesh (Saroar and Routray, 2012), Ethiopia (Gebrehiwot and Veen, 2013), Ghana (Yaro, 2013), USA Templeton et al. (2014), and Benin (Baudoin et al., 2014). Availability of accurate meteorological information may help farmers reduce risks caused by climate change (Risbey et al., 1999; Munang et al., 2010; Debela et al., 2015) or have optimal adaptive strategies (Amissah-Arthur, 2005; Challinor et al., 2007; Hassan and Nhemachena, 2008; Roco et al., 2015; Jalón et al., 2015).

Improving seasonal weather forecast could provide a valuable tool for different stakeholders to reduce adverse impacts of climate change. This matched the findings of Patt and Gwata (2002), Ziervogel and Downing (2004), Amissah-Arthur (2005), Klopper et al. (2006), Archer et al. (2007), Hamin and Gurran (2009), Marshall et al. (2011), Ebi et al. (2011), Jamir et al. (2013), and Kunimitsu et al. (2015). Improving weather forecast could also help farmers in different countries to have plausible adaptive planning to climate change in their agricultural production. This finding was found in many countries and regions such as Brazil (Lemos et al., 2002), South Africa (Boone et al., 2004), Burkina Faso (Roncoli et al., 2009), USA (Crane et al., 2011), the Mediterranean region (Grasso and Feola, 2012), and Côte d'Ivoire (Comoé et al., 2014).

However, there are still several disadvantages or constraints of improving weather forecast and providing climatological information in climate change adaptation. According to Murphy et al. (2001), seasonal forecast development could not be a solely successful strategy to mitigate negative impacts of climate hazards. Lemos (2003) revealed that climatological information could have negative or positive impacts depending on how the stakeholders use such information in decision-making. Hallegatte (2009) pointed out that providing certain and accurate weather forecast would not completely solve uncertainty in future climate change because climate change is not easily detected. Chikozho (2010) also concluded that improving access to climatological information is only half the battle for adaptation to climate change.

Patt and Gwata (2002) indicated that the constraints that reduce the effectiveness of seasonal climate forecast application include credibility, legitimacy, scale, cognition, procedures, and choice. According to Klopper et al. (2006), seasonal weather forecasts would be ineffective due to many constraints such as the means of providing, interpreting and applying forecasts in a variety of decision-making processes. According to Goddard et al. (2010), it is not easy to determine the impact of full integration of the weather forecast with other information on decision strategies. Ziervogel et al (2010) concluded that there were still challenges in using climatological information and weather forecast as the strategies to cope with climate variability and change. According to Maina et al. (2015) due to difficulties in translating climatological data into simple indices, weather forecasts in Papua New Guinea did not benefit farmers in climate change adaptation.

Economic Valuation Methodology of Meteorological Information

There are several methodologies to estimate economic valuation of meteorological information. The methodology for estimating the economic value of information is basis for calculating the economic value of meteorological information. Generally, welfare approach, econometric estimation, and contingent valuation surveys are three major methodologies of estimating economic value of meteorological information (Freebairn and Zillman, 2002; Macauley, 2005; Houghton, 2011; Nurmi et al., 2012; Deloitte, 2013).

Welfare approach focused on estimating the direct value of meteorological information is based on the market-based approach (Deloitte, 2013). In welfare approach, meteorological information has characteristics of private good and is an input of the production process (Freebairn and Zillman, 2002; Gunasekera, 2004). It implies that there is clear market and market price for meteorological information (Deloitte, 2013). According to Gunasekera (2004), market price is a useful tool to measure the marginal benefit of climatological information users. The users will purchase the meteorological information up to amount where the marginal value to them equal the price of information (Gunasekera, 2004). Based on the welfare approach, the economic value of meteorological information is the net surplus of this information (Deloitte, 2013). According to DotEcon Ltd. (2006), net surplus is sum of producer surplus and consumer surplus. It implies that: Net surplus = Producer surplus + Consumer surplus.

However, market-based approach may not be efficient for valuing meteorological information (Johnson and Holt, 1997; Gunasekera, 2004). This is because meteorological information has major characteristics of public good such as non-rivalry and non-excludability (Johnson and Holt, 1997; Stiglizt, 2000; Gunasekera, 2004; Teisberg et al., 2005; Houghton, 2011; Bernknopf and Shapiro, 2015). Thus, meteorological information must be viewed as a factor (input) in decision process of economic agents or decision makers to reduce uncertainties (Johnson and Holt, 1997; Gunasekera, 2004; Tong et al., 2013).

Econometric estimation is focused on the value added in the sector that used information as an input (Tong et al., 2013). It used the econometric model to calculate the indirect economic value of meteorological information through the value added (Deloitte, 2013). The value added could be output/productivity gains or a decrease in losses due to meteorological information (Gunasekera, 2004; Macauley, 2005; DotEcon Ltd., 2006; Bernknopf and Shapiro, 2015). In addition, the econometric approach estimates the economic value of meteorological information through a comparison of the net benefit or avoided cost with and without this information (Bernknopf and Shapiro, 2015). Prescriptive decision-making and descriptive behavioral response are two major approaches for econometric estimation (Freebairn and Zillman, 2002; Gunasekera, 2004; Nurmi et al., 2012).

Prescriptive decision-making approach focuses on solving circumstances of imperfect information about weather or climate conditions (Freebairn and Zillman, 2002). According to Gunasekera (2004), prescriptive decision-making approach emphasizes how users utilize meteorological information. It implies that individuals could use meteorological information to either maximize expected profits or minimize expected costs, under condition of imperfect knowledge about climate conditions (Wilks, 1997; Gunasekera, 2004).

Descriptive behavioral response studies aims to estimate the value of climatological information by observing behavior of users, using surveys, experiments and regression methods (Freebairn and Zillman, 2002). According to Gunasekera (2004), in descriptive behavioral response, meteorological information is dependent on its influence on the decisions of users. In addition, descriptive behavioral studies emphasize the realistic value of climatological information for the end-users (Nurmi et al., 2012).

Contingent valuation surveys emphasizes the willingness to pay of different stakeholders for meteorological information that has the characteristics of a public good (Freebairn and Zillman, 2002; Gunasekera, 2004; Houghton, 2011; Nurmi et al., 2012). In this approach, the analyst will ask users of meteorological information how much money they are willing to pay for a particular type and level of such information (Freebairn and Zillman, 2002; Gunasekera, 2004). This approach aims to complete a survey on experts of users of meteorological information (Nurmi et al., 2012). The main idea of this approach is that people may recognize the benefit of using meteorological information in decision-making process and are willing to pay for this information.

Economic Value of Weather Forecast and Meteorological Information in Climate Change Adaptation

According to Katz and Murphy (1997), weather has value if and only if it affects human behavior. Weather forecasts and climatological information brings high economic value for all economic activities (Amissah-Athur, 2005). Bernknopf and Shapiro (2015) also revealed that using geospatial information in decision-making would be beneficial to society. Economic value of weather forecast and meteorological information could be the gains in output, productivity or profit (Macauley, 2005; Solí and Leton, 2013), or a decrease in avoided cost (Wang et al., 2009; Häggquist and Söderholm, 2015).

Value of meteorological information could be an outcome of the choice in uncertain situations (Hirshleifer and Riley, 1979 and McCall, 1982 cited in Macauley, 2005). Borisova et al. (2009) identified that climatological information (information about ENSO) brought economic benefit for peanut farmers and cow-calf producers in the U.S. The value of the benefit brought by the geospatial information was over £230 million per annum in 2008/2009 for the government of England and Wales (Coote and Smart, 2010). Net welfare benefits of spatial information of New Zealand in 2008 and Australia in 2010 were also about US$70 million and US$1.2 billion respectively (Tong et al., 2013). Based on the estimates of the Center of International Economics - CIE (2014), the potential economic value of weather forecast to the agriculture industry in Australia was around AU$1.567 million. However, the higher quality of weather and climate forecast is not always associated with higher economic value (Marzban, 2011).

Value of meteorological information might also be an expected gain in output or productivity from using additional information (Borisova et al, 2009). Tena and Gómez (2009) revealed that improving quality of weather forecast and meteorological information could substantially increase the value added for farmers. In Australia, the potential economic value of meteorological information was around $10-12/ha with respect to perfect forecast of rainfall (Wang et al., 2009).

According to Cardoso et al. (2010), accurate meteorological forecast and climatological information played a crucial role in improving the productivity prediction of soybean production and agricultural planning in Brazil. Farmers in Zimbabwe who used meteorological information in planning had higher benefit (9%) than farmers who did not apply forecast information (Hansen et al., 2011). Solí and Letson (2013) also revealed that information on seasonal rainfall and temperature forecasts positively improved economic performance of agriculture in the U.S.

Economic agents or decision makers may use information or meteorological information to reduce risks of extreme events (Katz an Murphy, 1997). Williamson et al. (2002) concluded that better weather prediction could reduce substantially the cost for society in responding to extreme climate events. Economic benefit of meteorological information could be a reduction in vulnerability to adverse impact of climate variability and change through using this information in decision-making (Hansen, 2002). Hubbard and Millar (2014) indicated that the expected value of meteorological information could be the economic value of reducing uncertainty on a single variable. Several studies estimated the economic value of meteorological information through decreasing avoided cost. According to Williamson et al. (2002), the agricultural sector of the U.S saved an additional US$40 million per year in avoided irrigation costs through using of more accurate short-term weather forecast. Teisberg et al. (2005) indicated that U.S electricity generators saved US$166 million annually through using of meteorological information. According to Wang et al. (2009), Australian farmers may save US$54/ha in nitrogen reduction by using adequate meteorological information.

CHAPTER III

THEORETICAL AND CONCEPTUAL FRAMEWORK

Theoretical Framework

Willingness to Pay and Welfare Change

Willingness to pay (WTP) is the amount of money that an individual would give up to obtain a change and still be at the initial well-being (Mitchell and Carson, 1989 cited in Dong, 2013). According to Haab and McConnell (2002) “WTP is the maximum amount of money a person will pay in exchange for an improvement in circumstance”. WTP is also the maximum amount a person will pay to avoid a decline in circumstance (Haab and McConnell, 2002). Krugman and Wells (2012) defined “a consumer’s WTP for a good as the maximum price at which he would buy for that good”. According to Pearce et al. (2002), WTP comprises two components: (1) the actual payment; and (2) the excess of WTP over price – consumer’s surplus. Thus, WTP for a marketed good or service is the area of the AEQ_eO rectangle in the Figure 1. While, WTP for a non-marketed good or service is the area of ACO triangle in Figure 1 since there is no market price for non-marketed good or service (Pearce et al., 2002).

Normally, consumer surplus is a useful vehicle to measure consumer welfare (Just et al., 2004). For the marketed goods and services, consumer surplus (CS) is the incremental WTP for a good and service (Fleischer and Felsenstein, 2002). In addition, CS measures the net gain from the purchase of these goods and services (Pearce et al., 2002; Krugman and Wells, 2012). Consumer surplus is also the difference between their WTP for the goods and services and actual expenditure to obtain these goods and services (van Kooten, 2013). Dong (2013) mentioned the definition of Dupuit (1844) in that CS is the difference between the actual price and the amount that the consumer would be willing to pay for a commodity. In addition, Freman III et al. (2014) cited the definition of Marshall (1920) of CS as the excess of the price that the consumer would be willing to pay over that which he actually does pay. It is clear that there is a close relationship between willingness to pay (WTP) and consumer surplus (CS).

The ordinary consumer surplus is the area (AEP_e triangle in Figure 1) under a Marshallian ordinary demand curve and above the horizontal price line (Just et al., 2004; Dong, 2013; Freeman III et al., 2014; Loomis, 2014). In the case of non-marketed goods and services, consumer surplus is the whole area under the Marshallian demand curve (triangle ACO in Figure 1) because there is no market price (Pearce et al., 2002; Dong, 2013).

There are problematic issues in measuring benefits resulting from price or quantity changes in the concept of Marshallian consumer surplus (Samuelson, 1947; Silberberg and Suen, 1978 cited in Dong, 2013). Firstly, Marshallian demand curve does not hold the utility level constant while it keeps the income constant (Mitchell and

Carson, 1989 cited in Dong, 2013). Secondly, "the Marshallian CS measure cannot be defined in terms of the underlying utility function" (Freeman III et al., 2014). In addition, Bockstael and McConnell (2007) indicated the major problem of Marshallian consumer surplus is that "CS in principle is neither meaningful nor unique". It is because consumer utility is not observable (Just et al., 2004).

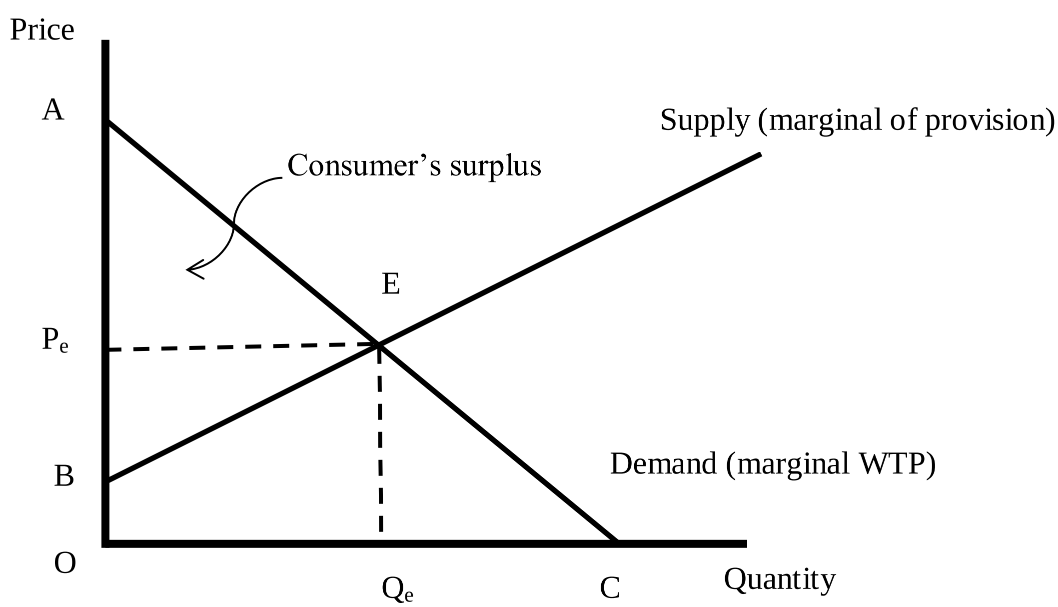

Figure 1. The ordinary consumer's surplus (source: Krugman and Wells, 2012; van Kooten, 2013)

Thus, Hicks defined compensating variation and equivalent variation in 1943 in order to overcome the drawback of Marshallian consumer surplus (Senbil and Kitamura, 2007; Dong, 2013; Freeman et al., 2014). Compensating variation (CV) is the amount of compensated or income received to hold the individual at the initial level of well-being

(Haab and McConnell, 2002; Dong 2013; Freeman III et al., 2014). While, equivalent variation (EV) is the amount paid or money received that leaves the individual at the final level of well-being (Haab and McConnell, 2002). EV is also the amount of money received that makes the individual accept the change (Senbil and Kitamura, 2007). Generally, "compensating and equivalent variation are defined as income adjustments that maintain the consumer at a particular level of welfare" (Just et al., 2004). Figure 2 shows the relationship among the compensating variation (CV), equivalent variation (EV), and consumer surplus (CS). The areas between the two price levels (P_1^0 and P_1^1) behind the Hicksian demand curves conditional initial and changed utility levels (U^0 and U^1) are CV and EV, respectively (Bocksteal and McConnell, 2007).

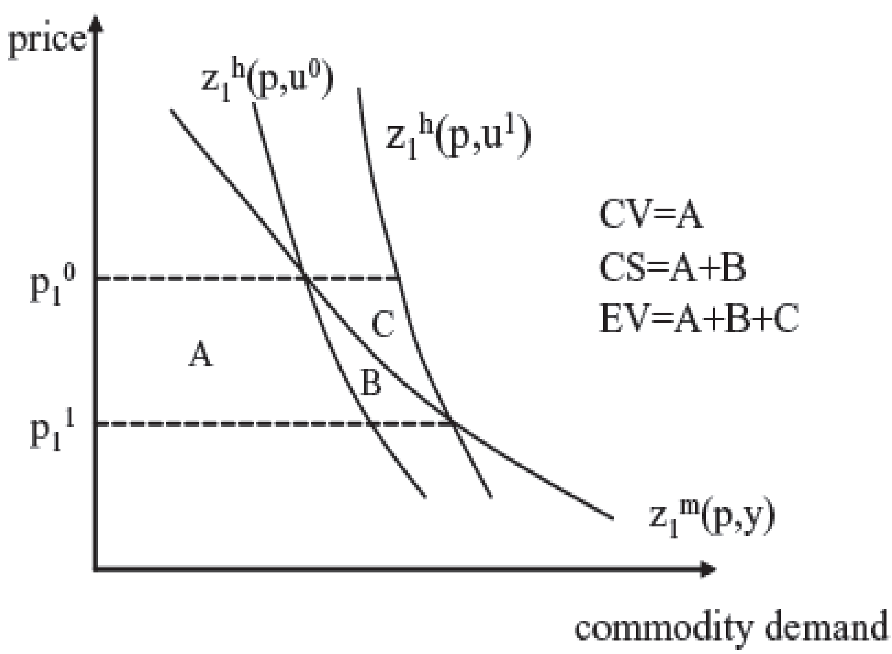

Figure 2. Relationship among CV, EV, and CS: Price decrease for consumption good (source: Bockstael and McConnell, 2007)

According to Haab and McConnell (2002), there is a link between CV and EV concepts and the concepts of WTP. Both of CV and EV concepts imply the incremental income that makes an individual indifferent to an exogenous change (Haab and McConnell, 2002). For welfare gain, CV is WTP to attain the gain; but for a welfare loss, EV will be WTP to prevent the loss (Senbil and Kitamura, 2007). Moreover, CV is WTP if the final well-being is better than the initial well-being while EV will be WTP when the well-being declines (Haab and McConnell, 2002; Bockstael and McConnell, 2007; Freeman III et al., 2014). Generally, willingness to pay (WTP) relates closely to compensating variation (CV) and equivalent variation (EV). In other words, CV and EV are the two alternative measures of WTP, which provides plausible interpretation for changing welfare of consumer (Just et al., 2004).

Externalities and Welfare Change

Theoretically, both producers and consumers will maximize their well-being and therefore social welfare reaches maximum level in perfect competitive market (Just et al., 2004). In other words, under perfect competitive market, both production and consumption processes are Pareto efficient (Just et al., 2004; Weimer and Vining, 2005). Social welfare is the sum of consumer’s surplus and producer’s surplus (Tong et al., 2013). However, changes in input prices, quantities or qualities of nonmarket goods and in the risks that individuals face influence social welfare (Freeman III, 2003).

Externalities are one of the causes of market failures that lead to decline in social welfare (Sterner and Coria, 2012). Extreme weather events with adverse impacts are also externalities in agricultural production. In addition, the risks or negative effects of extreme weather events could reduce agricultural productivity and therefore lead to welfare loss. Thus, this study applied welfare economics theory to analyze the effects of extreme weather events on agricultural production.

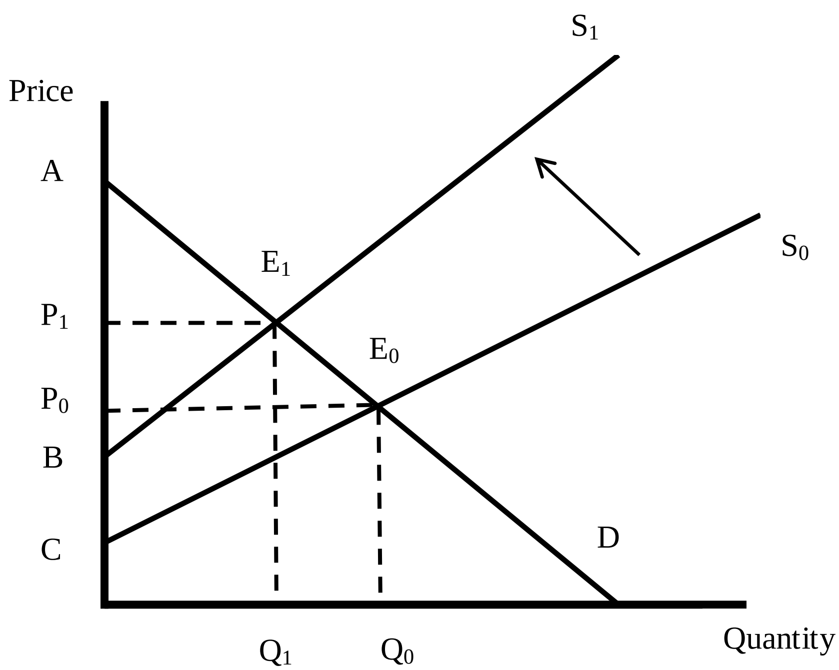

Figure 3. Effects of extreme weather events on social welfare (modified from Mjelde et al., 1989 and Nurmi et al., 2012)

In a perfectly competitive market, the supply curve of agricultural products and social welfare will be S_0 and the area of the AE_0C triangle, respectively (Figure 3). If extreme weather events happen, supply of agricultural products will decrease from Q_0 to

Q_1. The supply curve will shift to the left at S_1. The new equilibrium is at E_1 and both consumer surplus (CS) and producer surplus (PS) would reduce, resulting in a decrease of social welfare.

Under adverse impacts of extreme weather events, CS and PS at E_1 are the areas of the AE_1P_1 and BE_1P_1 triangles, respectively. They are lower than AE_0P_0 and CE_0P_0 triangles (at E_0). Decreases in CS and PS lead to decline in social welfare. At new equilibrium E_1, the social welfare (AE_1B triangle) is smaller than social welfare at initial equilibrium E_0 (AE_0C triangle). Finally, total social welfare loss is the area of BCE_0E_1 trapezoid. This loss resulted from negative effects of extreme weather events.

Normally, market failures violate the basic assumption of a perfect competitive market. The market failures and other pressures or stresses (e.g., extreme weather events) provide a widely accepted rational for the making of public policies (Weimer and Vining, 2005). In other words, policies or programs should treat the market failures or shock to eliminate welfare loss. According to Eckwert and Zilcha (2004), better information brought two influences, including direct and indirect effects on economic welfare. The direct effect is that having more reliable information will help agents face less uncertainty in decision-making (Eckwert and Zilcha, 2004).

In the case of extreme weather events, providing accurate climatological information could be a significant strategy that may help farmers reduce risks in agricultural production (Saroar and Routray, 2012; Jarmin et al., 2012; Gebrehiwot and Veen, 2013; Jalón et al., 2015). It implies that providing precise meteorological information could reduce welfare loss. On the other hand, improving weather forecast and providing accurate climatological information would increase both farmers' well-being and social welfare (illustration in Figure 4). If farmers face negative effects of extreme climate events, agricultural productivity will be at Q_0 and E_0, which is an equilibrium point. Social welfare in this case is the area of ABE_0 triangle.

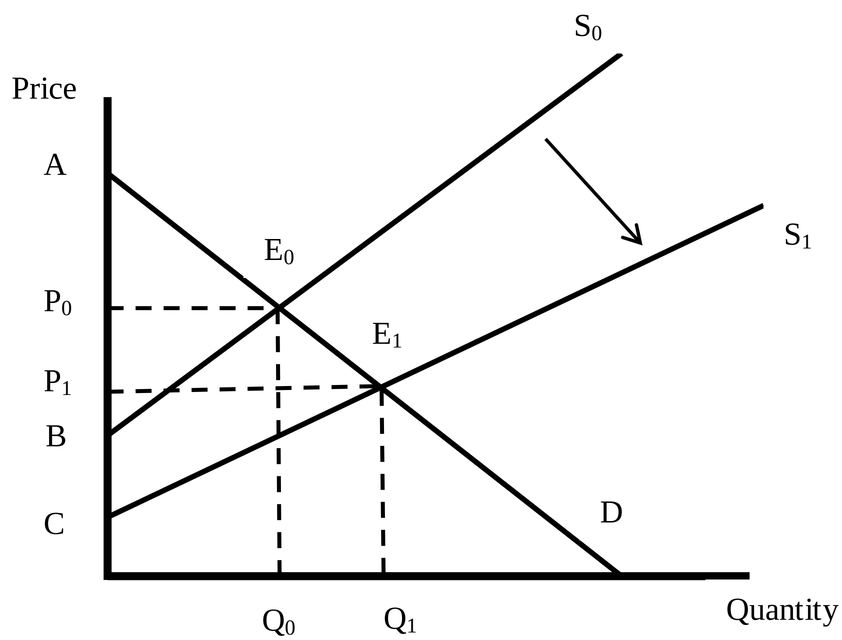

Figure 4. Effect of providing meteorological information on social welfare (modified from Mjelde et al., 1989; Freebairn and Zillman, 2002; Freeman III, 2003; and Nurmi et al., 2012)

With provision of timely and accurate climatological information, farmers may adjust their decisions and activities in agricultural production. It may lead to increase in agricultural output from Q_0 to Q_1 and therefore the supply curve will shift to the right at S_1. At new equilibrium (E_1), both CS and PS increase compared with those at initial equilibrium (E_0). Consumer surplus at E_1 (AE_1P_1 triangle) is larger than this value at E_0 (AE_0P_0 triangle). Similarly, producer surplus at E_1 (CE_1P_1 triangle) is also larger compared to producer surplus at E_0 (BE_0P_0 triangle). The total social welfare component in this case is the area of ACE_1 triangle that is also higher than social welfare at E_0 (ABE_0 triangle). Finally, the area of the BCE1E0 trapezoid in this case represents the total social welfare gain.

Economic Valuation for Non-marketed Goods and Services

Economic valuation refers to estimating monetary value of non-marketed assets, goods and services (Pearce et al., 2002). According to Freeman III (2003), the concept of economic valuation is based on the theory of neoclassical welfare economics. This theory implies that all economic activities aim to increase the well-being of the individuals who make up the society. In addition, each individual's welfare depends not only on marketed goods that the individual consumes but also on the quantities and qualities of non-marketed goods and services (Freeman III, 2003).

Generally, information or climatological information has characteristics of public goods or non-marketed goods because consumption of one person does not interfere with another's (Johnson and Holt, 1997; Stiglizt, 2000; Gunasekera, 2004; Teisberg et al., 2005; Weimer and Vining, 2005; Houghton, 2011; Bernknopf and Shapiro, 2015). According to Haab and McConnell (2002) and Bockstael and McConnell (2007), the market will not effectively allocate the public goods. Therefore, it needs improvement by public action to ensure the benefits of a decision are greater than its costs (Haab and McConnell, 2002; Sterner and Coria, 2012).

Broadly, there are two major economic valuation approaches for non-marketed goods and services that include the indirect or behavioral methods and direct or stated preferences methods (Habb and McConnell, 2002; Pearce et al., 2002; Loomis, 2014). According to Habb and McConnell (2002 and Pearce et al. (2002), behavioral approaches focus on observing individual's behavior in response to changes in public goods and estimating the value of changes in public goods. Meanwhile, stated preferences approach emphasizes economic valuation of non-marketed goods and services through constructed market and contingent or hypothetical questions (Habb and McConnell, 2002; Pearce et al., 2002).

Stated preference approach has played a crucial role in estimating the economic value of non-marketed goods and services. According to Carson et al. (2001), without the stated preference method, economists cannot measure the passive use aspects of non-marketed goods and services. In addition, stated preference methods have been widely applied in economic valuation of public goods (Habb and McConnell, 2002; Tietenberg and Lewis, 2010). Loomis (2014) concluded that both revealed preference and stated preference methods are just alternative tools for estimating WTP.

The advantage of stated preference method is its flexibility and therefore it can value a wide range of public good (Loomis, 2014). Botelho et al. (2016) also indicated that stated preference methods have advantages over revealed preference methods in the economic valuation of non-marketed goods and services. Stated preference methods provide the uniquely viable alternative for measuring non-use value of these goods and services (Botelho et al., 2016).

Contingent valuation method (CVM) is a specific stated preference technique that has been widely used to estimate demand for public goods (Kean, 1997). According to Haab and McConnell (2002), CVM is the most prevalent in stated preference approaches. CVM focused mainly on eliciting the willingness to pay of non-marketed goods and services (Carson et al., 2001; Camacho-Cuena et al., 2004; Batina and Ihori, 2005). On the other hand, WTP is the maximum amount of money that an agent or individual will pay in exchange for the public goods (Miyake, 2009). CVM provides a means of deriving values of public goods (Habb and McConnell, 2002; Tietenberg and Lewis, 2010).

CVM is also a survey-based technique that measures indirect benefit and estimate economic values of non-marketed goods and services (Kim, 2012; Dong, 2013; Markantonis et al., 2013). Moreover, CVM estimates a single WTP value for a single scenario, which combines the quantity and quality of a public good (Loomis, 2014). CVM is also the most popular method and is widely used to estimate economic value and beneficiaries of public goods (Hamed et al., 2015; Sarkhel et al., 2015).

Conversely, contingent valuation methods also have some limitations, including:

(1) misplacing of incentive compatibility in contingent valuation survey (Green et al., 1995 cited in Kean, 1997);

(2) individual's marginal WTP tends to be low for public goods such as environmental amenities (McFadden, 1994 cited in Kean, 1997);

(3) respondents pay insufficient attention to opportunity cost (Kean, 1997);

(4) major tools of estimation (logit and probit models) rarely satisfy the restrictions of economic theory (Hanemann and Kanninen, 1996 cited in Kean, 1997);

(5) preferences for public goods may be very imprecise (Dubourg et al., 1997 cited in Batina and Ihori, 2005); and

(6) there is a difference between hypothetical WTP level and actual WTP level (Batina and Ihori, 2005).

Dong (2013) also indicated some disadvantages of CVM. These include: (1) data-intensive requirement; (2) costly and time-consuming survey; and (3) dependence on people's views. According to Loomis (2014), the common disadvantage of CVM is hypothetical bias that means the stated WTP is not equal to their actual WTP.

However, careful study design and implementation scheme could effectively eliminate many alleged problems of CVM (Carson et al., 2001). Moreover, CVM is still useful for economic valuation of public goods because individuals still state correctly their WTP for these goods (Diamond and Hausman, 1994; Nunes and Schokkaert, 2003 cited in Batina and Ihori, 2005). Although there are still problems, CVM is an effective method to get WTP for public goods or public project (Batina and Ihori, 2005). According to Dong (2013), CVM is suitable for the economic valuation of non-marketed goods and services since it is flexible enough to estimate the economic value of anything.

In spite of the controversy, contingent valuation method (CVM) has been useful and still widely applied in estimating economic value of public goods (Kean 1997; Carson et al., 2001; Camacho-Cuena, 2004; Batina and Ihori, 2005; Boardman et al., 2006; Kim, 2012; Markatonis et al., 2013; Loomis, 2014; Sarkhel et al., 2015). Moreover, CVM is also a crucial method to calculate the economic value of information as well as climatological information that has public good characteristics (Freebairn and Zillman, 2002; Gunasekera, 2004; Macauley, 2005; Houghton, 2011; Nurmi et al., 2012).

At present, dichotomous choice format has been selected as the most desirable method and the most widely used in CVM (Ahmed and Gotoh, 2006; Boardman et al., 2006; Kim, 2012). Moreover, it has become the most popular format for ascertaining whether people are willing to pay or not for a non-marketed good (Freeman III et al., 2014; Saz-Salazar et al., 2016). In this format, investigators asked respondents whether they would be willing to pay a particular price to obtain a particular good or policy (Boardman et al., 2006)

The dichotomous choice format has many advantages and can produce more the realistic conservative estimations of WTP (Arrow et al., 1993). According to Boardman et al. (2006), the major advantage of dichotomous choice format is that it meets the necessary condition for incentive compatibility. It also provides an incentive for respondents to give truthful rather strategic answer like in the open-ended method (Boardman et al., 2006).

Conceptual Framework

Logically, climate change induces higher frequency and intensity of extreme weather events. These extreme events may directly destroy agricultural production and therefore have adverse effects on households' livelihood, particularly smallholder households. Thus, farmers would apply adaptive strategies to reduce losses due to extreme weather conditions. Farmers may differ in adaptive strategies to climate change since they have different livelihood assets.

Department for International Development - DIFID (1999) defined five livelihood assets including financial capital, human capital, natural capital, physical capital, and social capital. At the household level, human capital consists of the amount and quality of labor available. Social capital is the social resources upon that people can pursuit their livelihood objectives, such as network that can expand people's access to wider institutions, membership of more formalized groups and relationships of trust, reciprocity and exchange. Natural capital is natural stocks that are useful for people's livelihood and includes intangible public goods such as atmosphere and biodiversity or divisible assets used directly for production (trees, land, etc.). Physical capital encompasses basic infrastructure, e.g., enabling affordable transport, secure shelter and buildings, adequate water supply and sanitation, clean and affordable energy, and access to information and tools and equipment. Finally, financial capital comprises financial resources for achieving livelihood objectives, such as available stock and regular cash inflow.

The livelihood assets are factors affecting household's adaptive strategies to natural shocks (Figure 5). The households that have more natural capital and physical capital are expected to be more likely to apply adaptive strategies. It implies that farmers who have a large land area and more equipment may suffer greatly from risks of natural shocks. Therefore, they will be more likely to adapt to climate variability and change. Availability of adequate financial, human and social capitals would help households cope more effectively with climate change. In other words, these have positive effects on the farmers' decision of using adaptive strategies to climate change in agricultural production. Thus, households with better financial, human and social resources are expected to have higher probability in applying adaptive strategies to climate change.

Off-farm activity and access to credit, which could be the proxy of financial capitals, are factors affecting adaptive option to climate change (Gebregziabher et al., 2015). Households that have off-farm employment, alternative sources of income and available sources of finance are more likely to apply climate change adaptive strategies. This is because adaptive solutions in agricultural production may be costly. Educational level, age and gender of family members, and family size will influence farmers' adaptive strategies to climate change (Gebregziabher et al., 2015). Specifically, households with more educated members may be more likely to access information. The impossible reason could be experienced farmers understand the importance of mitigating adverse impacts of extreme climate events in agricultural production. Therefore, these households are more likely to adopt adaptive strategies.

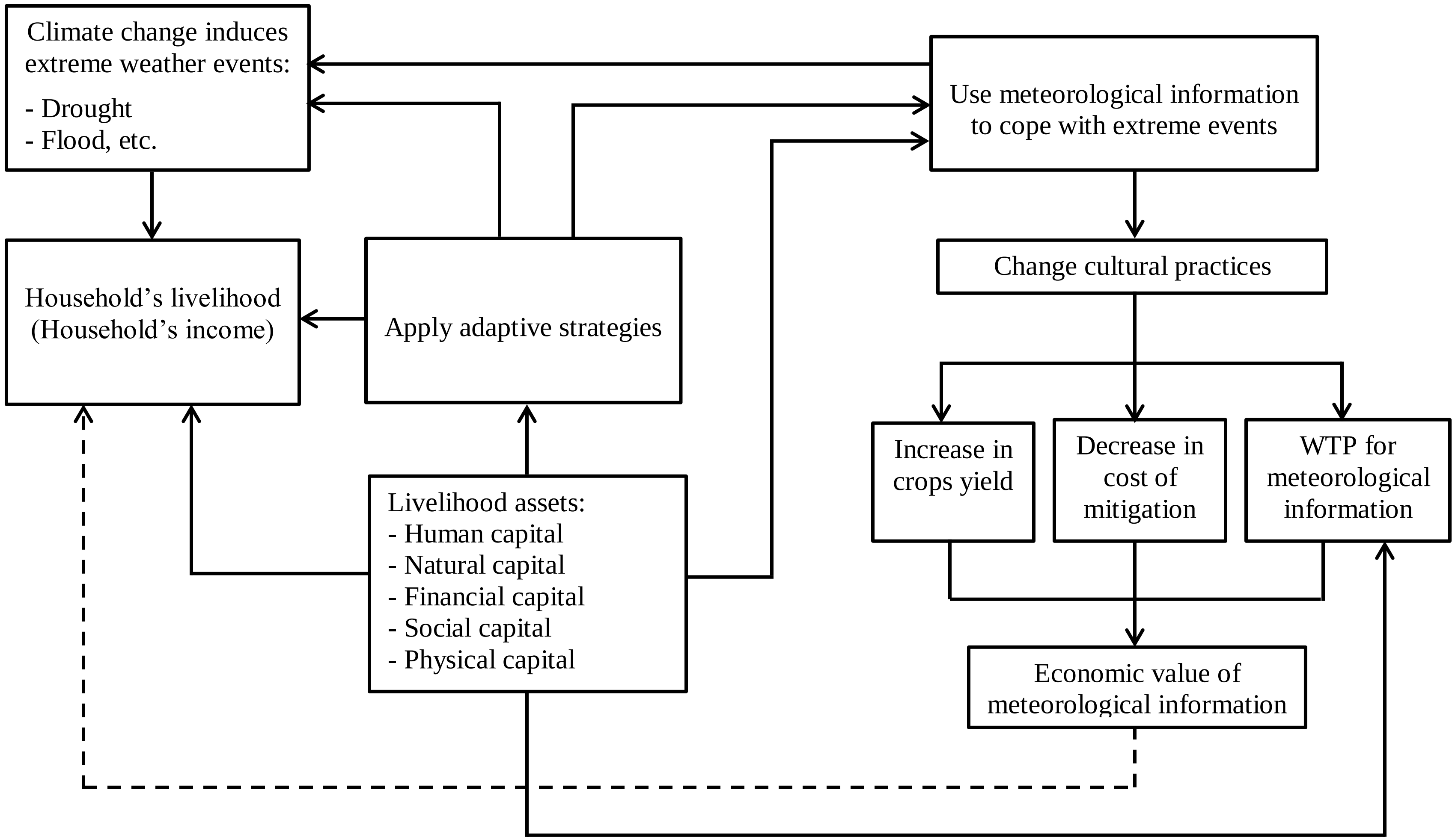

Figure 5. Factors affecting household's adaptive strategies to extreme weather events (DIFID, 1999; Hubbard and Millar, 2014; Bernknopf and Shapiro, 2015)

Age of household head and members may explain their farming experiences. Households with better farming experiences can counter more effectively extreme climate events or natural shocks. Household's membership in formal and informal social networks or institutions could be social capital (Gebregziabher et al., 2015). Through these social networks, farmers will share information about risks and adaptive options to climate change. Thus, they can effectively adapt to climate change.

Conceptually, livelihood assets may also affect farmers' decision in using meteorological to cope with climate change in agricultural production. Farmers who have larger land area and more production equipment are more likely to update and use meteorological information in climate change adaptation. The reason is that these farmers may be more vulnerable to extreme climate events. In summary, natural and physical capitals may have positive effects on farmers' decision in updating and using climatological information in climate change adaptation.

The effects of human and social capitals on farmers' decision in applying meteorological information in climate change adaptation may also be positive. It means that smallholder farmers who have more knowledge of climate change are more likely to apply climatological information to adjust their agricultural activities. Farmers who are involved in strong social network or institutions will also be more likely to use meteorological information in climate change adaptation.

Accurate meteorological information could bring benefits to smallholder farmers through increasing crop productivity or reducing cost of applying adaptive strategies

(Murphy, 1990; Macauley, 2005; Hay, 2007; Keller et al., 2007; Solí and Leton, 2013; Trærup and Stephan, 2014). Thus, farmers may be willing to pay for using precise climatological information to cope with climate change.

Household's livelihood assets may also influence the WTP level of farmers for using climatological information in climate change adaptation. Most of these assets are expected to have positive effects on farmer's WTP level. Specifically, households that have larger land area and more production equipment may have higher WTP level for using climatological information. This is because these households may suffer from high risks of extreme climate events.

Moreover, farmers who have available sources of finance and higher income could pay higher prices for accurate climatological information. The reason is that income is always a significant factor affecting consumer's behavior. Finally, people who are involved in strong social network and institutions and have better knowledge of climate change may have higher WTP level for meteorological information. It is because they are more likely to understand the importance of precise meteorological information in mitigating adverse impacts of extreme weather events in agricultural production.

According to Just et al. (2004), WTP is a plausible interpretation for the change in consumer welfare. In other words, WTP is a basis for estimating economic benefits of consuming goods and services. Thus, the economics of agrometeorological information in this study would be estimated based on the WTP of farmer for using precise such information in climate change adaptation. Conceptually, total economic value (TEV) approach is the basis for economic valuation of agrometeorological information (Figure 6). TEV includes use value and non-use value (Munasinghe, 1993; Pearce et al., 2002). Amed and Gotoh (2006) classified use value and non-use value into present use value and future use value, respectively.

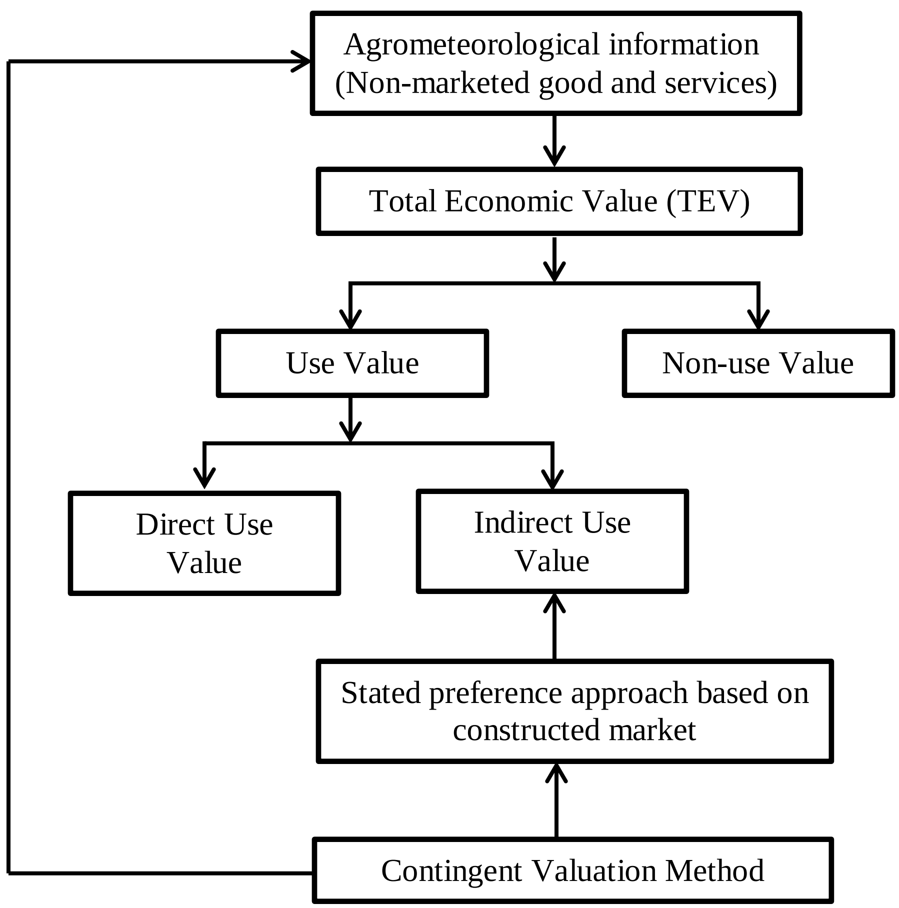

Figure 6. The Structure of Economic Valuation of Agrometeorological Information (Pearce et al., 2002)

There are three components of use value, including direct use value, indirect use value, and option value (Munasinghe, 1993; Pearce et al., 2002; Ahmed and Gotoh, 2006;

Pascual et al., 2010; Dong, 2013). Non-use value consists of altruistic value, bequest value, and existence value (Plottu and Plottu, 2007 cited in Dong, 2013). On the other hand, non-use value is divided into bequest value, existence value, and option value (Ahmed and Gotoh 2006; Markatonis et al., 2013). Table 2 defines the detailed meaning of specific value.

Table 2. Typology of values

VALUE	SUB-VALUE	MEANING
Use value	Direct use	Results from direct human use of goods or services (including consumptive or non-consumptive)
	Indirect use	Derived from the regulation services provided by goods, particularly environmental goods
	Option value	Related to the importance that people give to the future availability of non-marketed goods and services for personal benefit
Non-use value	Bequest value	Value attached by individual to the fact that future generation will also have access to the benefit from non-marketed goods and services
	Altruist value	Value attached by individual to the fact that the present generation will also have access to the benefit from non-marketed goods and services (intra-generational equity concern)
	Existence value	Value related to the satisfaction that individuals derive from the mere knowledge that non-marketed goods and services continue to exist

Source: adapted from Pascual et al., 2010; Dong 2013

All types of value in Table 2 are only suitable for the natural resources or environmental goods and services. The value of agrometeorological information in this study is mainly indirect use value. This is because farmers cannot directly consume meteorological information as other goods and services. Farmers may just use the meteorological information to adjust their production activities. In other words, meteorological information is a factor in decision-making of farmers. It is because meteorological information is one of non-marketed goods. The elicitation methods or stated preference approaches could effectively estimate indirect use value of non-marketed goods (Pearce et al., 2002; Pascual et al., 2010).

Hypotheses of the Study

The general hypothesis tested in this study is that there are significant effects of household's livelihood assets on farmers' decision in applying adaptive strategies to extreme weather event and economic value of agrometeorological information. The specific hypotheses included:

1. Households with higher damage level due to climate change and better livelihood assets will be more likely to apply different adaptive strategies to climate change compared to other households.
2. Households with higher damage level due to climate change and better livelihood assets will have a higher economic value for meteorological information in climate change adaptation.

CHAPTER IV

RESEARCH METHODOLOGY

The Study Area

The site of this study is the Ky Anh district, Ha Tinh province in the North Central Coast region of Vietnam (Figure 7).

Figure 7. Map of Vietnam (source: [http://www.hoangviettravel.vn/cam-nang-du-lich/ban-do/)](http://www.hoangviettravel.vn/cam-nang-du-lich/ban-do/)

Ha Tinh has a total area about 6,000 square kilometers. The province borders to Nghe An province in the north, Quang Binh province in the south, Laos PDR in the west, and East Sea in the eastern side (Figure 8). Ha Tinh province has 12 administrative units, including 2 cities and 10 districts. The province is very vulnerable to the adverse impacts of the extreme weather events such as storms, hot dry westerly winds, drought, heavy rains and floods (ISPONRE, 2009). The most vulnerable industry of the province to these extreme weather events is agricultural sector (ISPONRE, 2009).

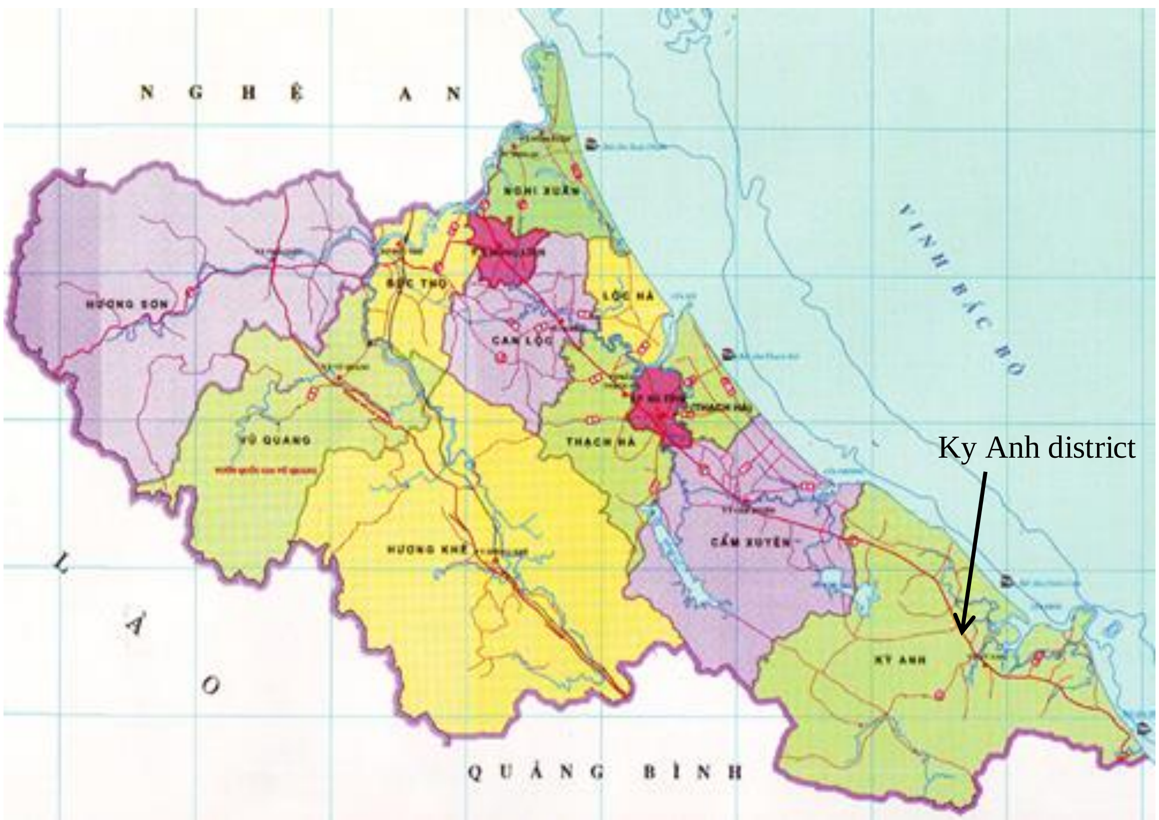

Figure 8. Map of Ha Tinh province (http://dpihatinh.gov.vn/?url=group&id=134)

Ky Anh district is located in the southern part of Ha Tinh province. The total area of the district is about 1,045 square kilometers (Le et al., 2015). There are 20 administrative units in Ky Anh district, including 1 district center and 19 communes. This study has chosen the Ky Son commune as specific study sites (Figure 9).

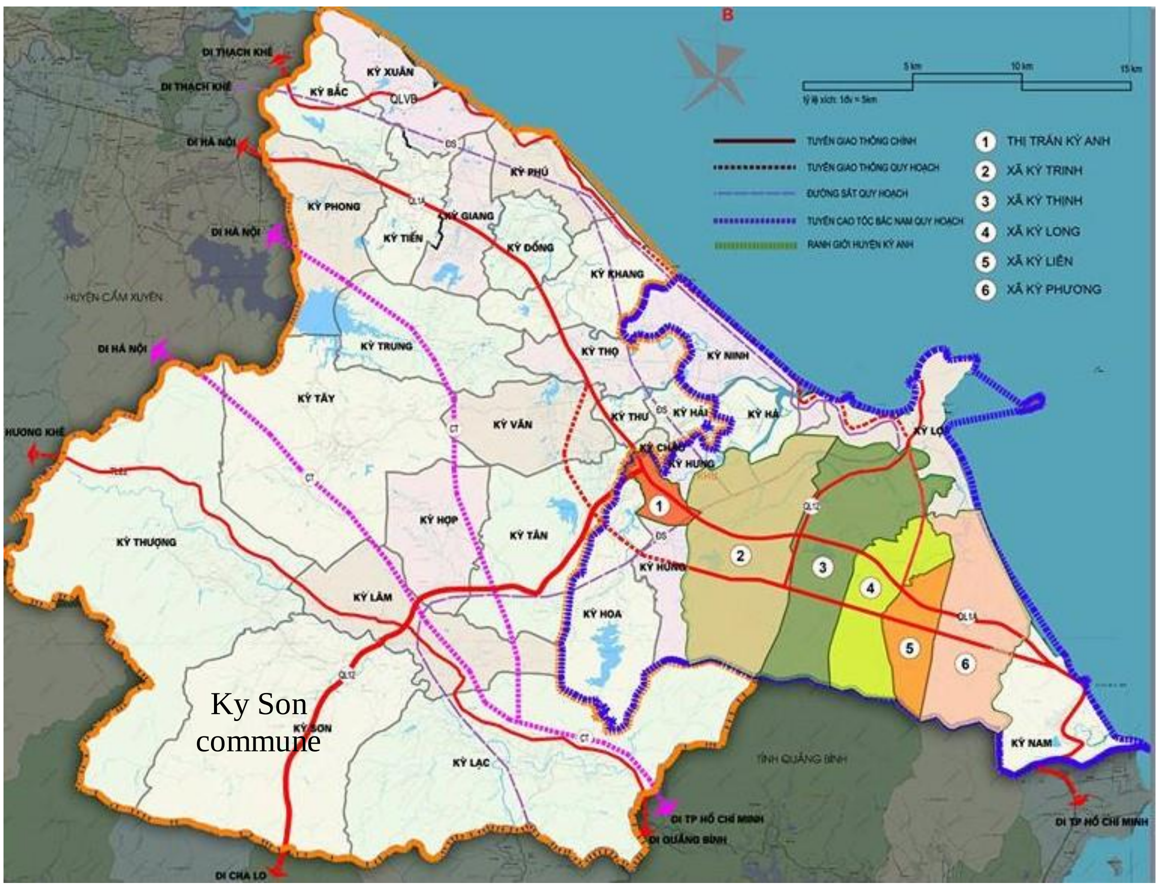

Figure 9. Map of Ky Anh district

Ky Son has a total area of 90 square kilometers (Le et al., 2015) and a total population of 6,344 people (Ky Son Communal People's Committee, 2016a). The commune borders Ky Thuong commune to the north, Ky Lac commune to the south, Ky Lam commune to the east. It also shares its southern border with Thach Hoa and Dong Hoa communes, Tuyen Hoa district, Quang Binh province (Le et al., 2014d). The major annual crops in the Ky Son commune are rice, peanut and cassava. In addition, agroforestry is also a major contributor (44% in 2015) to total income the commune (Ky Son Communal People's Committee, 2015 and 2016b). The poverty rate of the commune in 2015 was 14.0% and near-poor 8.3% (Ky Son Communal People's Committee, 2015).

Ky Son commune was chosen as the specific area of the study because it is the project site of the P48-FP2-SEA-ICRAF project. World Agroforestry Centre – ICRAF has conducted this project since January 2015. The My Loi village, in the Ky Son commune, is one of the six selected climate-smart villages (CSV) in Southeast Asia under this project. My Loi village became CSV of the project due to its exposure to multiple extreme weather events such as temperature and water stress, storm and typhoon (Le et al., 2014d).

The ICRAF's project focuses on establishing climatic zones and sets up seasonal forecast for each particular zone. It means that the project separated the study site into different climatic regions based on the prevailing climatic condition. In addition, the project also created seasonal forecast for each climate zone based on its collected meteorological information. The project has set up My Loi village as one pilot climatic zone.

Farmers in My Loi village (CSV) may access directly the project's seasonal forecast bulletin that that was made based on meteorological information at district level (ICRAF, 2015). Farmers in each climatic zone will also get seasonal forecast bulletin on localized meteorological information in their regions. In so doing, the major hypothesis of the project is that farmers who get seasonal forecast and agrometeorological information regarding specific climatic zone will effectively adapt to climate change in agricultural production.

Types of Data and Sampling Method

This study used both primary and secondary data. The secondary data include information on the socio-economic condition of the study area. The annual reports of the local government in the study sites, baseline ICRAF's reports and other published documents were major sources of secondary data for this study.

This study gathered primary data through personal interviews of farmers in My Loi and other villages of Ky Son commune using prepared questionnaires. It also applied stratified random sampling method, in which the stratum is the study place (village) in determining the sample size. It implies that sample size included respondents in all villages of Ky Son commune. In addition, the study randomly selected respondents in each stratum (village). Respondents are mainly farmers whose livelihood mostly depends on the agriculture and forestry sector.

The primary data collected in this study includes information regarding all livelihood capitals of the households. It also consisted of data about damage level due to extreme weather events in household's agricultural production and farmers' adaptation strategies to these events. By using this information, the study determined factors affecting decisions of farmers in implementing adaptive practices to extreme events in agricultural production. Moreover, it also analyzed the vulnerability status to extreme weather events in agricultural production in the study site by using the primary data.

Additionally, the study also gathered primary data about WTP of farmers for seasonal forecast and meteorological information. This data provided basis for estimating the economic value of seasonal forecast bulletin and agrometeorological information in the study site.

This study used the formula of Yamane (1967) to determine sample size. The formula is as follows:

$$n = \frac{N}{1 + N * e^2}$$

Where: N is total population of study area, n is sample size, and e is expected error (maximum acceptable value of expected error is 10%).

Total households Ky Son commune in 2016 is 1,954. At five percent (5%) of expected error, the sample size in this commune is about 332 households.

$$n_1 = \frac{1{,}954}{1 + 1{,}954 * 0.05^2} = 332.03 \approx 332$$

The study applied dichotomous choice or referendum format to gather WTP data. This format requires equal part of sample size according to the number of bid level. It implies that sample size must be divided into different groups that equal to the number of bid level. In addition, each group has to have equal number of respondent.

In this study, there were five bid levels (see more detailed in analysis tools). Thus, the study selected five equal groups (each group has equal number of 80 people). Finally, sample size of this study includes 400 people who represent 400 different households in the commune. Sample size consists of the respondents in all villages of Ky Son commune. The study selected almost farmers in My Loi village (project site). Meanwhile, the number of respondents in each other village was determined based on the proportion of the total households of the village.

This study classified respondents based on location (project site and non-project site) since My Loi village is one of the first CCAFS climate-smart villages in Southeast Asia under P48-FP2-SEA-ICRAF project that has been conducted by World Agroforestry Centre (ICRAF). In addition, farmers in project site have been provided several training courses on climate change, and pilot seasonal forecast bulletin. Thus, this study attempted to test whether perception and adaptive behavior of farmers in project site is different from those of farmers in non-project site.

This study focused on interviewing farmers because most of their economic activities depend on weather and climatic condition. Table 3 shows detailed sample size of this study.

Table 3. Detailed sample size of the study

No.	VILLAGE	NUMBER OF RESPONDENT	PERCENTAGE
1	My Loi	104	26.0
2	My Lac	52	13.0
3	My Tan	27	6.8
4	Son Binh 1	31	7.8
5	Son Binh 2	52	13.0
6	Son Binh 3	44	11.0
7	Son Trung 1	37	9.2
8	Son Trung 2	53	13.2
9	**Total sample size**	**400**	**100.0**

Table 4 shows the general characteristics of respondents in the study sites. Most of the characteristics of selected households in My Loi village (project site) are not significantly different from those of the households in other villages (none project site). This implies that the respondents in this study are highly homogeneous, and could contribute to the reliability of the study.

There is a difference in the three indicators between My Loi village and the other villages. These parameters include annual crop area, proportion of participants in the training on climate change, and access percentage to agricultural credit. Percentage of people who attended the training on climate change of My Loi village is significantly higher than the other villages. There were many training courses on climate change in My Loi village (project site), thus farmers in this village have more chance of attending these training courses compared with the people in the other villages. However, the average annual crop area and assessing proportion to credit of farmers in My Loi village are substantially lower than those in the other villages are.

Table 4. General characteristics of respondents in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF	WHOLE SAMPLE (n = 400)
Age (year)	44	44	0^{ns}	44
Educational level (schooling year)	8.0	7.8	0.2^{ns}	7.9
Farming experience (year)	24.1	23.6	0.5^{ns}	23.7
Household size (number of people)	4.2	4.3	-0.1^{ns}	4.3
Total labor (laborer)	3.0	3.0	0^{ns}	3.0
Agricultural labor (laborer)	2.0	2.0	0^{ns}	2.0
Forest land area (ha)	1.2	1.4	-0.2^{ns}	1.3
Institutional member (% of respondent)	93.3	97.0	-3.7^{ns}	96.0
Annual crop income (VND million)	14.6	15.2	-0.6^{ns}	15.1
Forestry income (VND million)	5.2	4.4	0.8^{ns}	4.6
Non-farm income (VND million)	18.9	15.2	3.7^{ns}	15.4
Off-farm income (VND million)	24.4	21.0	3.4^{ns}	21.9
Total income (VND million)	70.5	68.6	1.9^{ns}	69.1
Livestock income (VND million)	9.3	13.1	-3.8^{*}	12.1
Annual crop area (sao/500m^2)	5.0	7.2	-2.2^{***}	6.6
Training attendance (% of respondent)	82.7	55.1	27.6^{***}	62.3
Access to credit (% of respondent)	51.0	67.2	-16.2^{***}	63.0

DIFF is a different value between two samples; ***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Analytical Tools

Basic Statistical Methods

This study used descriptive statistics to show the general status of respondents. Moreover, the study also applied this method to analyze the vulnerability situation to extreme weather events in agricultural production in the study region. The parameters used include maximal value, minimal value, standard deviation, frequency and others.

This study used these parameters to analyze the general characteristics of respondents such as total income, damaged level due to extreme weather events, agricultural labor, and others.

This study also used the T-test to compare the mean values of different characteristics between two different groups of farmers. One group of farmer respondents were from project site (My Loi village), while the other group were from the non-project site (other villages).

T-test has null hypothesis (H_0) and alternative hypothesis (H_a). H_0 implies that the mean value of specific factor is identical among two group ($\mu_1 = \mu_2$) while H_a means at least one mean value is different from the other ($\mu_1 \neq \mu_2$).

The formula of statistical parameter (t_s) is as follows:

$$t_s = \frac{\overline{\mu_1} - \overline{\mu_2}}{\delta\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}, \text{ and } \delta = \sqrt{\frac{(n_1 - 1) * \delta_1^2 + (n_2 - 1) * \delta_2^2}{n_1 + n_2 - 2}}$$

Where: $\overline{\mu_1}$ and $\overline{\mu_2}$ are mean values of group 1 and 2; δ_1^2 and δ_2^2 are variance of group 1 and 2; n_1 and n_2 are sample size of group 1 and 2, respectively.

If $|t_s| > t_{\alpha/2}$ (n) the null hypothesis (H_0) will be rejected, whereas it will be accepted. The value of $t_{\alpha/2}$ (n) is given T-table.

This study also applied the two-sample Z-test for the difference between proportions (Z-test) to compare percentages of the indicators between two mentioned farmer groups. The null and alternative hypotheses (H_0 and H_a) of this test are as follows:

H_0: There is no difference between proportion of sample 1 and proportion of sample 2 ($p_1 = p_2$)

H_a: The proportion of sample 1 is different from proportion of sample 2 ($p_1 \neq p_2$)

This test also requires estimating statistical parameter (Z-test). The formula of Z-test is as following:

$$Z - test = \frac{p_1 - p_2}{\sqrt{\bar{p} * (1 - \bar{p}) * \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

Where:

p_1 and p_2 are proportions of sample 1 and sample 2, respectively;

n_1 and n_2 are size of sample 1 and sample 2, respectively;

$\bar{p} = \frac{x_1 + x_2}{n_1 + n_2}$; x_1 and x_2 are number of successes in sample 1 and sample 2, respectively.

If Z-test $\geq$ 1.96 or Z-test $\leq$ -1.96 the null hypothesis (H_0) will be rejected, otherwise it will be accepted. Rejecting null hypothesis means there is sufficient evidence to conclude that the two samples have different proportions.

Regression Analysis

Binary Logit Model. The binary logit model has been widely adopted since 1960s because it has analytical advantages in dealing with discrete binary outcomes (Cramer, 2003). The general form of a binary logit model is as follows (Cramer, 2003; Greene, 2003):

$$P_i\,(Y_i = 1) = \frac{e^{X\beta}}{1+e^{X\beta}}$$

Where:

P_i is the probability of occurring one event (Y_i = 1: event occur; Y_i = 0: event does not occur),

β is vector of parameters, and

X is vector of factors affecting.

Marginal effect (ME) coefficient is a major tool to analyze the binary logit model. Marginal effect coefficients are determined through the following formula (Greene, 2003):

$$ME = \frac{\partial \Lambda(X'\beta)}{\partial X} = \Lambda(X'\beta)[1-\Lambda(X'\beta)]\beta$$

Where: X is independent variable matrix in logit model (factors affecting)

β is matrix of parameters in logit model

This study used the binary logit model to analyze factors influencing farmers' decision on adaptation to extreme weather events in agricultural production. Farmers who applied at least one adaptive strategy get value as one (1). By contrast, zero (0) notes for farmers who did not use any adaptive strategies. The binary logit model was also used to analyze factors influencing farmers' decision in using meteorological information to cope with extreme events in agricultural practices. One (1) notes farmers who used meteorological information given by weather forecast news to adjust agricultural production activities. By contrast, zero (0) notes farmers who did not change any of their agricultural production activities even if they get meteorological information given by weather forecast news. The explanatory variables of the binary logit models are explained in Table 5.

Table 5. Definition of explanatory variables of the empirical binary logit models in the study

VARIABLE DEFINITION	NOTATION	MEASURED UNIT
Age of respondent	AGE	Year
Educational level of respondent	EDU	Year
Household’s farm income	FINC	VND million/year
Damage due to extreme weather events	DAMAGE	VND million/year
Availability of household’ agricultural labor	AGLABOR	Laborers
Farm size	FSIZE	Sao (500 m^2)
Farming experience	FEXPER	Years
Number of cultivated plots	PLOT	Plot
Gender of respondent	GEN	1 = male; 0 = female
Access to credit	CREDIT	1 = yes; 0 = no
Attendance in climate change training	TRAIN	1 = yes; 0 = no
Membership in local organizations	MEMBER	1 = yes; 0 = no
Location	LOCAT	1 = project site; 0 = no

This study used marginal effect (ME) coefficients to determine the effects of different factors that influence farmer’s probability of applying adaptive strategies and adjusting agricultural production activities. The parameters of these binary logit models and the marginal effect coefficients were estimated by the STATA 11.0 software.

The Multivariate Probit Model. Based on the collected data, the farmer's adaptive strategies to extreme weather events in this study area offer multiple choices. Theoretically, these options are highly interrelated and interdependent. In other words, multiple adaptive strategies of farmers to extreme events in agricultural production are correlative. The correlation between the different multiple options is mainly the source of the correlation between error terms (Belderbos et al., 2004). However, the multivariate probit model could eliminate these correlations (Nhemachena and Hassan, 2007; Huguenin et al., 2009; Gebregziabher et al., 2015).

The multivariate probit (MVP) model includes simultaneous models. These models reflect the influences of the set of explanatory variables on each of the different options and allow error terms to be freely correlated (Golob and Regan, 2002; Greene, 2003; Lin et al., 2005). In addition, the MVP model allows a flexible correlation structure for the unobservable variables (Huguenin et al., 2009). The MVP model assumes that given explanatory variables, the multivariate response is an unobserved latent variable arising from a multivariate normal distribution (Piya et al., 2013). The formula of the multivariate probit model for observation i and equation m, is as follows (Cappellari and Jenkins, 2003; Huguennin et al., 2009; Tocco et al., 2013):

$Y_{im} = 1$ if $Y_{im}^* > 0$ and 0 otherwise ($i = 1, 2, \ldots, N$; $m = 1, 2, \ldots, M$)

$Y_{im}^* = X_{im}'*\beta_m + \varepsilon_{im}$

Where: N is number of observations, M is number of options,

X_{im} is matrix of explanatory variable, β_m is matrix of parameters, and

ε_{im} is matrix of error terms.

This study applied the MVP model to analyze factors affecting farmer's probability of applying different adaptive strategies to extreme weather events in agricultural production. Based on collected data, there were five major farmer's adaptive options to extreme climate events in the Ky Son commune. They include changing crop varieties, switching to new cultivar types, adjusting farming calendar, following up weather forecasts, and intercropping.

This study also used the MVP model to determine factors influencing farmer's decision in using meteorological information to cope with extreme weather events. Most of the farmers in study area adjusted their agricultural production activities based on meteorological information given by weather forecast news. The major adjustments made by farmers include changing planting dates, adjusting application of farm inputs, and shifting harvesting calendar.

In the MVP models, value of each option in the set of different possibilities (adaptive practices, or farming adjustments) is dichotomous (1, 0). It means that if farmers adopt a specific adaptive strategy or adjust one farming activity based on meteorological information they will get one (1) otherwise they will get zero (0).

There are different factors influencing farmer's decision in applying each of these major adaptive strategies and adjusting farming activities based on meteorological information. These factors relate directly to all livelihood assets including human, physical, social, economic, and natural capitals. Table 6 shows different explanatory variables of the empirical MVP models in the study. The coefficients of the MVP models were estimated by the STATA 11.0 software.

Table 6. Definition of explanatory variables of the empirical MVP models in the study

VARIABLE DEFINITION	NOTATION	MEASURED UNIT
Age of respondent	AGE	Year
Educational level of respondent	EDU	Year
Household’s farm income	FINC	VND million/year
Damages due to extreme climate events	DAMAGE	VND million/year
Availability of household’s agricultural labor	AGLABOR	Laborers
Farm size	FSIZE	Sao (500 m^2)
Farming experience	FEXPER	Number of year
Number of cultivated plots	PLOT	Plot
Gender of respondent	GEN	1 = male; 0 = female
Access to credit	CREDIT	1 = yes; 0 = no
Attendance in climate change training	TRAIN	1 = yes; 0 = no
Membership in local organizations	MEMBER	1 = yes; 0 = no
Location	LOCAT	1 = project site; 0 = no

Contingent Valuation Method

Meteorological information in Vietnam has characteristics of the public goods since the National Meteorological and Hydrological Services (government office) has solely provided such information (World Bank et al., undated). Thus, this study used contingent valuation method (CVM) to estimate economic value of seasonal forecast bulletin and meteorological information in the study area.

In this study, 400 farmers in eight villages of Ky Son commune were personally interviewed using a structured questionnaires and a dichotomous choice or referendum format. There were five bid levels in this study ranging from VND 20,000 (US$0.9) to VND 60,000 (US$2.6). These bid levels were determined through focus group discussion (FGD) that included 10 farmers in My Loi village. Through the FGD, the bid values were determined based on a monthly fee for cell phone and other cost that participants paid to the local government. A pilot survey of 20 respondents in My Loi (project site) and My Lac village (non-project site) of Ky Son commune was also conducted to fix the bid levels.

The following scenario was presented to the respondents before they were asked about their WTP for seasonal forecast bulletin. The scenario was as follows:

Seasonal forecast based on meteorological information of specific climatic zones has been proven to have many advantages for climate change adaptation. This forecast will help farmers to make adjustment on their agricultural practices so that they are more efficient and effective in adaptation to climate change. Through these agricultural adjustments, farmers may reduce losses resulting from extreme weather events during agricultural production. However, getting seasonal forecast based on meteorological information of specific climatic zone is costly. The cost includes expense of setting up meteorological station for different climatic zones. It also consists of payment for the people who are responsible for collecting meteorological information and providing seasonal forecasts. ICRAF's project has been making seasonal forecasts based on collected meteorological information at the district level since August 2015. Are you *willing to pay for making available this kind of seasonal forecast? However, the payment will become a part of the production input and will be taken or deducted from the gross income.*

The study divided 400 respondents into five equal groups or respondents per group. Interviewers asked the farmers in each group whether they are willing to pay for one specific bid level (e.g., VND 20,000; VND 30,000; VND 40,000; VND 50,000; and VND 60,000) to get detailed seasonal forecast information at their respective locations.

After getting WTP, the mean value of WTP ($\overline{WTP}$) was estimated based on binary logit model with bid price as one of the explanatory variables (Boardman et al., 2006). The formula of binary logit model is as follows:

$$P_i\,(Y_i = 1) = \frac{e^{Z_i}}{1 + e^{Z_i}} \text{ and } Z_i = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \alpha_i D_i + \varepsilon_i$$

Where: Y_i (1: “yes” with particular bid level; 0: no)

β_0 is intercept, β_i and α_i are parameters; ε_i is error terms; X_i is quantitative explanatory variable including bid price; and

D_i is dummy variable.

The value of $\overline{WTP}$ was calculated based on the coefficients of above binary logit model. The formula of $\overline{WTP}$ is as follows (Hanemann, 1994 and Bateman, 2002 cited in Bar et al., 2015; Boardman et al., 2006):

$$\overline{WTP} = \frac{\ln(1 + e^{Z_i})}{\beta_{bid}} \text{ or}$$

$$\overline{WTP} = -\frac{\beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \alpha_i D_i}{\beta_{bid}}$$

Where:

β_0, β_i, and α_i are intercepts and parameters of binary logit model, respectively;

β_{bid} is coefficient of bid price explanatory variable in binary logit model; and

X_i and D_i are mean values of quantitative and qualitative explanatory variable of the model.

The economic value of seasonal forecast and climatological information in the study area is the sum of WTP for this bulletin and the number of beneficiaries in the region. The sum of WTP is determined by multiplying mean WTP ($\overline{WTP}$) with the total number of beneficiaries who are willing to pay for a particular bid level. In estimating the total economic value (benefit) of seasonal forecast and meteorological information in the study area, the following formula was used:

Total economic value = $\overline{WTP}$ * total beneficiaries * percentage of people who are willing to pay for seasonal forecast bulletin (* is times or multiply by).

Beneficiaries in the study site are the number of agroforestry households whose production activities are dependent on weather and climatic conditions. Based on the economic value of seasonal forecast bulletin, policy makers may decide whether seasonal forecast bulletin should be made or not. The seasonal forecast bulletin should be widely disseminated to farmers if its economic value is greater than the cost of making and providing this bulletin.

Both coefficients of binary logit model and value of mean WTP ($\overline{WTP}$) was estimated using the STATA 11.0 software. Table 7 shows different variables used in the empirical binary logit model on farmers' WTP for seasonal forecast bulletin.

Table 7. Definition of variables in the empirical binary logit model on farmers' WTP for seasonal forecast and meteorological information

VARIABLE DEFINITION	NOTATION	MEASURED UNIT
Dependent Variable		
Respondent's decision on paying for a particular bid level		1 = if say "yes" 0 = if say "no"
Independent Variables		
Bid level	BID	VND thousand
Age of respondent	AGE	Year
Educational level of respondent	EDU	Year
Household's farm income	FINC	VND million/year
Damage due to extreme weather events	DAMAGE	VND million/year
Availability of household's agricultural labor	AGLABOR	Laborer
Farm size	FSIZE	Sao (500 m^2)
Farming experience	EXPER	Year
Number of cultivated plot	PLOT	Plot
Gender of respondent	GEN	1 = male; 0 = female
Access to credit	CREDIT	1 = yes; 0 = no
Attendance in climate change training	TRAIN	1 = yes; 0 = no
Membership in local organizations	MEMBER	1 = yes; 0 = no
Location	LOCATION	1 = project site; 0 = no

Limitation of the Study

Economic value of seasonal forecast bulletin and localized meteorological information in the study area using the contingent valuation method (CVM), had some biases. Firstly, at present there is no meteorological information market in Vietnam. Thus, the respondents do not directly pay for this information and are likely to face difficulties in providing the correct bid price. This is a hypothetical problem of contingent valuation method (Boardman et al., 2006). Secondly, there is also difficulty in determining the exact number of beneficiaries that is an important component for estimating the economic value of seasonal forecast bulletin and agrometeorological information. This difficulty arose because beneficiaries (farmers) in the study site have the option to share seasonal forecast and meteorological information with other farmers in the surrounding areas.

CHAPTER V

RESULTS AND DISCUSSIONS

Climate Change and Its Impacts on Agricultural Production in the Study Area

Climate Change in the Study Site

Climate change has caused higher frequency and intensity of extreme weather events such as storms, flood, drought, cold spell in Ha Tinh province (Ha Tinh Provincial People's Committee, 2014). Moreover, the frequency and the strength of these natural disasters are likely to be more serious in the context of upcoming climate change in the province (ISPONRE, 2009). These extreme occurrences have also affected greatly and directly agricultural production of the region (Ha Tinh Provincial People's Committee, 2014).

Increase in average monthly temperature and decrease in rainfall level over the last five decades (1961-2015) have signaled climate change in Ky Anh district (Figure 10, 11 & 12). These could be the reasons for the increasing frequency and intensity of extreme weather events in the district.

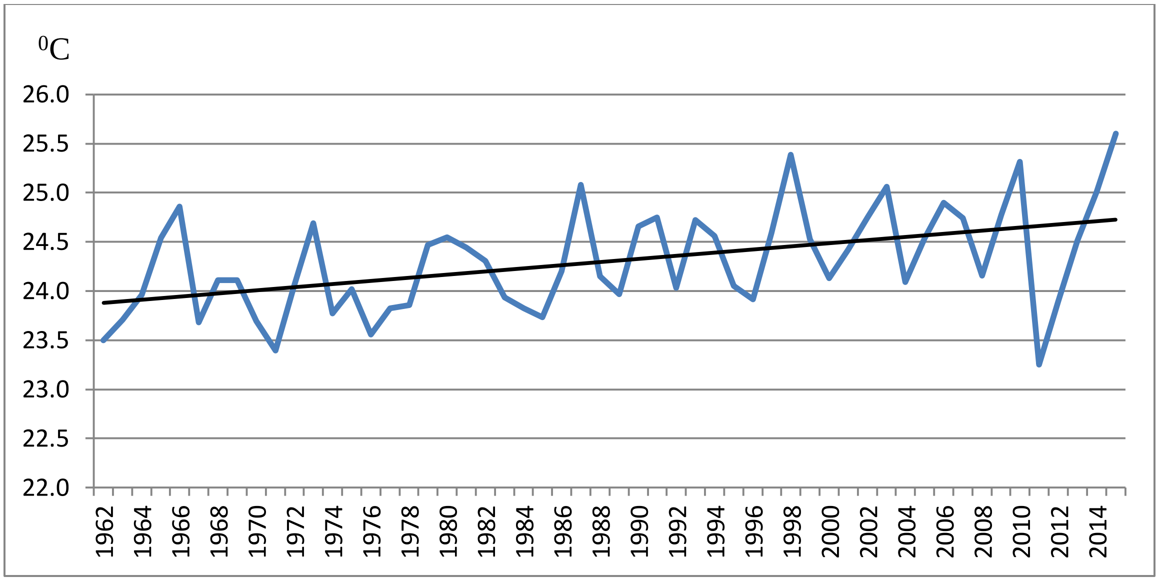

Figure 10. Average monthly temperature trend of Ky Anh district, 1961-2015 (IMHEN, 2016)

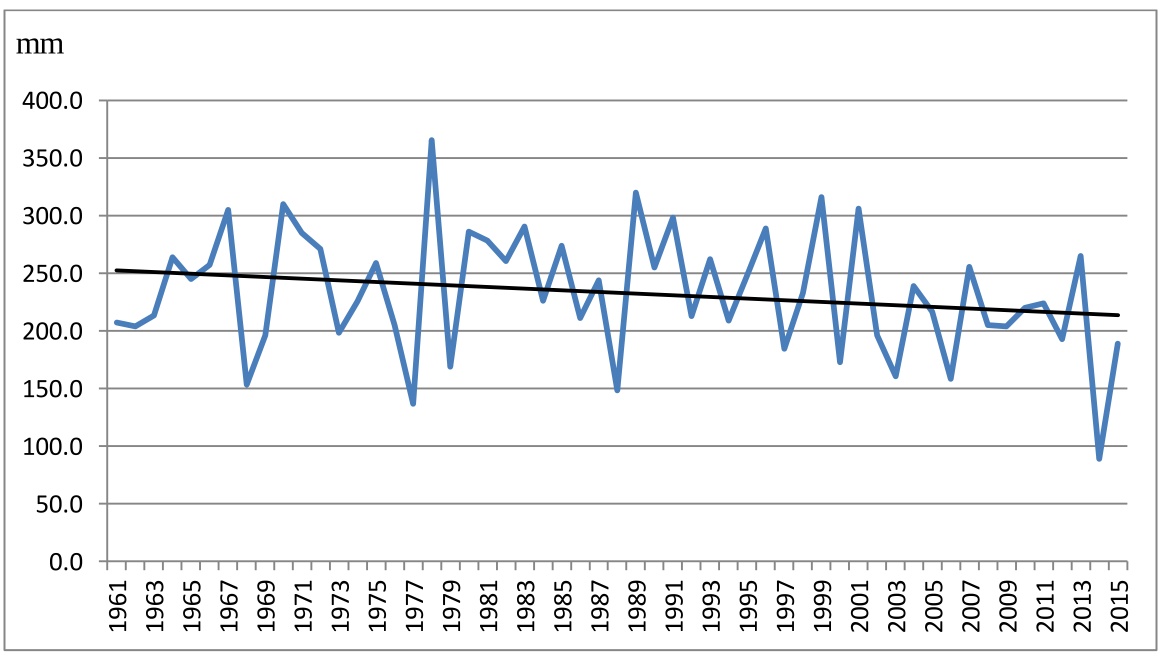

Figure 11. Average monthly rainfall trend of Ky Anh district, 1961-2015 (IMHEN, 2016)

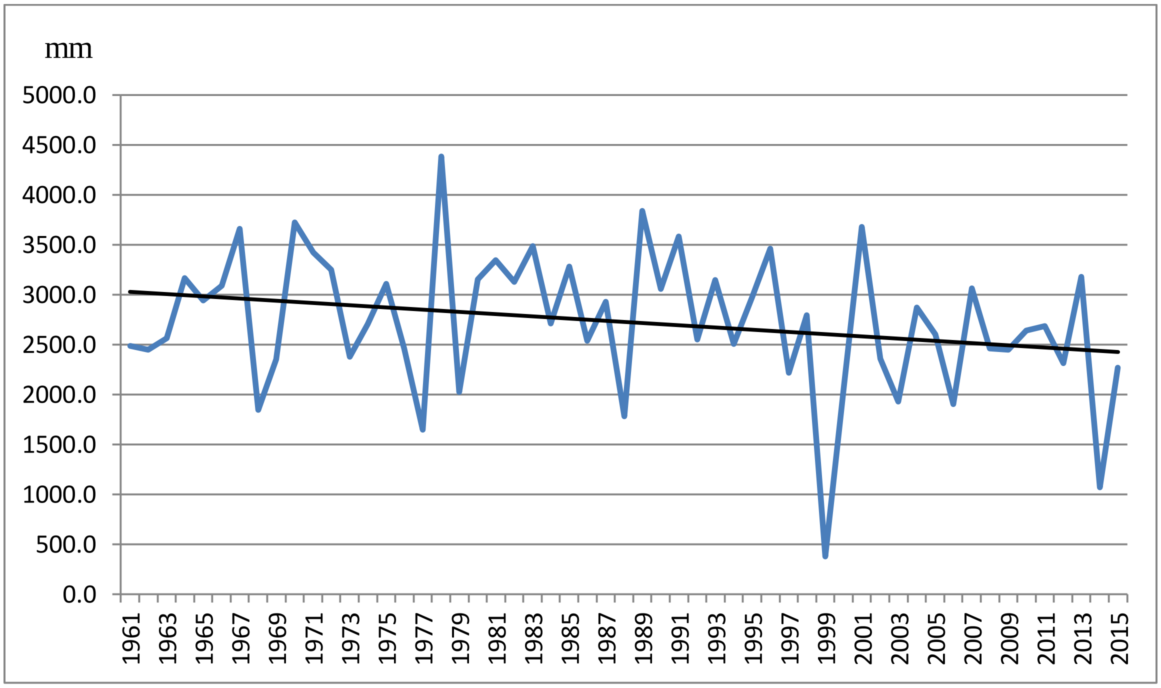

Figure 12. Total rainfall trend of Ky Anh district, 1961-2015 (IMHEN, 2016)

The extreme weather events such as drought, flood, cold spells and typhoons occur annually in the region; with droughts are the most frequent. Every year, the Ky Anh district faces three months of drought starting from April and most seriously in July (ISPONRE, 2009). The length of the drought incidence has also been increasing over time (Coulier, 2016).

In addition, people in the region have also been experiencing with increasing frequency of the adverse effects of climate change. Most of the respondents (72%) revealed that they knew or heard about the term climate change, which shows that people in the area are likely to be familiar with climate change (Figure 13).

Figure 13. Farmers' perception on the term climate change in Ky Son commune, Ky Son district, Ha Tinh province, Vietnam, 2016

However, the percentage of knowledgeable people on climate change of My Loi village (92%) is higher as compared with other villages (66%). This may be because many training courses on climate change have been conducted in My Loi village (project site). It seems that the training courses improved the awareness of local people on climate change. Thus, there should be more training courses on climate change in other villages (non-study site) to enhance the level of knowledge of farmers on this issue.

Along with the recognition of the occurrence of climate change, local people in Ky Son commune have also mentioned that drought and flood are the most frequent extreme weather events in the commune (Figure 14). Many farmer respondents (78%) in Ky Son commune reported that drought is the most frequent extreme event in the region during the last five years. In addition, they have also revealed the increase in intensity and length of drought in the region (Coulier, 2016). Flood is also the second frequent extreme weather event in the area. Twenty two percent (22%) of the respondents reported the very frequent flood occurrences in the area. Meanwhile, nearly 60 percent of the people also identified the regular appearance of floods in the commune in recent years.

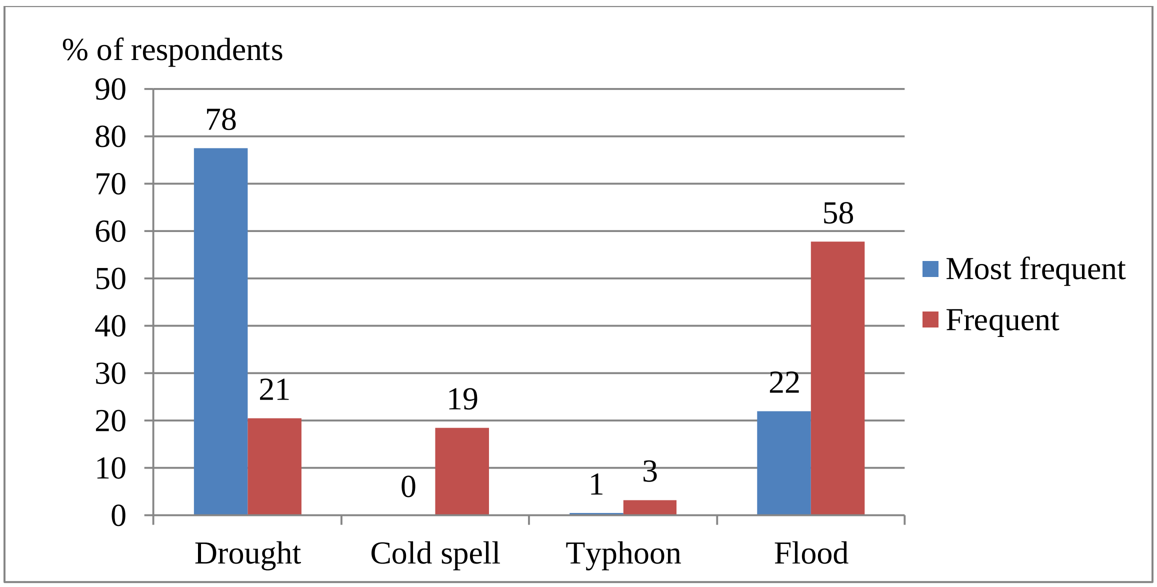

Figure 14. Farmers' perception on the occurrence of the extreme weather events during the last five years in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

Drought occurs annually in the commune from February to July. All the time, it covers the first crop season in the area. Normally, the first crop season of the commune starts from January and finishes in June. Floods start annually in August and are more frequent in October when the wintertime begins. This time is also the harvesting calendar of the second crop season in the commune. Thus, it could be concluded that crop production in the Ky Son commune is mainly affected by drought and flood both of which are the extreme weather events.

Climate Change Impacts on Agricultural Production in the Study Site

Ha Tinh province has experienced adverse effects of extreme weather events which resulted from climate change on agricultural production. For instance, in 2010, the province could not harvest 5,000 hectares of rice due to drought (Ha Tinh Provincial People's Committee, 2014). In Ky Anh district, agricultural production has also recorded adverse impacts of climate change, especially the effects of extreme weather events (Table 8).

Table 8. Correlation coefficients between meteorological indicators and yields of major annual crops in Ky Anh district, Ha Tinh province, Vietnam, 2016

ITEM	CROP YIELD*			
	Rice	Peanut	Cassava	Corn
Average monthly rainfall	-0.5000	-0.2863	-0.0347	-0.4997
Total rainfall	-0.5000	-0.2863	-0.0346	-0.4997
Average monthly temperature	-0.1710	-0.0418	-0.2256	-0.0197

***** See Appendix A. The study calculated correlation coefficients based on time series data on meteorology and crop yields from 2000 to 2015 of study site of Department of Planning under MARD (2016) and Ha Tinh Statistical Office (2016).

The negative correlation coefficients (Table 8) mean that the extreme trends of rainfall levels and temperature have adversely affected the yields of major crops of the district. The district has experienced a decrease in rainfall level while average temperature tends to increase in the region (Figure 10, 11 & 12 in pages 73 & 74). Thus, the negative correlation coefficients between rainfall levels, temperature and crop yields of the region imply that a decrease in rainfall and an increase in monthly temperature reduce yields of the major crops in the area, especially rice and corn. Hence, reducing the damages of extreme events is imperative for the region since the livelihood of most of the people in this area is mainly dependent on agricultural production. In addition, rice, corn and peanut are the major annual crops in the area (Ky Son Communal People's Committee, 2016).

Farmers in the study site have also recognized the adverse effects of climate change on their agricultural production. A number of people (67%) revealed that the decrease in their crop yield is the direct effect of climate change on their agricultural production (Table 9). They also mentioned that climate change could increase their production (38%) or adaptation costs (9%). In addition, some people (4%) revealed that the reduction in the cultivated land area and soil erosion also resulted from climate change.

Most the percentages of the well-informed farmers on the adverse impacts of climate change in My Loi village (89%, 55% and 10%) are significantly higher as compared with other villages (59%, 32% and 2%). This may be because farmers in My Loi village had more chance to attend the training courses on climate change compared with the farmers in the other villages. This again confirmed the important role of training courses in improving perception and knowledge of local people about climate change and its adverse impacts.

Table 9. Farmers' perception of adverse impacts of climate change on agricultural production in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM^{M}	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF	WHOLE SAMPLE (n = 400)
Decrease crop yield	89	59	30^{***}	67
Increase production cost	55	32	23^{***}	38
Reduce cultivated land	7	9	-2^{ns}	9
Soil erosion	3	4	-1^{ns}	4
Intensify adaptation cost	10	2	8^{***}	4

DIFF is different value between two samples; ***, **, are significant at 1% and 5%, respectively; ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

Table 10 shows the losses of farmers in the study site due to damages caused by extreme weather events that resulted from climate change. A number of the farmers (64% in My Loi village, 54% in other villages, and 56% in whole commune) reported that they could not cultivate in the second season (summer-autumn season) due to drought. This again shows the seriousness and/or adverse effects of drought on agricultural production in the region. The second crop season (summer-autumn season) in the region starts annually in June. However, June and July are the extreme season of drought in the area and this trend is more likely to increase in the recent years (ISPONRE, 2009). Most of the farmers cannot do anything in the rice field because of drought and poor irrigation systems in the region.

Table 10. Farmers' losses in agricultural production due to extreme weather events in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016

ITEM	MY LOI VILLAGE (n=104)	OTHER VILLAGES (n=296)	DIFF	WHOLE SAMPLE (n=400)
Have been damaged by extreme events (% of respondent)	89	73	16^{***}	78
Cannot plant for the 2^{nd} season due to drought (% of respondent)	64	54	10^{ns}	56
Loss proportion of annual crop in the total crop income (%)	18	19	-1^{ns}	19
Estimated loss of annual crop per ha (VND million/USD)	10.7 (469)	8.2 (360)	2.5^{**} (110)	9.0 (395)
Estimated loss of annual crop per year (VND million/USD)	2.1 (92)	2.6 (114)	-0.5^{*} (-22)	2.4 (105)

DIFF is different value between two samples;

***, **, * are significant at 1%, 5%, 10%, respectively; and

ns is non-significant

The numbers in parentheses are loss levels in US dollar (in 2016, US$1 = VND 22,800)

Farmers also try to cultivate green bean in the second crop season. However, yield of green bean is also low because of lack water during this season. As a result, farmers vacated mostly their cultivated land in the summer-autumn season and worked as hired agricultural laborers. Hired agricultural labor has contributed an important role to household's income in Ky Son commune (Coulier, 2016).

In addition, many farmers (78%) in the study site reported that extreme weather events have damaged their agricultural production, especially annual crop production (Table 10). On the average, each household in My Loi village, other villages and whole region lost estimably 2.1, 2.6 and VND 2.4 million (92, 114 & US$105) due to extreme events, respectively. These estimated loss levels are equivalent to 10.7, 8.2, and VND 9.0 million (496, 360 & US$395) per hectare, respectively. The losses are mainly a decreasing crop yields and an increasing production cost (cost of seedling, fertilizer, etc. for replanting). Although the loss level of annual crops may be low in terms of the overall picture for most people, it appears to be high for farmers in Ky Son commune. It is because this loss already occupied nearly 20% of household's income from annual crops. This proportion burdened farmers in the commune, especially poor farmers whose livelihood depends largely on agricultural production.

In summary, climate change, which has occurred in Ky Anh district, was manifested by increased average monthly temperature and decreased rainfall level. These phenomena reduced the yields of major crops such as rice, corn, and peanut in the region. Many farmers in the area have perceived climate change through frequent occurrences of extreme weather events, especially drought and flood. They also recognized the adverse effects of these extreme events on their agricultural production as well as their livelihood. Most of the farmers (78%) in the region reported that extreme weather events have damaged their agricultural production. The farmers' estimated losses due to extreme events in agricultural production amounted to around 20 percent of their total income from annual crops. Therefore, implementing significant adaptive strategies is meaningful for farmers to reduce the risks of climate change in the region.

Farmers' Adaptation to Climate Change in Agricultural Production in the Study Area

Farmers' Adaptive Strategies to Climate Change in Agricultural Production

Climate change has occurred and affected adversely agricultural production, especially annual crop in the Ky Son commune. This is evident by the farmers' reports of their losses in agricultural production due to frequent occurrences of extreme weather events in the region. Therefore, to reduce the situation, farmers have increased their attention and applied different adaptive practices to eliminate or minimize the damaging effects of climate change (Table 11). A large number of farmers (74%) in the commune reported that they applied at least one adaptive strategy to extreme weather events caused by climate change in their agricultural production.

Table 11. Farmers' adaptation to climate change in agricultural production in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016 (% of respondent)

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF*	WHOLE SAMPLE (n = 400)
Apply at least one adaptive strategy	78	72	6^{ns}	74
Number of adaptive strategy used by farmers:				
1	5	10	-5^{***}	9
2	36	37	-1^{ns}	36
3	41	38	3^{ns}	39
4	12	14	-2^{ns}	13
5	6	2	4^{ns}	3

* DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions

In the My Loi village, the farmers who applied three and two adaptive strategies occupied the first and second highest proportions (41% and 37%). This trend was also the same for the whole commune (39% and 36%). In other villages, meanwhile, proportions of farmers who use two and three adaptive tactics were almost the same (around 40%). In whole commune, several people (13%) applied four adaptive strategies while very few people (3%) had five adaptive options to extreme weather events in agricultural production. It implies that farmers in the commune have applied diversified adaptive strategies to extreme weather events in their agricultural production.

The major adaptive strategies to extreme weather events of farmers include changing crop varieties, switching to new cultivar types, adjusting farming calendar, following up weather forecasts, and intercropping (Table 12). Most of the farmers (85%) chose following up weather forecasts as priority adaptive tactic to extreme weather events in agricultural production. Thus, improving the quality of weather forecast and meteorological information could significantly increase adaptive efficiency of farmers to climate change in agricultural production in the study area.

Table 12. Farmers' major adaptive strategies to climate change in agricultural production in Ky Son commune, Ky Anh district, Ha Tinh, Vietnam, 2016 (% of respondent)

STRATEGIES^{M}	MY LOI VILLAGE (n = 81)	OTHER VILLAGES (n = 213)	DIFF*	WHOLE SAMPLE (n = 294)
Follow up weather forecasts	87	85	2^{ns}	85
Change crop variety	70	65	5^{ns}	66
Adjust farming calendar	38	25	13**	28
Switch to new cultivar types	6	25	-19***	20
Intercropping	15	5	10***	8

* DIFF is different value between two samples; ***, ** are significant at 1% and 5%, respectively; ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

A quite large number of the respondents (70% in the My Loi village; 65% in the other villages; and 66% in the whole commune) also changed crop varieties to cope with extreme events in agricultural production (Table 12). Farmers in the region reported that they used drought-tolerance varieties, especially in rice production during the second crop season. They also used short-season seedling of rice to avoid floods that always occur during harvesting time of the second season. Annually, floods in the study area start in August and occur most frequently in September until November (ISPONRE, 2009).

Adjusting farming calendar, switching to new cultivar types, and intercropping were also other adaptive strategies that farmers applied to cope with extreme events. The proportion of farmers who varied farming calendar and applied intercropping at My Loi village (38% and 15%) was significantly higher than in other villages (25% and 5%). Conversely, other villages had higher percentage of people who changed cultivar types compared to My Loi village. My Loi village has more available water sources for agricultural production than other areas since most of its cultivated land is located near the rivers and streams. Thus, farmers in the village could still plant popular annual crops such as rice, peanut, and green bean. In other villages, however, drought has been increasingly serious. Therefore, many people in these areas had to switch to new cultivar types. Some people planted grass for livestock (cow, goat). Some others used the most dried area of cultivated land to plant acacia (the most popular forestry tree in the commune).

Local officers, especially extension workers played important role in providing adaptive options for farmers in the study site (Table 13). About 70% of the farmers in the commune stated that their adaptive strategies to extreme events have come from consultancy of local officers. In My Loi village, along with consultancy of local officers, training courses on climate change were also important supplies of adaptive strategies for farmers to cope with extreme weather events. The percentage of people who learnt adaptive strategies from training courses on climate change in My Loi village (67%) is significantly higher as compared with other villages (5%). As the project site, My Loi village has many training courses on climate change compared with other villages. Thus, people in the village were more familiar with climate change concepts as well as adaptive strategies. Other sources for farmers in the My Loi village to refer coping solutions to extreme weather events included neighbors, public media, and own experience.

Table 13. Sources of information for adaptive strategies to climate change in agricultural production in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

SOURCES^{M}	MY LOI VILLAGE (n= 81)	OTHER VILLAGES (n = 213)	DIFF*	WHOLE SAMPLE (n = 294)
Local officers	69	71	-2^{ns}	70
Training courses	67	5	62^{***}	22
Public media	19	23	-4^{ns}	21
Neighbors	24	58	-34^{***}	49
Own experience	16	20	-4^{ns}	19

* DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

In the non-project site, along with consultancy of local officers, learning knowledge from neighbors was also the significant way for farmers to accumulate adaptive strategies. Nearly sixty percent (58%) of the respondents in the non-project site reported that they learnt adaptive tactics from their neighbors. Public media also played a substantial role for farmers in coping with climate change in the non-project site. Moreover, about 20% of farmers in this site applied adaptive strategies to extreme events by their own experiences.

By contrast, training courses on climate change has contributed slightly to farmers' adaptive strategies to extreme weather events in non-project site. Only few farmers (5%) in the non-project site reported that their adaptive strategies to extreme weather events have come from the training course on climate change. The reason is the number of farmers in the non-project site who participated in training courses on climate change was very few. Based on survey data, only 4% of respondents in non-project sites attended the training courses on climate change. In addition, awareness of farmers on climate change in Ha Tinh province is still limited (Ha Tinh Provincial People's Committee, 2014 and 2015). Therefore, there should be more training courses on climate change in the region. Alternatively, the training courses on other fields in the area could also integrate climate change concepts to improve farmers' adaptive solution to extreme events.

In summary, many farmers (74%) in the region have used at least one adaptive action to cope with extreme weather events in agricultural production. There were five major adaptive strategies of farmers to extreme weather events in the study area. In the whole commune, the number of farmers who applied three adaptive strategies occupied the highest proportion (39%). Extraordinarily, several farmers (3%) had five adaptive practices to extreme weather occurrences.

The prevalent adaptive tactics in the region included changing crop varieties, switching to new cultivar types, adjusting farming calendar, updating weather forecast news, and intercropping. Among them, updating weather forecast news and changing crop varieties are the most popular practices. There were also five sources of information for farmers' adaptive practices to extreme weather events in which consultancy of local officer was the most predominant. Applying knowledge of training course on climate change was the second popular strategy of farmers in project site, while the second prevalent tactic for people in non-project sites was learning from neighbors.

Factors Affecting Farmers' Decision on Adaptation to Climate Change in Agricultural Production

This study estimated binary logit model to analyze the factors affecting farmers' general decision in applying adaptive strategies to extreme events. The theoretical model hypothesized 13 explanatory variables regarding all households' livelihood assets (see Analytical Tools). However, after testing for multicollinearity problem (see Appendix B) the study selected only nine explanatory variables for the empirical model. In addition, this study also applied a robust standard error procedure to address the heteroskedasticity of the model. According to Wooldridge (2013), robust standard error could solve effectively heteroskedasticity since it gives relatively accurate P-value to ensure the significance of the model.

The dependent variable represents for farmers' decision in applying adaptive strategies to extreme weather events in their agricultural production and is binary outcomes (0, 1). One (1) denoted the respondents who adapted to extreme weather events in their agricultural production, while zero (0) implies the farmers who did not adapt. The Log pseudolikelihood (-198.32) in Table 14 is highly significant (Prob > χ^2 = 0.000). It implies that there was an overall significant relationship between the nine explanatory variables considered and the probability of adaptation to extreme weather events of farmers at 1% significant level.

Value of Pseudo R^2 (0.1425) is also highly significant (Prob > χ^2 = 0.000), meaning that the nine explanatory variables explained significantly 14.25% of changing the dependent variable of the model. In other words, the nine explanatory variables in the model explained 14.25% of changing the probability that farmers adapted to extreme weather events in agricultural production. Among explanatory variables, farm size, damage level, and training attendance were the factors that affected significantly the farmers' probability of adaptation to extreme weather events in their agricultural production.

Table 14. Factor affecting farmers' decision on adaptation to climate change in agricultural production in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016

VARIABLES	COEFFICIENTS	P-VALUE	MARGINAL EFFECTS	P-VALUE
Training attendance (1: yes; 0: no)	1.136***	0.000	0.157***	0.000
Damage level	0.281**	0.025	0.047**	0.014
Farm size	0.140***	0.000	0.023***	0.000
Gender (1: male; 0: female)	-0.402ns	0.158	-0.072ns	0.174
Educational level	0.019ns	0.743	0.003ns	0.743
Availability of agricultural labor	0.106ns	0.621	0.018ns	0.620
Farming experience	0.011ns	0.356	0.002ns	0.358
Access to credit (1: yes; 0: no)	0.285ns	0.271	0.049ns	0.280
Membership in organizations (1; 0)	0.763ns	0.162	0.153ns	0.224
Constant	-1.844**	0.047	-	-
Log pseudolikelihood	-198.32	-	-	-
Wald $\chi^2(9)$	41.61	-	-	-
Prob > χ^2	0.0000	-	-	-
Pseudo R^2	0.1425	-	-	-
Number of observation	400	-	-	-

***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Results of the empirical model in Table 14 show that three factors (training attendance, farm size, and damage level) affect significantly farmers' decision on adaptation to climate change. Of these factors, attendance training had the highest significant effect (0.157) on the probability that farmers adapt to climate change. Specifically, farmers who attended the training course on climate change have 15.7% higher in the probability of adaptation to extreme weather events than other farmers did, ceteris paribus. The positive sign of farm size in this model means that households with large farmland areas are more likely to adapt to climate change as compared with other households. Households with high damage level have 4.7% higher in the probability of adaptation to climate change compared to households with low damage level. While, the factors that have no significant effects on farmers' decision on adaptation to climate change include gender, educational level, family agricultural labor, farming experience, access to credit, and membership in local organization.

Farmers in the study area have applied five specific adaptive practices to extreme weather events in their agricultural production (Table 12 in page 84). To analyze the factors affecting the probability that farmers adopt each specific adaptive practice, this study employed the multivariate probit (MVP) model. The dependent variable of the MVP model include five specific choices (specific adaptive practices of farmers), and take value of 1 if farmers apply specific adaptive practices and 0 otherwise. After testing for multicollinearity problem by using correlation matrix among explanatory variables, this paper selected only nine explanatory variables for the MVP model. This study also applied robust standard error procedure to address the issue of heteroskedasticity of this model. The estimates of the MVP model are shown in Table 15. Values of Wald $\chi^2(45)$ is significant at 1% (Prob > χ^2 = 0.0000), ensuring the existence of the model.

Table 15. Factors influencing farmers' decision in adopting specific adaptive practices to climate change in agricultural production in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016

VARIABLES	ADAPTIVE PRACTICES				
	Y_1	Y_2	Y_3	Y_4	Y_5
Training attendance	0.558^{***}	-0.267^{ns}	0.669^{***}	0.667^{**}	0.819^{***}
Farm size	0.051^{***}	0.065^{***}	0.042^{***}	0.057^{***}	0.009^{ns}
Damage level	0.069^{*}	0.042^{ns}	0.036^{ns}	0.082^{**}	-0.005^{ns}
Farming experience	0.015^{**}	0.005^{ns}	0.011^{ns}	0.015^{**}	-0.004^{ns}
Gender	-0.435^{***}	0.063^{ns}	0.160^{ns}	-0.112^{ns}	0.070^{ns}
Access to credit	0.065^{ns}	0.195^{ns}	0.322^{**}	0.258^{*}	0.031^{ns}
Educational level	0.043^{ns}	0.028^{*}	0.029^{ns}	0.081^{**}	0.009^{ns}
Agricultural labor	0.073^{ns}	-0.079^{ns}	0.118^{ns}	0.083^{ns}	0.063^{ns}
Membership in organizations	0.622^{ns}	0.558^{ns}	0.627^{ns}	0.469^{ns}	0.140^{ns}
Constant	-1.516^{**}	-2.214^{***}	-2.705^{***}	-1.915^{***}	-1.767^{***}
Correlation	Coefficients			P-value	
ρ_{21}	0.529^{***}			0.000	
ρ_{31}	0.358^{***}			0.000	
ρ_{41}	0.842^{***}			0.000	
ρ_{51}	0.214^{*}			0.053	
ρ_{32}	0.156^{*}			0.053	
ρ_{42}	0.564^{***}			0.000	
ρ_{52}	0.338^{***}			0.002	
ρ_{43}	0.568^{***}			0.000	
ρ_{53}	-0.089^{ns}			0.327	
ρ_{54}	0.293^{***}			0.001	
Log pseudolikelihood			-817.44		
Wald $\chi^2(45)$			137.85		
Prob > χ^2			0.0000		
Number of observation			400		

Likelihood ratio test of H_0: $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{43} = \rho_{53} = \rho_{54} = 0$
$\chi^2(10) = 260.12$ Prob > $\chi^2 = 0.0000$

***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Y_1 = Change crop variety;

Y_2 = Switch to new cultivar types;

Y_3 = Adjust farming calendar;

Y_4 = Update weather forecast news; and

Y_5 = Intercropping

The value of $\chi^2(10)$ is also highly significant (Prob > χ^2 = 0.0000), showing that there is correlation between five adaptive practices. Most correlation coefficients are highly significant, meaning that there is interdependence between different adaptive practices used by the farmers. This validates the feasibility of the MVP model in this study. The results in Table 15 show that attendance in climate change training and farm size significantly affected the farmers' probability of adoption of four of five adaptive practices in farmers' agricultural production. The households with member attended the training courses are more likely to adapt to climate change by changing crop varieties, adjusting farming calendar, following up weather forecasts, and intercropping.

Similarly, the households with large farmland are more likely to change crop varieties, adjust farming calendar, switch to new cultivar types, and follow up weather forecasts in coping with climate change. Farming experience and damage level significantly influences the farmers' probabilities of changing crop varieties and following up weather forecasts in coping with climate change. Experienced farmers have higher probabilities of changing crop varieties and following up weather forecasts in coping with climate change compared to inexperienced farmers. Similarly, households with high damage level due to climate change are more likely to change crop varieties and follow up weather forecasts in coping with climate change compared to other households. Contrary to this, these two factors do not significantly affect farmers' decisions in switching to new cultivar types, adjusting farming calendar, and intercropping. Educational level significantly and positively influences the farmers' probabilities of switching to new cultivar types and following up weather forecasts.

Farmers who have higher educational level are more likely to adapt to climate change by switching to news cultivar types and following up weather forecasts.

There is significant relationship between access to credit and farmers' decisions in adjusting farming calendar and following up weather forecasts at 5% and 10% significant level, respectively. Households that can access available credit sources are more likely to adapt to climate change in their agricultural production by adjusting farming calendar and following up weather forecasts. Gender significantly influences only the farmers' probability of changing crop varieties in coping with climate change. While, there is no significant relationship between availability of agricultural labor, membership in local organizations and the farmers' probabilities of adaptation to climate change.

In terms of specific adaptive strategies, households with member attended in the training courses on climate change are more likely to change crop varieties in coping with climate change. Changing crop varieties is also significantly adopted by the households that have larger farmland area and high damage level caused by climate change. Experienced farmers are more likely to change crop varieties in coping with climate change, but this adaptive practice is significantly less likely to be adopted by male farmers. Households with larger farm size and household's heads who have higher educational levels are more likely to switch to new cultivar types in coping with climate change in their agricultural production. Following up weather forecasts is significantly influenced by attendance in climate change training, farm size, farming experience, educational level, damage level, and access to credit. Finally, intercropping is significantly applied by only households with member attended in the training courses on climate change.

From results of the binary logit model and multivariate probit model, attendance in climate change training and farmland are the most determinant factors affecting the farmers' decision on adaptation to climate change. Farmers who attended the training courses on climate change are more likely to adopt adaptive practices compared with other farmers who did not attend. Most of the farmers in the study site still have limited awareness and knowledge on climate change (Ha Tinh People's Committee, 2014). Thus, farmers who attended in the training courses on climate change may have better understanding about climate change and its impacts as well as the importance of adaptation in reducing losses. Hence, they are more likely to adapt to climate change to reduce losses in their agricultural production. This is opposite to the findings of Piya et al. (2013) in Nepal, and Mu et al. (2015) in Myanmar that training significantly has negative effects on or does not significantly affect the probability of adaptation of farmers.

The probability of adaptation to climate change of households with larger farm size is significantly higher than that of the households with smaller farmland. This finding supports the results of the studies of Nhemachena and Hassan (2007), Piya et al. (2013), Ashraf et al. (2014), Mu et al. (2015), Asfaw et al. (2016), and Jin et al. (2016), that farm size mostly increases the probability of adaptation to climate change of farmers. The possible reason could be the households with larger farmland may face higher damage level caused by climate change, which encourages them adapt to reduce losses in their agricultural production. This reason is strengthened by positive and significant effect of damage level on the probability of adaptation to climate change of farmers in the study site. Results of the binary logit and multivariate probit models in this study shows that households with higher damage level caused by climate change are more likely to adopt adaptive practices.

By contrast, family agricultural labor and membership in local organization do not significantly influence the probability of adaptation to climate change of farmers. These are in line with the findings of Piya et al. (2013) and Mu et al. (2015). Piya et al. (2013) found that membership in organization is not significant determinant of farmers' decision on adaptation to climate change in Nepal. Meanwhile, Mu et al. (2015) revealed that availability of agricultural labor does not significantly influence the probability of adaptation to climate change of households in Myanmar. In the study site, the availability of agricultural labor is not significant different among households, that could explain why the probability of adaptation to climate change of farmers is not significantly influenced by this factor. In addition, most of the farmers (96%) in the study site have involved at least one local organization (Table 4 in page 59). However, most of the organizations in the study site seem to be social-oriented, except only Farmer's Union is responsible for providing information on seedlings and some basic farming techniques. Thus, membership in these organizations is not sufficient for farmers to improve adaptive capacity to cope with climate change.

Farmers' Using Meteorological Information in Climate Change Adaptation

Farmers' Using Meteorological Information to Cope with Climate Change in Agricultural Production

Monitoring weather forecast news was the most popular adaptive strategy to extreme weather events utilized by farmers in the study site (Table 12 in page 84). It explained why most of farmers in the area updated daily weather forecast news. Many farmer respondents (86% in the My Loi village, 84% in the other villages, and 84% in the whole commune) reported that they follow daily weather forecast news to get meteorological information for their agricultural production (Table 16).

Table 16. Sources of information and frequency of following up weather forecasts of farmers in Ky Son commune, Ky Son, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF*	WHOLE SAMPLE (n = 400)
Following up weather forecasts				
Daily follow	86	84	2^{ns}	84
Irregular follow	11	10	1^{ns}	10
Source of information ^{M}				
National weather forecast news	98	95	3^{ns}	96
Provincial weather forecast news	34	7	27^{***}	14
National agri. weather forecast news	10	8	2^{ns}	8
Other sources	4	9	-5^{ns}	7

* DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions. M is multiple choices.

National weather forecast news through television, radio and public loudspeaker systems had been the main sources for farmers to get meteorological information. Most of the farmers (96% in the whole commune) in the study area reported that they have accessed meteorological information from national weather forecast news. Moreover, farmers could also access such information through other available sources (national agricultural weather forecast news, provincial weather forecast news, internet, etc.).

People in the study site indicated several benefits of following up weather forecasts in coping with extreme event in agricultural production (Table 17). A quite large number of the farmers (69% in the whole commune) believed that they could reduce damage level in their agricultural production caused by the extreme weather events if they follow daily weather forecast news.

Table 17. Farmers' perception on benefits of following up weather forecasts in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016 (% of respondent)

ITEM^{M}	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF*	WHOLE SAMPLE (n = 400)
Reduce damages in agricultural production	64	71	-7^{ns}	69
Having suitable production plan	40	40	0^{ns}	40
Save production cost	43	26	17***	31
Support for pest and disease prevention	6	3	3^{ns}	4

* DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

About 40% of the farmer respondents revealed that following weather forecast news could help them have a suitable production plan. Some other people (43% in the

My Loi village, 26% in the other villages, and 31% in the whole commune) thought that they could reduce production cost through accessing weather forecast news. Finally, only few farmers (4% in the whole commune) identified that getting information from weather forecast news could support for their plan of pest and disease prevention for crops.

This study analyzed the specific adjustments of farmers in agricultural production activities by using meteorological information given by the weather forecast news. It aims to explore exhaustively how farmers use meteorological information given by weather forecast news to cope with extreme weather events in their agricultural production. Due to identifying several benefits of following weather forecast news (Table 19 in page 98), many farmers (87% in My Loi village, 85% in other villages, and 85% in the whole commune) reported that they used meteorological information to adjust their agricultural production activities (Figure 15). This again implies the importance and necessity of improving quality of weather forecast news and meteorological information in coping with extreme weather events in agricultural production.

The specific adjustments of farmers based on meteorological information given by the weather forecast news include changing planting dates, adjusting application of farm inputs, and shifting harvesting calendar (Table 18). Among these adjustments, changing planting dates is the most common practice. It is because many respondents (92% in the whole commune) reported that they changed the planting date after getting meteorological information given by the weather forecast news. This aims to save production costs through reducing seedling, fertilizer, and pesticide costs that resulted from replanting due to damages caused by the extreme weather events.

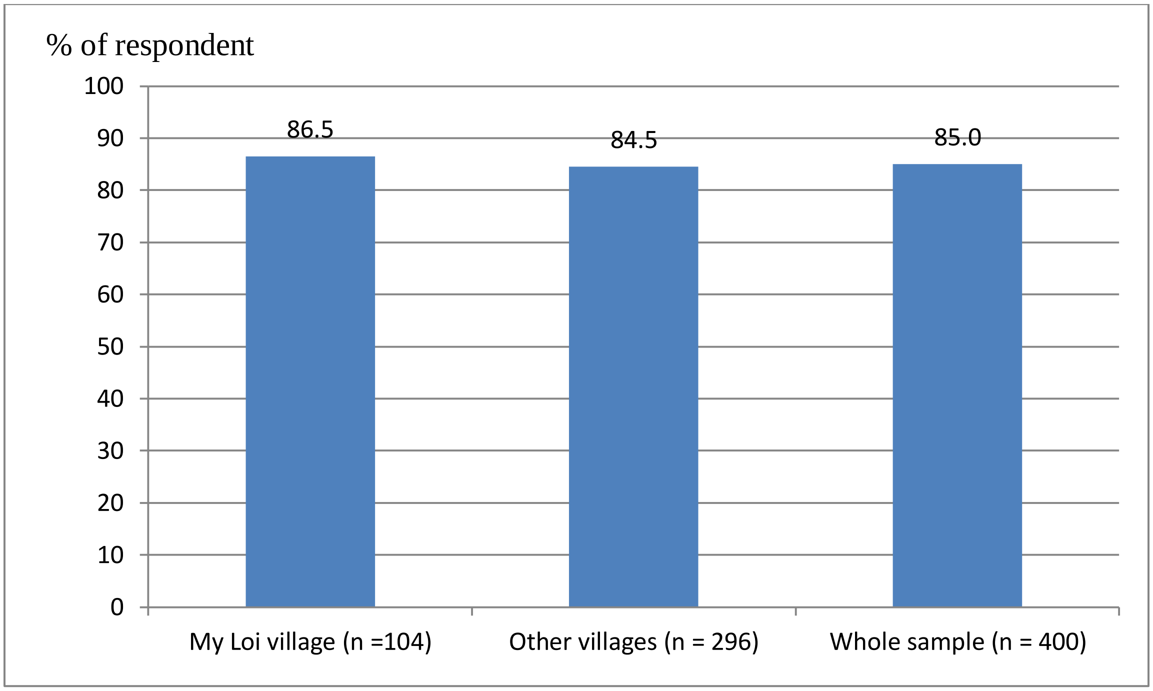

Figure 15. Farmers' decision in using meteorological information to cope with climate change in agricultural production in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

Table 18. Farmers' major adjustments for cultural activities by using meteorological information to cope with climate change in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM^{M}	MY LOI VILLAGE (n = 90)	OTHER VILLAGES (n = 250)	DIFF	WHOLE SAMPLE (n = 340)
Change planting dates	93	92	1^{ns}	92
Adjust application of farm inputs	59	40	19^{***}	45
Shift harvesting calendar	41	40	1^{ns}	41

DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

Adjusting application of farm inputs is the second popular option that farmers used to cope with extreme events in agricultural production by using meteorological information given by the weather forecast news. Forty five percent (45%) of the farmers in the study area reported that they adjusted the application of farm inputs (fertilizers, pesticides) in their crop production by using meteorological information. About 41 percent (41%) of the respondents revealed that after they get meteorological information, shifting harvesting calendar is also a significant way to cope with extreme weather events in agricultural production. Shifting harvesting calendar connect with adjustment in farming calendar that is one of the popular adaptive strategies that many farmers in the study area applied to cope with extreme weather events (Table 12 in page 84).

Why do farmers update meteorological information to adjust agricultural activities in adaptation to extreme weather event? The answer is that they have recognized the benefits of using such information in coping with these climate stresses in their agricultural production. Specifically, farmers have indicated four different advantages of applying meteorological information to alter agricultural production activities. These benefits include increasing crop yields, reducing production cost, diminishing adaptation cost, and decreasing damaged level caused by extreme weather events (Table 19).

Most of the farmer respondents (66% in the whole commune) reported that by using meteorological information to adjust agricultural production activities they could reduce their production cost. Forty percent (40%) of other farmers were certain of increasing in crop yields by using meteorological information. About 36% of respondents also identified that they may have lower damage level from extreme events if they use meteorological information to change agricultural production activities. Finally, there was only 9% of farmers perceived the lower adaptation cost that resulted from using meteorological information to regulate agricultural production activities.

Table 19. Farmers' perception on benefits of using meteorological information to adjust agricultural activities in coping with climate change in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM^{M}	MY LOI VILLAGE	OTHER VILLAGES	DIFF	WHOLE SAMPLE
Reduce production cost	67	66	1^{ns}	66
Increase crop yield	48	37	11^{ns}	40
Decrease damage level	31	38	-7^{ns}	36
Reduce adaptation cost	20	4	16^{***}	9

DIFF is different value between two samples; *** is significant at 1% and ns is non-significant based on Z-test for the difference between proportions. M is multiple choices

In My Loi village, 20% of the farmers revealed that the benefit of using meteorological information to adjust agricultural production activities is the low adaptation cost. This proportion (20%) of My Loi village was significantly higher than that of other villages (4%). The reason is that farmers in My Loi village are more familiar with adaptation "term" since they have many chances to attend the training course on climate change. Therefore, their awareness on adaptation to climate change is much better than that of the farmers in other villages. Thus, there is need of more training courses on climate change in other villages (non-project site) to improve knowledge and/or awareness of farmers on this issue.

In brief, people in the study area have recognized four different explicit values of following weather forecast news (Table 17 in page 97) and using meteorological information (Table 19 in page 101) in coping with extreme events. The most considered benefit of following weather forecast news and using meteorological information in confronting extreme weather events was the low production cost. Thus, many farmers (85%) in the region have used meteorological information given by the weather forecast news to adjust their agricultural production activities. There were three specific adjustments including changing planting date, adjusting application of farm inputs such as fertilizers and pesticides, and shifting harvesting calendar.

Factors Affecting Farmers' Decision in Using Meteorological Information to Cope with Climate Change

Based on meteorological information given by the weather forecast news, farmers in the study site have adjusted their agricultural production activities to cope with extreme events. The binary logit model was used to analyze the factors affecting farmers' decision in using meteorological information to cope with extreme weather events in their agricultural production. The dependent variable of this model is binary outcome (0, 1). Specifically, if a farmer used meteorological information given by the weather forecasts to adjust at least one agricultural production activity, his/her value will be one (1). Otherwise, he/she will get value of zero (0).

After eliminating multicollinearity by estimating correlation coefficients among explanatory variables (Appendix B), the study chose nine independent variables for the empirical binary logit model. These independent variables included gender, educational level, farm size, damaged level of extreme events, family's agricultural labor supply, farming experience, training attendance, and membership in organizations. The issue of heteroskedasticity of this binary logit model in the study was addressed by applying the robust standard error procedure

Table 20. Factor affecting farmers' decision in using meteorological information to cope with climate change in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

VARIABLES	COEFFICIENTS	P-VALUE	MARGINAL EFFECTS	P-VALUE
Training attendance	1.102^{**}	0.025	0.086^{***}	0.005
Educational level	0.286^{***}	0.002	0.028^{***}	0.001
Farming experience	0.050^{***}	0.000	0.005^{***}	0.000
Farm size	0.104^{**}	0.046	0.010^{**}	0.035
Damage level	0.061^{ns}	0.483	0.006^{ns}	0.476
Gender	-0.174^{ns}	0.638	-0.018^{ns}	0.650
Agricultural labor	0.280^{ns}	0.370	0.028^{ns}	0.366
Access to credit	0.415^{ns}	0.172	0.043^{ns}	0.186
Membership in organizations	-0.207^{ns}	0.756	-0.019^{ns}	0.737
Constant	-2.991^{**}	0.047	-	-
Log pseudolikelihood	-149.08	-	-	-
Wald $\chi^2(9)$	30.38	-	-	-
Prob > χ^2	0.0003	-	-	-
Pseudo R^2	0.1183	-	-	-
Number of observation	400	-	-	-

***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Table 20 shows the estimated parameters of the empirical binary logit model on farmers' decision in using meteorological information to adjust cultural activities. The values (30.38) of Wald $\chi^2(9)$ is highly significant at 1% significant level (Prob>χ^2 = 0.0003). This implies that the significance of the binary logit model in explaining the decisions in changing cultural practices by using meteorological information of farmers. Values of Pseudo R^2 (0.1183) is also highly significant at 1% significant level (Prob > χ^2 = 0.0003). This means the independent variables of the model explained 11.83% of changing in the probability that farmers use meteorological information to adjust cultural activities.

Among explanatory variable considered, educational level, farm size, farming experience, and training attendance are four factors that significantly influence the decisions of farmers (Table 20). Of these factors, training attendance had the highest significant effect level (0.086) on farmers' decision in using meteorological information to change cultural activities. The farmers who participated in the training courses on climate change were 8.6% higher in the probability of changing cultural activities than those who did not attend. Knowledgeable people on climate change may have better awareness about benefits of using meteorological information in adaptation to extreme events. Therefore, they are more likely to adjust cultural activities based on meteorological information given by weather forecast news. Thus, the training courses on climate change have played an important role in improving farmers' adaptive capacity to extreme occurrences in their agricultural production.

Positive significant coefficients of educational level and farming experience showed that educated and experienced farmers are more likely to adjust cultural activities base on meteorological information (Table 20 in page 103). The better-educated and more experienced farmers have a better understanding of impacts of climate change as well as the benefits of using meteorological information in coping with extreme weather events. Thus, they are more likely to use meteorological information to modify their cultural activities compared with other farmers. It is clear that there should be more training courses on climate change for the farmers who have low educational level and less farming experiences. This may help these farmers improve their adaptive capacities and cope more effectively with extreme weather events in their agricultural production.

Farm size also affected significantly the probability that farmers in the study area change their cultural activities based on meteorological information. Farmers who have large farmland area are more likely to use meteorological information given by the weather forecast news to adjust cultural activities. Higher expected levels of damages for large farmland area could cause these farmers to have higher probability of adjusting cultural activities based on meteorological information.

While, there were five factors that did not significantly affect farmers' probability of changing cultural activities based on meteorological information. These include gender, damage level, availability of agricultural labor, access to credit, and institutional participation (Table 20 in page 103). Men and women in Ky Son commune made joint decisions on farming activities (Coulier, 2016). It explained why gender has no significant effect on the farmers' probability of changing cultural activities in the region. Insignificant difference in availability of agricultural labor among households exists

(Table 4 in page 59). Thus, there is no significant effect of agricultural labor on the farmers' probability of adjusting cultural activities based on meteorological information.

Many farmers in the study area have estimated their loss level caused by extreme weather events in their agricultural production. However, there are still farmers who cannot calculate this damage level. It implies that the damage level of farmers may be not much different. Thus, damage level did not significantly affect the decision of farmers in using meteorological information to adjust their cultural activities. Finally, overlapping and inefficiency in operation of the local organization could cause membership in local organizations had no significant effect on the farmers' probability of changing cultural activities. Thus, improving the operational efficiency of the local organizations toward integrating the concepts of climate change into the action plans is crucial issue. This may improve farmer's adaptive capacity and help them adapt effectively to extreme weather events in their agricultural production.

Farmers in the study site had three changes in cultural activities based on meteorological information given by the daily weather forecasts (Table 18 in page 99). To determine the factors influencing the probability that farmers adjust each particular cultural activity, this study estimated another multivariate probit (MVP) model. In this MVP model, dependent variable includes three different options and each option is binary outcome (0, 1). One (1) explains the farmers who adjust one particular cultural activity based on given meteorological information. Otherwise, they will get value of zero (0). For example, if a farmer changes planting date he will get value of one (1) otherwise his/she will get value of zero (0).

This study addressed the issues of heteroskedasticity and multicollinearity and of this MVP model by using the correlation matrix (Appendix B) and the robust standard error procedure. The explanatory variables of the model include gender, educational level, farm size, farming experience, damage level, training attendance, availability of agricultural labor, access to credit, and membership in local organizations.

Results of the MVP model are shown in Table 21. The value of (107.01) Wald $\chi^2(36)$ is highly significant at 1% since Prob > χ^2 = 0.0000, showing the significant relationship between the probability that farmers change a specific cultural activity based on meteorological information and explanatory variables. Furthermore, the value (70.827) of $\chi^2(3)$ is also highly significant (Prob > χ^2 = 0.0000). This implies that there is a correlation between three adjustments of cultural activities of farmers in the study area. In other words, this justifies the existence of three simultaneous equations in the MVP model instead of individual equation.

The probability that farmers change planting date by using meteorological information was significantly affected by training attendance, educational level, farming experience, and farm size (Table 21). The farmers' probability of adjusting application of farm inputs was significantly influenced by five different factors. These include training attendance, educational level, farming experience, access to credit, and membership in local organizations. Finally, training attendance, educational level, and farm size affected significantly the probability that farmers shift harvesting date based on meteorological information.

Table 21. Factors influencing farmers' decision in adjusting specific cultural activities to cope with climate change based on meteorological information in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

VARIABLES	ADJUSTMENTS		
	Change planting dates	Adjust application of farm inputs	Shift harvesting calendar
Training attendance	0.385^{**}	0.609^{***}	0.483^{***}
Educational level	0.084^{**}	0.150^{***}	0.070^{*}
Farming experience	0.023^{***}	0.030^{***}	0.010^{ns}
Farm size	0.041^{**}	0.020^{ns}	0.032^{**}
Access to credit	0.127^{ns}	0.283^{**}	0.147^{ns}
Membership in organizations	-0.216^{ns}	1.024^{*}	0.115^{ns}
Gender	-0.252^{ns}	-0.199^{ns}	-0.126^{ns}
Damage level	0.020^{ns}	0.017^{ns}	0.025^{ns}
Agricultural labor	0.141^{ns}	0.061^{ns}	0.049^{ns}
Constant	-0.852^{ns}	-3.747^{***}	-1.822^{***}
Correlation	Coefficients		P-value
ρ_{21}	0.475^{***}		0.000
ρ_{31}	0.507^{***}		0.000
ρ_{32}	0.419^{***}		0.000
Log pseudolikelihood		-757.41	
Wald $\chi^2(36)$		107.01	
Prob > χ^2		0.000	
Number of observation		400	

Likelihood ratio test of H_0: $\rho_{21} = \rho_{31} = \rho_{32} = 0$
$\chi^2(3) = 70.827$ Prob > $\chi^2 = 0.0000$

***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Training attendance was the most significant factor for the probability that farmers adjust their cultural activities based on meteorological information. The reason is that it influenced significantly all the probabilities that farmers change planting date, adjust application of farm inputs, and shift harvesting calendar at 5% significant level (Table 21). This implies that farmers who attended training courses on climate change are more likely to change planting and harvesting dates, and adjust application of farm inputs compared with those who did not attend, ceteris paribus.

Education level also influenced significantly all the probabilities of changing cultural activities based on meteorological information of farmers. Specifically, educational level affected significantly the probabilities that farmers adjust the application of farm inputs, change planting date, and shift harvesting calendar at 1%, 5%, and 10% significant level, respectively. The better-educated farmers are more likely to adjust their cultural activities based on meteorological information to cope with extreme weather events compared with the other farmers.

Farm size has significant effect on the probabilities of changing planting and harvesting dates of farmers based on meteorological information at 5% significant level. Farmers who owned large farmland were more likely to adjust planting and harvesting dates to cope with extreme weather events compared with other farmers. Farming experience affected significantly the probabilities that farmers change planting date and adjust application of farm inputs based on meteorological information at 1% significant level. Based on meteorological information given by the weather forecast news, experienced farmers were more likely to change planting date and adjust the application of farm inputs than inexperienced farmers.

Membership in local organizations only affected significantly the probability that farmers adjust the application of farm inputs based on meteorological information at 10% significant level. It means that farmers who are involved in the local organizations were more likely to adjust the application of farm inputs based on meteorological information to cope with extreme weather events. The Farmer's Union (one of the local organizations) is responsible for disseminating the techniques regarding agricultural production to people. Therefore, members of this organization are more likely to adjust the application of farm inputs such as applying fertilizer and spraying pesticides compared to non-member farmers.

Clearly, training attendance, education level, farming experience and farm size played important roles in improving farmers' behavior in coping with extreme weather events. Through the training courses on climate change, farmers may have better understanding about the benefits of using meteorological information in coping with extreme weather events. Thus, they may be more likely to adjust their cultural activities based on meteorological information given by the weather forecast news. Hence, intensive training courses on climate change for farmers, especially for inexperienced farmers should be encouraged to improve farmers' adaptive behavior and capacity to climate change in the study area. The farmers who own large farmland area may have higher damage level in agricultural production caused by extreme weather events. However, these farmers may have low mitigation cost in coping with extreme weather events since they may apply easily and comprehensively adaptive practices when they have large farmland area. Hence, these farmers were more likely to adjust their cultural activities by using meteorological information. Again, completion of policies for land consolidation should also be considered to help farmers in the study area cope effectively with climate change.

Gender, damage level and availability of household's agricultural labor did not have any significant effects on the probabilities that farmers adjust their cultural practices based on meteorological information (Table 21 in page 108). Joint decision-making between men and women, indifference in availability of agricultural labor supply among households, and underestimation of damage level could be persuasive reasons for above problem. Access to credit also did not significantly influence the probability of changing farming calendar (planting and harvesting dates) of farmers. It may be updating meteorological information to change farming calendar might not require much money.

In summary, there is an overall relationship between the probabilities that farmers adjust cultural activities based on meteorological information given by the weather forecast news and different factors. These factors relate to all household's capital assets. Among factors considered, training attendance and educational level were factors that positively and significantly affected all the farmers' decisions in changing cultural activities based on meteorological information. Farm size and farming experience are the second important factors since they affected significantly two out of three probabilities that farmers change their cultural activities by using meteorological information. While, gender, damage level, availability of agricultural labor, and membership in local organizations have no any significant effects on the probabilities of changing cultural activities based on meteorological information of farmers.

Economic Value of Weather Forecast and Agrometeorological Information in the Study Area

Availability of Meteorological Information in the Study Area

In Vietnam, National Centre for Hydro-Meteorology Forecasting (NCHMF) has mainly provided weather forecast information. NCHMF also has sub-center in the different regions of the whole country. At provincial level, Provincial Centre for Hydro-Meteorology Forecasting is responsible for forecasting and providing meteorological information in the provincial scale.

Through weather forecast news, farmers may get the information on temperature, rainy trend, and warning about occurring tendency of extreme events such as typhoon, hot spells, and cold spells. However, this meteorological information is only at wide scales (regional and provincial scales). Although the farmers can easily access weather information through many different sources, there are still many problems for meteorological information. For instance, meteorological information has been not downscaled to local level, not detailed enough, short-term, and has considered unreliable or incorrect (Coulier, 2016). Thus, there is need of downscaling, localizing, improving quality and long-term forecasting for meteorological information. This may help farmers cope more effectively with climate change in agricultural production.

Farmers in the study site have increasingly used meteorological information to adjust their agricultural production activities in the context of coping with extreme weather events (Figure 15 & Table 18 in page 99). However, in reality at the study site, meteorological information is too broad, not comprehensive enough and not always accurate (Coulier, 2016). The reason is that national weather forecast news on television is the main source of meteorological information for the people in the region (Table 16 in page 96). However, the national weather forecast news has broadly provided meteorological information at both national and regional levels. This explained why weather information for local people is always inaccurate, not detailed enough, and is incomplete. Thus, many people in the region (85% & 96%) have appreciated the meteorological station in My Loi village (project site) and seasonal forecast bulletin of the project (Table 22).

Table 22. Farmers' perception on the necessity and importance of meteorological station and seasonal forecast bulletin in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n =296)	DIFF*	WHOLE SAMPLE (n = 400)
Meteorological station in the village	86	85	1^{ns}	85
Seasonal forecast bulletin	98	96	2^{ns}	96

* DIFF is different value between two samples; ns is non-significant based on Z-test for the difference between proportions

The ICRAF's project established the meteorological station in My Loi village since September 2015 (Figure 16 & 17). It aims to collect daily basic weather information such as temperature, rainfall, humidity at the village and/or commune levels. An individual is responsible for recording the basic weather information of the village and give such information to head of the village. The head of the village announces daily meteorological information to people in the village through loudspeaker systems.

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Figure 16. Meteorological station in My Loi village

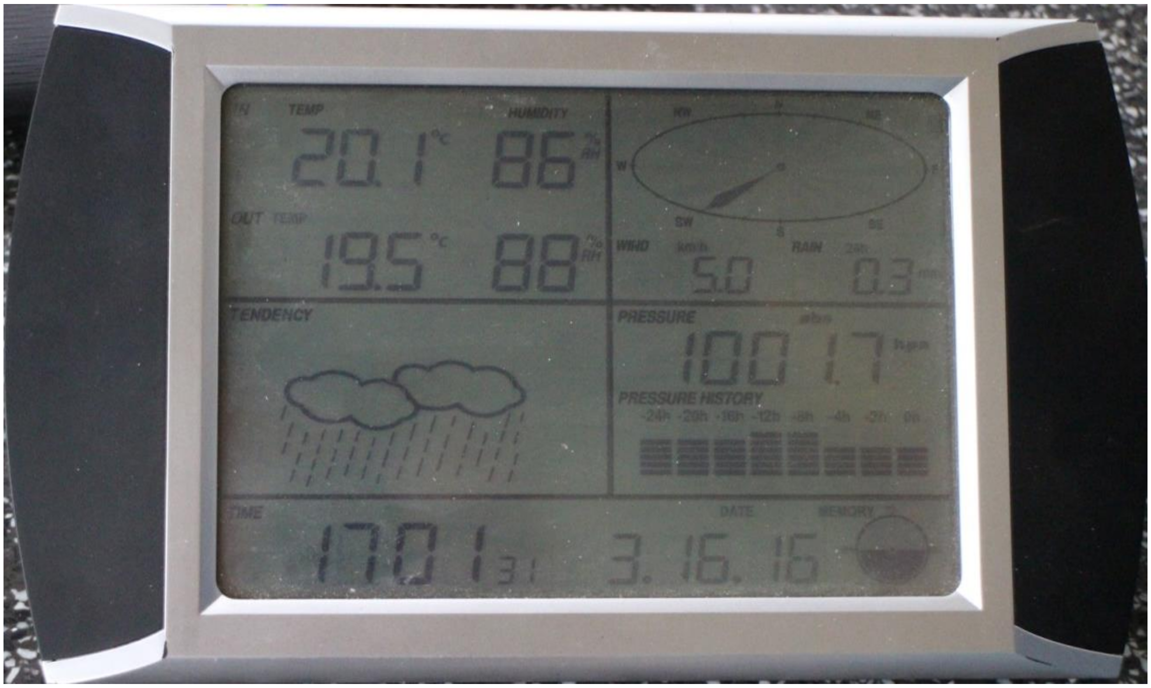

Figure 17. Recording equipment of meteorological station in My Loi village

The project has also gathered localized meteorological information and provided to local people, especially the poor farmers. The project also compared the localized meteorological information of the village with similar information at district level of Ky Anh meteorological station. Ky Anh meteorological station has gathered climatological information since 1961. The comparison of information between the two stations is a basis for making seasonal forecast bulletin. If the meteorological information is not much different between the two stations, meteorological information of station at district level will be used as input for seasonal forecast bulletin.

At present, the project has made pilot seasonal forecast bulletin by using meteorological information at district level of Ky Anh Meteorological Station. Some specialists of different hydrometeorology offices (Institute of Meteorology, Hydrology and Environment; Ha Tinh Provincial Centre of Hydrometeorology) were mainly responsible for making this bulletin. Member staffs of Sub-Department of Agriculture and Rural Development at district level and local people also contributed to publication of the seasonal forecast bulletin.

The project has made seasonal forecast bulletin every three months. The content of the seasonal forecast bulletin includes different parts (Figure 18). The first part is forecasting information including the trends of temperature, rainy, hot or cold spells within three months. Hydrometeorology specialists are responsible for providing forecasting information of the bulletin. The second part of the bulletin contains weather forecast information based on experiences of local people. The third part encompasses agro-advisory information including adaptive solutions to extreme weather events according to different scenarios of rainfall and temperature trend of the region. The Sub-Department of Agriculture and Rural Development at district level provided agro-advisory information for the bulletin. Initially, each agroforestry household in My village (project site) has one bulletin every three months. Other households can refer to the seasonal forecast bulletin on the information board of the village (Figure 19). The project has delivered the seasonal forecast bulletin to farmers before planting and harvesting dates. It hopes that farmers can use information from the bulletin to adjust their production activities to cope with extreme weather events.

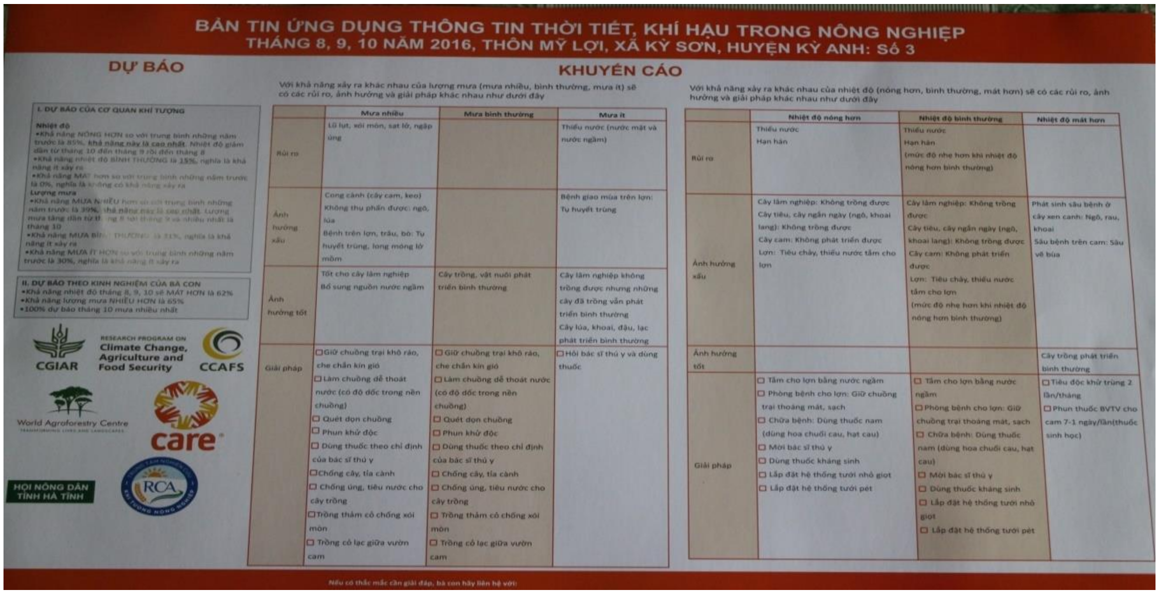

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Figure 18. Seasonal forecast bulletin in the study area

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Figure 19. Seasonal forecast bulletin on information board of My Loi village

In short, farmers in the study area could easily access meteorological information through the national weather forecast news in the public media. The available meteorological information for the farmers includes data on temperature, rainfall, humidity, and the trend of extreme weather events. However, the meteorological information is too broad, not comprehensive enough and not always accurate. Thus, most farmers (96%) in the area have appreciated the necessity and importance of the seasonal forecast bulletin and agrometeorological information that have been provided by ICRAF's project.

Farmers' Willingness to Pay for Seasonal Forecast and Agrometeorological Information

After recognizing the necessity of seasonal forecast bulletin, a quite large number of the respondents (64% in the My Loi village, 56% in the other villages, and 58% in the whole commune) were willing to pay for seasonal forecast bulletin and localized meteorological information (Table 23 in page 120). This implies that farmers in the study area have increasingly recognized the importance of seasonal forecast bulletin and meteorological information in coping with climate change.

There were five different bid levels ranging from VND 20,000 (US$0.9) to VND 60,000 (US$2.6) per month (Figure 20). About 30 % of the respondents reported that they would pay VND 20,000 (US$0.9) per month for seasonal forecast bulletin. While, only 11 % of the farmers was willing to pay VND 60,000 (US$2.6) per month for this bulletin. Generally, there was downward trend of the percentage of the farmers who were willing to pay for different bid levels. It implies that the paying trend of people for seasonal forecast bulletin fits the law of demand in economic theory. The higher price level leads to the lower demand level for goods and services.

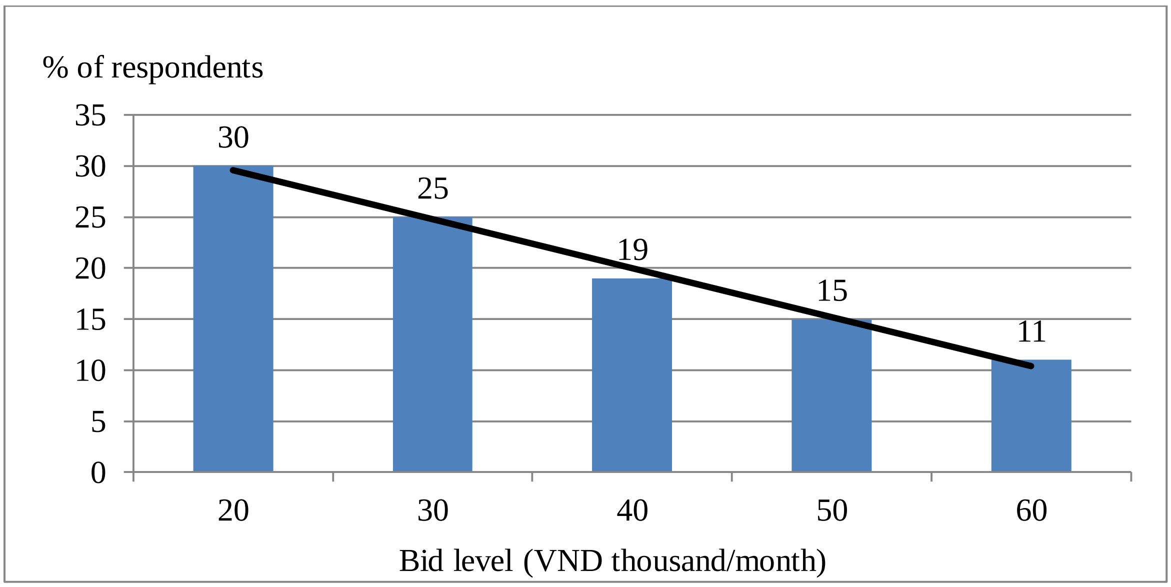

Figure 20. Farmers' willingness to pay for seasonal forecast bulletin and meteorological information in Ky Son commune, Ky Anh district, Ha Tinh, Vietnam, 2016

There were five separate reasons that explain why people are willing to pay for seasonal forecast bulletin (Table 23). Among these reasons, reducing damage level of agricultural production is the most important reason for farmers. Approximately 83% of the respondents in the whole commune claimed that through paying for seasonal forecast bulletin they expect to have low damage level in agricultural production. The second reason for willingness to pay given by respondents for seasonal forecast bulletin is to have suitable adaptive activities to extreme weather events in agricultural production.

Table 23. Farmers' reasons of paying and not paying for seasonal forecast bulletin and agrometeorological information in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (% of respondent)

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n = 296)	DIFF*	WHOLE SAMPLE (n = 400)
Saying "yes" for one bid level	***64***	***56***	***12^{ns}***	***58***
Reasons for willingness to pay (M)				
Reduce damage for agri. production	94	78	26***	83
To have suitable adaptive activities	73	54	19***	59
Save adaptation cost to extreme events	25	25	0^{ns}	25
Contribute to community development	13	18	-5^{ns}	17
Fit family's income	12	15	-3^{ns}	14
Saying "no" to any bid levels	***36***	***44***	***-8^{ns}***	***42***
Reasons for not willingness to pay (M)				
Low income	68	70	-2^{ns}	70
Cannot recognize benefits of forecasting	32	17	15**	20
It is government responsibility	14	17	-3^{ns}	16
Do not believe in quality of forecasting	16	13	3^{ns}	14

* DIFF is different value between two samples; ns is non-significant based on Z-test for the difference between proportions. (M) is multiple choices

A quite large number of farmers reported that they were willing to pay for seasonal forecast bulletin in order to get plausible adaptive strategy in coping with extreme events. Farmers also mentioned three other reasons to explain why they paid for the seasonal forecast bulletin. Several people (25%) thought they could reduce adaptation cost to extreme weather events in agricultural production. Some other farmers (17%) would like to contribute to development of community. While, 14% of the farmer respondents revealed that the bid levels fit their income.

Although many farmers have perceived the necessity of the seasonal forecast bulletin, there were still a number of farmers were not willing to pay for this bulletin.

These farmers indicated four different reasons why they did not want to pay for seasonal forecast bulletin, foremost of which is low income as reported by 70% of the respondents. Several farmers (20% in the whole commune) were not willing to pay for the bulletin since they were not aware of the benefits of the forecasting. Some other farmers (16%) thought government has to pay for seasonal forecast bulletin. In addition, about 14% of respondents did not believe in the quality of the seasonal forecast bulletin. These reasons explained why they were not willing to pay for the seasonal forecast bulletin and meteorological information. Thus, improving quality of seasonal forecast bulletin and making it becomes understandable are very crucial to encourage more people to pay for the bulletin. In addition, public recognition of economic value of meteorological information is also imperative to convince local people to pay for the seasonal forecast bulletin. If people do not see or recognize the value of climatological information, they will not pay or use this information (GFDRR, undated).

This study compared general characteristics of the farmers who were willing to pay and those who were not willing to pay for seasonal forecast bulletin and meteorological information. This aims to recognize the basic difference in the characteristics of these two groups of farmers. Farmers who were willing to pay for seasonal forecast bulletin have three indicators that are significantly higher than the parameters of the farmers who were unwilling to pay (Table 24). These parameters include training attendance, farm income, and farm size. It means that farmers who were willing to pay for seasonal forecast bulletin and agrometeorological information are the farmers who attended the training courses, and had higher farm income and larger farmland areas. This again explains the importance of increasing the training courses and supporting mechanisms for land consolidation for local people in the study area.

Table 24. General characteristics of farmers who were and were not willing to pay for seasonal forecast bulletin and meteorological information in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

ITEM	PAYING GROUP (n = 233)	NOT PAYING GROUP (n = 167)	DIFF*
Age	43	44	-1^{ns}
Education level (schooling year)	8	8	0^{ns}
Farming experience (year)	23	24	-1^{ns}
Farm size (sao/500m^2)	7	6	1**
Farm income (VND million/USD)	16 (US$702)	13 (US$579)	3***
Training attendance (% of respondent)	66	58	8**
Institutional member (% of respondent)	94	98	-4**

* DIFF is different value between two groups; ***, **, are significant at 1% and 5%, respectively; ns is non-significant based on T-test for mean, and Z-test for the difference between proportions.

By contrast, the percentage of farmers who were involved in the local organizations of the paying group was significantly lower as compared with the not-paying group. This implies that even if farmers participated in local organizations they are still not willing to pay for seasonal forecast bulletin and meteorological information. It seems that the local organizations have ineffectively worked in improving farmers' knowledge on the importance and necessity of seasonal forecast bulletin in adaptation to climate change. Hence, increasing working efficiency of the local organizations should be considered to improve farmers' adaptive capacity to extreme weather events in agricultural production.

In brief, many people (96%) in the study site have been aware of the necessity and importance of seasonal forecast bulletin and localized agrometeorological information in coping with extreme weather events. Thus, a quite large number of the farmers (58%) were willing to pay for this bulletin. The payment levels of the farmers range from VND 20,000 (US$0.9) to VND 60,000 (US$2.6) per month. The major reason that farmers were willing to pay for seasonal forecast bulletin and localized meteorological information is reducing damage level of agricultural production. By contrast, low income is major cause that farmers in the study area did not pay for the bulletin and localized meteorological information. In addition, farmers who were willing to pay for seasonal forecast bulletin and agrometeorological information are mainly the people who attended the training courses, and had higher farm income and larger cultivated land areas.

Economic Value of Seasonal Forecast and Localized Meteorological Information in the Study Area

To have a basis for estimating economic value of agrometeorological information through seasonal forecast bulletin, this study estimated binary logit model for willingness to pay (WTP) of farmers for seasonal bulletin. This also aimed to analyze the factors influencing the probability of WTP for seasonal forecast bulletin of farmers. The dependent variable of the model is discrete choice (0, 1). One (1) denoted for people who say “yes” to one specific bid level while zero (0) signified for farmers who say “no”. The empirical model includes 11 explanatory variables that were checked the issue of multicollinearity (Appendix C). This study also addressed the issue of the heteroskedasticity of the model by using robust standard error procedure.

Table 25. Estimated result of binary logit model on farmers' willingness to pay for seasonal forecast bulletin and localized agrometeorological information in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016

VARIABLES	COEFFICIENTS	P-VALUE	MARGINAL EFFECTS	P-VALUE
Bid	-0.067***	0.000	-0.016***	0.000
Age	-0.025**	0.031	-0.006**	0.030
Gender	0.641**	0.029	0.145**	0.020
Annual crop income	0.038**	0.014	0.009**	0.014
Membership in organizations	-1.413**	0.028	-0.263***	0.001
Educational level	-0.022ns	0.383	-0.005ns	0.382
Damage level	0.008ns	0.888	0.002ns	0.888
Availability of agricultural labor	0.165ns	0.361	0.039ns	0.361
Plot number of land	-0.043ns	0.168	-0.010ns	0.168
Access to credit	-0.333ns	0.183	-0.078ns	0.176
Training attendance	0.208ns	0.473	0.049ns	0.466
Constant	5.084***	0.000	-	-
Log pseudolikelihood	-227.33	-	-	-
Wald $\chi^2(11)$	76.65	-	-	-
Prob > χ^2	0.000	-	-	-
Pseudo R^2	0.1636	-	-	-
Observation (n)	400	-	-	-

***, **, * are significant at 1%, 5%, and 10%, respectively; ns is non-significant

Table 25 shows that the values of Wald $\chi^2(11)$ is significant at 1% significant level (Prob > χ^2 = 0.000), meaning that there is an overall significant relationship between the probability that farmers are willing to pay for seasonal forecast bulletin and 11 explanatory variable. Pseudo R^2 (0.1636) is also highly significant (Prob > χ^2 =

0.000), showing that 11 explanatory variables explained 16.36% of changing of the probability of paying for seasonal forecast bulletin of farmers.

Among these explanatory variables, there were five factors, which have significant effects on the probability of willingness to pay for the seasonal forecast bulletin of farmers (Table 25). These include bid level, age, gender, annual crop income, and membership in the local organizations. Specifically, gender and annual crop income have significant and positive effects on the probability of WTP for seasonal forecast of farmers. However, bid level, age and membership in the local organizations affected significantly and negatively the probability that farmers were willing to pay for seasonal forecast bulletin.

The higher bid level causes the lower probability of paying for seasonal forecast bulletin of farmers. It matches the normal demand law of classical economic theory. The old farmers have less chance to earn extra income compared to the young farmers. Therefore, the old farmers are less likely to pay for the seasonal forecast bulletin compared with the young farmers. Inefficiency in operating of local organizations could explain the negative sign of this variable in the model. It means that the local organizations have not improved yet knowledge and awareness on the concepts as well as the importance of adaptation to climate chance for their members. Thus, even if the farmers were members of these organizations, they have been still not willing to pay for seasonal forecast bulletin.

The annual crop income significantly and positively influenced the probability of WTP for seasonal forecast of farmers. It means that households with higher annual crop income were more likely to be willing to pay for seasonal forecast bulletin, ceteris paribus. This is consistent with the classical economic theory that people who have higher income tend to have higher demand for goods and services. In addition, households with high level of annual crop income may highly depend on crop production. Therefore, they are more likely to be willing to pay the seasonal forecast bulletin to adjust cultural activities to hope this may reduce loss of extreme events in crop production. Estimated result also indicated that men farmers tend were more likely to have higher payment level for the probability of WTP for seasonal forecast bulletin compared with the women farmers, ceteris paribus. In fact, men in the study area often earn considerably more income through off-farm works compared to women (Coulier, 2016). Thus, they might have more authority in buying goods and services compared with women. This explained why men were more likely to be willing to pay for seasonal forecast bulletin.

Six insignificant variables of the model include education level, damage level, availability of household's agricultural labor, number of cultivated plot, access to credit, and training attendance. It means these factors have no any significant effects on the probability farmers that farmers were willing to pay for the seasonal forecast bulletin. The indistinctness in number of cultivated plot and availability of agricultural labor among households could specify ambiguous effects of these two variables on the farmers' probability of WTP for the seasonal forecast bulletin. Finally, most farmer respondents (96%) have recognized the importance and necessity of seasonal forecast bulletin in confronting extreme weather events (Table 22 in page 113). This is possible reason to explain why the probability of WTP for the seasonal forecast bulletin was not substantially different between trained farmers and non-trained farmers.

This study calculated the mean WTP of farmers for seasonal bulletin in the study area based on the estimated coefficients of the empirical binary logit model. By using the following formula and applying STATA software, the study estimated the mean WTP of people in the study site (Table 28).

$$\overline{WTP} = -\frac{\beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \alpha_i D_i}{\beta_{bid}}$$

Table 26. Farmers' estimated WTP level for seasonal forecast bulletin in Ky Son commune, Ky Anh district, Ha Tinh province, Vietnam, 2016 (VND thousand/month)

ITEM	MY LOI VILLAGE (n = 104)	OTHER VILLAGES (n =296)	DIFF*	WHOLE SAMPLE (n =400)
Mean	50.4	45.4	6.0***	46.7
Max	80.0	104.4	-	104.4
Min	32.2	26.3	-	26.3
Std. Deviation	9.25	9.15	-	9.42

*DIFF is different value between two samples; *** is significant at 1%

In the whole commune, the mean WTP level of farmers for seasonal forecast bulletin was around VND 47,000 (US$2.1) per month. People could pay the highest value of VND 104,400 (US$4.6)/month and the lowest value of VND 26,300 (US$1.2)/month for the seasonal forecast bulletin, respectively. The WTP of farmers in the My Loi village

(VND 50,400 or US$2.2) was significantly higher than that of farmers in the other villages (VND 45,400 or US$2.0). This may be because farmers in the My Loi village have received pilot seasonal forecast bulletin while farmers in the other village have not. Thus, farmers in My Loi village have realized the initial benefit of this bulletin hence they were willing to pay higher payment level for the bulletin.

By using mean estimated WTP levels, the study estimated economic value of the seasonal forecast bulletin in Ky Son commune (Table 27). The annual total estimated economic values of seasonal forecast bulletin of the My Loi village, the other villages, and the whole commune were around VND 58 million (US$2,522); VND 377 million (US$16,535); and VND 450 million (US$19,737), respectively. This may be the basis for authorities to decide whether they should make seasonal forecast bulletin to help farmers cope effectively with extreme weather events. If the annual economic value of seasonal forecast bulletin is higher than its making cost it will be strong evidence for making this bulletin.

Table 27. Estimated economic value (EV) of seasonal forecast bulletin in Ky Son, Ky Anh, Ha Tinh, Vietnam, 2016 (VND million)

PLACE	MEAN WTP	NUMBER OF BENEFICIARIES (n^b)	ECONOMIC VALUE (VND million)	
			Monthly	Yearly
My Loi village	50.4	95	4.8	57.5
Other villages	45.4	692	31.4	377.0
Whole commune	46.7	803	37.5	450.0

Economic value (EV) = Mean WTP * number of beneficiary
n^b = the total of agroforestry households * % of farmers who say “yes” to the bulletin

In summary, there was significant relationship between the probability that farmers were willing to pay the seasonal forecast bulletin and 11 explanatory factors. Among these factors, bid level, age, gender, annual crop income, and membership of local organizations have significant effects on the probability of paying the seasonal forecast bulletin of farmers. While, educational level, damage level, availability of household's agricultural labor, access to credit, and training attendance did not affect significantly this probability of farmers.

The mean WTP level for seasonal forecast bulletin of farmers in the project site (VND 50,400 or US$2.2/month) was significantly higher than that of farmers in the non-project site (VND 45,400 or US$2.0/month). On the average, each farmer in the Ky Son commune was willing to pay VND 46,700 (US$2.1) per month for seasonal forecast bulletin. The annual estimated economic value of the seasonal forecast bulletin in the whole commune is VND 450 million (around US$20,000 in 2016).

CHAPTER VI

CONCLUSIONS AND POLICY RECOMMENDATIONS

Conclusions

Climate change has caused the increase in the frequency and the intensity of the extreme weather events such as typhoon, flood, drought and cold spells in Ha Tinh province. It has affected strongly and directly agricultural production of the province. Climate change has also occurred in Ky Anh district through increasing average monthly temperature and decreasing rainfall level. These phenomena reduced yields of major crops of the district such as rice, corn, and peanut.

Many farmers are very much aware of climate change due to the frequent occurrence of extreme weather events, especially drought and floods. They also recognized the adverse effects of these extreme events on their agricultural production as well as their livelihood. Most of the farmers (78%) in the region reported that extreme weather events damaged their agricultural production. The farmers' estimated loss due to extreme events was around 20% of total their income from annual crops.

Generally, farmers in the study area have increasingly considered adaption to climate change in agricultural production. Most of the farmers in the region have used at least one adaptive strategy to extreme weather events in agricultural production. There were five major adaptive practices to extreme weather occurrences in the study site, including changing crop varieties, switching to new cultivar types, adjusting farming calendar, following up weather forecasts, and intercropping. Among these adaptive strategies, monitoring weather forecasts and changing crop varieties were the most popular adaptive tactics.

There were also five different sources of information that farmers referred the adaptive strategies to extreme weather events. Of these options, getting consultancy of local officer was the most predominant for farmers in both the project and the non-project sites. Applying knowledge of training course on climate change was the second popular way of farmers in the project site, while the second prevalent tactic for farmers in the non-project sites was learning from neighbors.

There was a significant relationship between the probability that farmers applied adaptive practices to confront with extreme weather events and influential factors. The factors affecting the probability of applying these adaptive strategies include gender, educational level, farm size, availability of agricultural labor, damage level, farming experience, training attendance, access to credit, and membership in local organizations. Among these factors, six factors have significant effects on the probability that farmers apply adaptive strategies to extreme events. These six variables include gender, education level, training attendance, farm size, farming experience, and damage level. Of these, farm size and training attendance affected significantly most of the probabilities of choosing adaptive practices of farmers. Educational level, farming experience, and access to credit had significant impacts on the two of five adaptive responses of farmers. Meanwhile, gender influenced significantly only the probability that farmers change crop varieties to cope with extreme weather events in their agricultural production.

Farmers in the study area have recognized four different explicit values of following weather forecast news in coping with extreme events. Thus, many farmers in the region used meteorological information given by the weather forecast news to adjust their cultural activities. There were there major adjustments mentioned by farmers such as changing planting date, adjusting the application of farm inputs, and shifting harvesting calendar.

There was also a significant relationship between the probabilities that farmers use meteorological information to adjust their cultural activities and different factors. These factors related to all household's livelihood capital assets. Among them, educational level and training attendance are the two factors that had significant and positive effects on all the probabilities that farmers adjusted their cultural practices based on meteorological information. Farm size affected significantly the probability that farmers changed the application of farm inputs. Farming experience has significant effects on the farmers' probabilities of changing planting dates and adjusting the application of farm inputs. While, gender, availability of household's agricultural labor and damage level seem to have no significant effects on the farmers' probabilities of adjusting their cultural activities based on meteorological information.

The meteorological information, which farmers in the study area have had, is too broad, not comprehensive enough and is not always accurate. Thus, most farmers have recognized the necessity and importance of seasonal forecast bulletin that was made by using meteorological information at local level in coping with extreme weather events. In addition, many farmers in the study area were willing to pay for seasonal forecast bulletin and agrometeorological information. Bid level, age, gender, annual crop income, and membership in the local organizations had significant effects on the probability that farmer were willing to pay for seasonal forecast bulletin and meteorological information. While, educational level, damaged level, availability of household's agricultural labor, access to credit and training attendance did not significantly influence this probability of farmers.

A quite large number of the farmers in the study area were willing to pay for the seasonal forecast bulletin and localized meteorological information. The payment levels of farmer ranged from VND 20,000 (US$0.9) to VND 60,000 (US$2.6) per month. The most popular reason that explained why many farmers were willing to pay for seasonal forecast bulletin and localized meteorological information was reducing damaged level of agricultural production. In addition, farmers who were willing to pay for seasonal forecast bulletin and agrometeorological information are mainly the farmers who attended the training courses on climate change, and had higher farmer income and larger farmland areas. However, there has been still several farmer in the study area did not want to pay for seasonal forecast bulletin and localized meteorological information. Low income was the most popular reason that explained why they were not willing to pay for the bulletin and localized meteorological information.

The mean WTP level for seasonal forecast bulletin of farmers in the project site (VND 50,400 or US$2.2/month) was significantly higher than that of farmers in the non-project site (VND 45,400 or US$2.0/month). On the average, each farmer in Ky Son commune was willing to pay VND 46,700 (US$2.1) per month for seasonal forecast bulletin and localized meteorological information. The annual estimated economic value of the seasonal forecast bulletin in the whole commune is VND 450 million (approximately US$20,000 in 2016).

Policy Recommendations

At present, there have been several adaptive policies/programs to climate change in Ha Tinh province (Appendix D). However, the implementation of these policies has been still ineffective in the province, especially at the local levels. The reasons include limited awareness on climate change of farmers and overlapping adaptive policies/programs in the province (Ha Tinh People's Committee, 2014). Thus, there is a need of suitable solutions to improve adaptive capacity of farmers to climate change and extreme weather events in agricultural production. Based on empirical results, this study proposed several solutions to improve adaptive capacity of farmers to extreme weather events and increase economic value of localized meteorological information as follows:

Broaden Training Courses Offering on Climate Change

Empirical results of this study showed that training courses on climate change has greatly improved awareness and adaptive behavior of people to this event. Specifically, people who attended the training courses on climate change have increasingly perceived the adverse impacts of this phenomenon. Thus, they are more likely to apply adaptive strategies to climate change in agricultural production.

In addition, training attendance affected significantly the probability that farmers applied adaptive strategies to extreme weather events in agricultural production. It also had significant effect on the probability that farmers used meteorological information to adjust their cultural activities to cope with extreme occurrences. It implies that farmers who attended in training course on climate change were more likely to adapt to extreme weather events compared with other those who did not attend.

It is apparent that training courses on climate change played an important role in coping with extreme weather events in the study area. However, there have been still few these training courses in the region. Many people (62%) in the area reported that they attended at least one training course (Table 4 in page 59). However, based on survey data, only 21% of the farmers participated in the training courses on climate change. In addition, most of the farmers who attended in the training courses on climate change live in My Loi village (the project site). Meanwhile, very few people (around 4%) in the non-project sites had a chance to participate in these training courses. Thus, increasing the frequency of the training courses on climate change could be very helpful for the region, especially in the non-project site. It may help people in the area adapt more effectively and efficiently to climate change, specifically to extreme weather events in agricultural production.

The authorities could broaden the training courses on climate through various ways. First is increasing number of training courses on climate change for the farmers in the non-project areas. Secondly, climate change concepts and adaptive strategies should be integrated into other training courses in the region. Lastly, simple and understandable bulletins or information materials on climate change should be provided to the farmers, especially farmers who have less farming experience and low educational level, and stay in the non-project sites.

Institute Policies that Would Promote Consolidation of Farmland

Results of this study revealed that farm size had a significant and positive effect on farmers' decision in applying adaptive practices to extreme weather events in their agricultural production. People who have large farmland area were more likely to apply adaptive strategies to cope with extreme weather occurrences in agricultural production and were more likely to be willing to pay for seasonal forecast bulletin. Thus, policies that would provide incentives to consolidate the small land areas should be instituted.

At the central level, the Vietnamese Government has instituted the policy that encourages cooperation, association, and land agglomeration in agricultural production since 2013. This policy defined that land consolidation is the combination of agricultural lands among individuals, enterprises, and farmers' representatives. Government issued this policy through Decision No.62/QĐ-Ttg of Prime Minister on October 25 2013. This program provided supports on administrative and financial mechanisms to encourage the cooperation and association between enterprises, farmers' representatives, and individuals in agricultural production. It also encourages the farmers to contribute individual's land for enterprises to develop larger area of land, thus have higher production efficiency. The support of the government for members of the cooperation or association include a subsidy on production cost (seeding, pesticides, fertilizer, etc.), and training cost.

Based on the orientation of central government about land consolidation, authorities at local government might implement or formulate this policy through several options. Firstly, local authorities should simplify administrative procedures to encourage enterprises to join this program. Secondly, local authorities ought to integrate the guidelines of land consolidation into other development projects of the region. This could utilize the financial support of these projects in order to make available the mechanism for enterprises, farmers and other organization in this program. Thirdly, there is a need to demonstrate the practical results of land consolidation of other regions to encourage farmers in the area to participate in the program. Lastly, local authorities should also carry out the propagandized campaign about benefits of land consolidation in coping with extreme weather events. This campaign could convince more farmers to participate in the efforts to consolidate land areas to enhance the productivity of the farms and be more effective in adapting to climate change.

Integrate Concepts of Climate Change Adaptation into the Operation of the Local Organizations

Results of this study indicated that there were no evidences to show that membership in the local organizations have significant effects on farmers' decision in adaptation to extreme weather events. This means that these organizations have been not promoting adaptive practices for climate change among their members. In addition, results of the study also revealed that institutional participation had negative effect on the probability that farmers would be willing to pay for seasonal forecast bulletin. It means farmers who are involved in the local organizations were less likely to be willing to pay for the seasonal forecast bulletin. The reason could be that the payment for the seasonal forecast bulletin would be an additional cost to them.

The observed results of this study show that most of the farmers (96%) in the study area are member of at least one local institution or organization (Table 4 in page 59). These institutions include Farmer's Union, Women's Union, Interested Group, Cooperative, and others. Most of these organizations have focused on general and social issues such as low interest loans; campaign on family planning; and social support. Meanwhile, there is only Farmer's Union discuss about farming techniques and seasonal crop calendar (Coulier, 2016). It seems that these organization have not considered climate change concepts and related issued yet. Hence, improving operational efficiency of local organizations toward integrating the concepts of climate change adaptation in the action plans of these organizations would be a momentous strategy for the study area.

The authorities could involve leaders of these institutions in the training courses on climate change to improve their awareness about the issue. Through these training courses, the leaders could also disseminate knowledge on climate change to other members in the institutions. In addition, there is a need to integration of climate change concepts into the operation of local organizations. This integration may initially help members of the institutions comprehend better climate change concepts hence, they could adapt effectively to extreme weather events.

Continue Downscaling Weather Forecast and Localizing Agrometeorological Information

According to Selvaraju (2013), farmers could use localized weather information in making management decision to reduce the risks of climate change. Thus, to help farmers effectively confront climate change, authorities should consider downscaling weather forecast to local level and localizing agrometeorological information. Localizing meteorological information in agriculture provides a full range of climatic advices, its impacts on agricultural production and management practices (Selvaraju, 2013).

The results of this study showed that most farmers in the study area were aware of the importance and necessity of seasonal forecast bulletin and localized meteorological information in. In addition, many farmers were willing to pay for this bulletin with bid levels ranging from VND 20,000 (US$0.9) to VND 60,000 (US$2.6) per month. The total annual estimated economic value of seasonal forecast bulletin of Ky Son commune is VND 450 million (approximately US$20,000 in 2016). This could be useful for authorities to decide on whether or not it would be financially viable to downscale weather forecast and localize meteorological information in the area.

In localizing climate information process, policy makers should consider local characteristics or aspects such as community perception, local knowledge, livelihood pattern, gender, and other related issues (Selvaraju, 2013). Moreover, authorities should also consider public recognition of economic value of meteorological information. Local people will not pay or use climatological information if they do not see or recognize the value of this information (GFDRR, undated). Thus, there is a need for more economic evaluation of the viability of downscaling weather forecast and localizing meteorological information activities in other areas (commune, district). Economic evaluation could provide the economic justification for downscaling weather forecast and localizing meteorological information. This would be useful in making decisions in the choice of the most effective adaptive options for addressing extreme weather events. This serves as valuable basis to convince the government to invest on downscaling weather forecast and localizing meteorological information in the context of climate change adaptation.

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APPENDICES

Appendix A. Correlation matrix between meteorological indicators and crop yields in Ky Anh district

	Rainfall	Rice yield	Peanut yield	Cassava yield	Corn Yield
Rainfall	1				
Rice yield	-0.50004	1			
Peanut yield	-0.28629	0.247563	1		
Cassava yield	-0.03466	0.188302	0.841997	1	
Maize yield	-0.49972	0.621994	0.158771	-0.02923	1

	Total rainfall	Rice yield	Peanut yield	Cassava yield	Corn Yield
Total rainfall	1				
Rice yield	-0.50001	1			
Peanut yield	-0.28627	0.247563	1		
Cassava yield	-0.03463	0.188302	0.841997	1	
Maize yield	-0.49972	0.621994	0.158771	-0.02923	1

	Temperature	Rice yield	Peanut yield	Cassava yield	Corn Yield
Temperature	1				
Rice yield	-0.17098	1			
Peanut yield	-0.04181	0.660619	1		
Cassava yield	-0.22563	0.771989	0.907797	1	
Maize yield	0.019695	0.310653	0.474177	0.404424	1

Appendix B. Correlation coefficients among independent variables of the empirical binary logit and multivariate probit models in the study

```
. corr  Age Gender Edu Fzise Damage Aglabor Plot Exper AcropInc Credit Training Member Location
(obs=400)
```

	Age	Gender	Edu	Fzise	Damage	Aglabor	Plot	Exper	AcropInc	Credit	Training	Member	Location
Age	1.0000												
Gender	0.1591	1.0000											
Edu	-0.1419	0.0866	1.0000										
Fzise	0.1527	-0.0294	-0.0740	1.0000									
Damage	0.0833	0.0688	0.2196	0.2508	1.0000								
Aglabor	0.2014	-0.0039	-0.0736	0.1904	0.0375	1.0000							
Plot	0.1630	-0.0274	-0.1211	0.6345	0.1411	0.1323	1.0000						
Exper	0.9318	0.0732	-0.1498	0.1751	0.0900	0.2184	0.1885	1.0000					
AcropInc	0.1681	0.0871	-0.0263	0.6437	0.3355	0.1702	0.4698	0.1887	1.0000				
Credit	-0.1198	-0.0058	0.0280	-0.0719	-0.0190	0.0195	-0.0662	-0.1182	-0.1503	1.0000			
Training	0.1763	0.1127	-0.0063	-0.0851	0.0209	0.0887	-0.0774	0.1713	0.0374	-0.1134	1.0000		
Member	0.1669	-0.0347	-0.0952	0.1557	0.1087	0.0629	0.1400	0.1894	0.1084	-0.0243	0.0739	1.0000	
Location	0.0244	0.0940	0.0193	-0.2119	-0.0017	-0.0266	-0.1986	0.0191	-0.0285	-0.1478	0.7019	-0.0826	1.0000

```
. corr  Gender Edu Fzise Damage Aglabor Exper Credit Training Member
(obs=400)
```

	Gender	Edu	Fzise	Damage	Aglabor	Exper	Credit	Training	Member
Gender	1.0000								
Edu	0.0866	1.0000							
Fzise	-0.0294	-0.0740	1.0000						
Damage	0.0688	0.2196	0.2508	1.0000					
Aglabor	-0.0039	-0.0736	0.1904	0.0375	1.0000				
Exper	0.0732	-0.1498	0.1751	0.0900	0.2184	1.0000			
Credit	-0.0058	0.0280	-0.0719	-0.0190	0.0195	-0.1182	1.0000		
Training	0.1127	-0.0063	-0.0851	0.0209	0.0887	0.1713	-0.1134	1.0000	
Member	-0.0347	-0.0952	0.1557	0.1087	0.0629	0.1894	-0.0243	0.0739	1.0000

Appendix C. Correlation coefficient matrix of independent variables of binary logit model for farmers' WTP for seasonal forecast bulletin

```
. corr  Bid Age Gender Edu Damage Aglabor Plot AcropInc Credit Training Member
(obs=400)
```

	Bid	Age	Gender	Edu	Damage	Aglabor	Plot	AcropInc	Credit	Training	Member
Bid	1.0000										
Age	-0.0559	1.0000									
Gender	0.0166	0.1591	1.0000								
Edu	0.0047	-0.1419	0.0866	1.0000							
Damage	-0.0694	0.0833	0.0688	0.2196	1.0000						
Aglabor	0.0027	0.2014	-0.0039	-0.0736	0.0375	1.0000					
Plot	-0.0688	0.1630	-0.0274	-0.1211	0.1411	0.1323	1.0000				
AcropInc	-0.1050	0.1681	0.0871	-0.0263	0.3355	0.1702	0.4698	1.0000			
Credit	-0.0110	-0.1198	-0.0058	0.0280	-0.0190	0.0195	-0.0662	-0.1503	1.0000		
Training	0.0130	0.1763	0.1127	-0.0063	0.0209	0.0887	-0.0774	0.0374	-0.1134	1.0000	
Member	0.0090	0.1669	-0.0347	-0.0952	0.1087	0.0629	0.1400	0.1084	-0.0243	0.0739	1.0000

Appendix D. Empirical result of binary logit model for farmers' WTP for seasonal forecast bulletin and value of mean WTP

```
Logistic regression                               Number of obs   =        400
                                                  Wald chi2(11)   =      76.65
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -227.32701                 Pseudo R2       =     0.1636
```

Y	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Bid	-.0666405	.0087709	-7.60	0.000	-.0838311	-.04945
Age	-.0245939	.0114072	-2.16	0.031	-.0469515	-.0022363
Gender	.6411166	.2941208	2.18	0.029	.0646504	1.217583
Edu	-.0221206	.0253361	-0.87	0.383	-.0717786	.0275373
Damage	.0079285	.0563107	0.14	0.888	-.1024385	.1182955
Aglabor	.1652161	.1807919	0.91	0.361	-.1891295	.5195618
Plot	-.0429289	.0311572	-1.38	0.168	-.103996	.0181382
AcropInc	.0379605	.0154928	2.45	0.014	.0075951	.068326
Credit	-.3332495	.2504709	-1.33	0.183	-.8241634	.1576643
Training	.208478	.2907031	0.72	0.473	-.3612897	.7782457
Member	-1.413083	.6428039	-2.20	0.028	-2.672956	-.1532106
_cons	5.084356	.939247	5.41	0.000	3.243466	6.925247

```
. mfx compute

Marginal effects after logit
      y  = Pr(Y) (predict)
         =  .60912238
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
Bid	-.0158666	.00208	-7.64	0.000	-.019936	-.011797	40
Age	-.0058556	.00271	-2.16	0.030	-.011158	-.000553	43.7975
Gender*	.1453159	.06238	2.33	0.020	.023047	.267584	.24
Edu	-.0052668	.00603	-0.87	0.382	-.017083	.00655	7.8675
Damage	.0018877	.01341	0.14	0.888	-.024394	.028169	1.892
Aglabor	.0393367	.04304	0.91	0.361	-.045025	.123699	2.0775
Plot	-.010221	.00741	-1.38	0.168	-.024749	.004306	6.6475
AcropInc	.0090381	.00366	2.47	0.014	.001862	.016214	15.07
Credit*	-.0784121	.05794	-1.35	0.176	-.191969	.035145	.63
Training*	.0489078	.06711	0.73	0.466	-.082624	.180439	.21
Member*	-.2625867	.08203	-3.20	0.001	-.42336	-.101813	.96

```
(*) dy/dx is for discrete change of dummy variable from 0 to 1

. gen bidcoeff = (_b[Bid])*(-1)

. predict yhat, xb

. gen numerator = yhat + (bidcoeff*Bid)

. gen hhWTP = numerator/bidcoeff

. sum  hhWTP
```

Variable	Obs	Mean	Std. Dev.	Min	Max
hhWTP	400	46.65698	9.424391	26.2601	104.3599

```
. sum  hhWTP if  Location==1
```

Variable	Obs	Mean	Std. Dev.	Min	Max
hhWTP	104	50.35409	9.246225	32.21674	80.00076

```
. sum  hhWTP if  Location==0
```

Variable	Obs	Mean	Std. Dev.	Min	Max
hhWTP	296	45.358	9.152587	26.2601	104.3599

Appendix E. Adaptive policies/programs to address climate change and extreme weather events in Ha Tinh province

Policies	Type of documents/ Issued office	Issued time	Key points relate to adaptation to climate change and extreme weather events
275/QĐ-UBND	Decision/Ha Tinh Provincial People's Committee	2011	- Established Provincial Steering Committee on Climate Change
2313/QĐ-UBND	Decision/Ha Tinh Provincial People's Committee	2011	- Aims to evaluate level and impacts of climate change on different regions in the province - Determined adaptive solutions to climate change in the province - Improve people's awareness and increase human resources for climate change adaptation
963-CTr/TU	Action Plan/Ha Tinh Provincial Committee of the Party	2013	- Regulated specific objectives in adaptation to climate change in the province: + Build up capacities for forecasting and early warning systems + Adapt initiatively to climate change + Reduce damages of extreme events - Focused on building up forecasting capacity to extreme weather events - Encouraged applying IT in managing hydrometeorology databases, forecasting, and early warning
21/2013/QĐ-UBND	Decision/Ha Tinh Provincial People's Committee	2013	- Assigned responsibilities for Provincial Center of Hydrometeorology including: + Evaluating quality of hydrometeorology information including agro-meteorological information and other hydrometeorology information; + Conducting hydrometeorology forecast in the province (no specific regulations to agrometeorological information). + Editing and providing bulletin and news on weekly and monthly hydrometeorology information and extreme weather events (no specific regulations to agrometeorological information). + Apply IT in to forecasting to improve quality of forecasting

Policies	Type of documents/ Issued office	Issued time	Key points relate to adaptation to climate change and extreme weather events
45/KH-UBND	Action Plan/Ha Tinh Provincial People's Committee	2014	- Focused on improving people's awareness on climate change and adaptation to climate change; - Strengthen studying and applying sciences and technology in climate change adaptation; - Increase state's management on climate change; - Increase international cooperation in climate change adaptation
25/QĐ-UBND	Decision/Ha Tinh Provincial People's Committee	2016	- Assigned responsibilities for different departments, organizations in the province in coping with natural disaster and natural disaster prevention - Assigned Provincial Center of Hydrometeorology: + Update exactly hydrometeorology information to support for natural disaster prevention (did not indicate specifically for agriculture) + Make planning for forecasting and early warning of hydrometeorology events
3029/QĐ-UBND	Decision/Ha Tinh Provincial People's Committee	2016	- Determined prior directions in climate change adaptation for the province: + Improve awareness on climate change + Develop human resource for climate change adaptation + Strengthen managing and monitoring abilities on climate change adaptation + Complete mechanism and policy systems for climate change adaptation + Increase applying modern technologies in climate change adaptation such as applying early warning systems in natural disaster prevention - Focused on improving capacity of forecasting and early warning for extreme weather events in general (did not focus on specific fields)

Appendix F. Questionnaire of the study

QUESTIONNAIRE

Topic: Economic value of agro-meteorological information in climate change adaptation in Vietnam

Interview place: Village..

Full name of interviewer:..

PART I. GENERAL INFORMATION

1. General information about interviewee

Age……... Gender (1: Male; 0: Female)……….............

Educational level (number of schooling year)……. Farming experience (year)……………........

Relationship with household head (*1: household head; 2: wife/husband; 3: child; 4: farther/mother; 5: brother/sister; 6: other (specify)*…………………..)………

2. General information of household's head (if interviewee is not houshold's head)

Age…….. Gender (1: Male; 0: Female)……….............

Educational level (number of schooling year)……… Farming experience (year)……………........

3. Family size and labor supply

Family size…………………………………... Male………………………

Labor supply (16 year old above)……………... Male………………………

Agricultural labor (16 year old above)………... Male………………………

4. At present, has family have a loan for agricultural production?

[ ] Yes [ ] No

5. If yes, please specify amout and sources for loan?

Source	Amount (VND million)
Agriculture and Rural Development Bank	
Society and Policy Bank	
Othe banks	
Other sources (Specify)	

6. If yes, how does family use the loan?

[ ] Buy materials for crop production (seedling, fertilizer, pesticide...)

[ ] Buy materials for livestock

[ ] Buy materials for adaptation to extrerme events

[ ] Other (Specify)...

7. Cultivated land area? Total number of plot........................

Plot	Area (m^2)	Cropping pattern (Code)
Plot 1		
Plot 2		
Plot 3		
Plot 4		
Plot 5		
Plot 6		
Plot 7		
Plot 8		
Plot 9		
Plot 10		

Code: *1: two rice seasons; 2: one rice season; 3: peanut, bean; 4: corn; 5: vegetable; 6: forest; 7: cassava; 8: other (specify)…………………………………….*

8. Training attendance?

Type of training	Participant (code)	When?	Application (1: Yes; 0: No)
Cropping techniques			
Livestock techniques			
Aquaculture			
Natural disaser prevention			
Climate change adaptation			
Other (Specify)……………………..			

Participant code: *1: household's head; 2: husband/wife; 3: father/mother; 4: child; 5: brother/sister; 6: Other (Specify)......................*

9. Institutional participation?

[ ] Farmer's Union

[ ] Interested Group

[ ] Other (Specify)………………………………………………………………………

PART II. PERCEPTION ON CLIMATE CHANGE AND ADAPTATION OF FARMERS TO EXTREME WEATHER EVENTS IN AGRICULTURAL PRODUCTION

2.1. Perception on climate change

10. Have you known or hear climate change term?

[ ] Yes [ ] No

11. If yes, what are the sources of information?

[ ] Public media (newspaper, radio, TV, internet)

[ ] Training courses

[ ] Propaganda of local officers

[ ] Learn from relatives and neighbors

[ ] Other (Specify)……………………………………………………………

12. How do you understand about climate change?

[ ] Increase in temperature

[ ] Higher frequency of natural disasters

[ ] Other (Specify)…………………………………………………………………….

13. What are impacts of climate change on agricultural production?

[ ] Decrease in crop yield

[ ] Increase in production cost

[ ] Increase in adaptation cost

[ ] Other (Specify)……………………………………………………………………….

14. In recent 5 years, which do extreme weather events occur in the area?

[ ] Drought [ ] Cold spells [ ] Tornado

[ ] Hail [ ] Typhoon [ ] Flood

[ ] Other (Specify)…………………………………………………………………………

15. Rank the occurence of extreme weather events accord to frequency of happening in recent 5 years? (1: is the highest level)

Event	Ranking
Drought	
Cold spell	
Tornado	
Hail	
Typhoon	
Flood	
Other (Specify)……………………………..	

16. Effects of extreme weather events on household's agricultural production?

Sector	Affected level (1: serious; 2: normal; 3: have no effects)					
	Drought	Cold spell	Tornado	Hail	Typhoon	Flood
Cropping cultivation						
Livestock						
Aquaculture						
Forestry						

2.2. Agricultural production status and farmers' adaptation to climate change

17. Area of major crops in 2016?

Crop type	No.of plot	Area (m^2)	Compare to 2015	
			Increase	Decrease
Spring rice				
Summer-Autumn rice				
Spring peanut				
Summer-Autumn peanut				
Summer-Autumn bean				
Cassava				
Other (Specify)				

18. If cultivated area increase/decrease, what is the reason?

+ Spring rice:

……
……

+ Summer-Autumn rice:

……
……

+ Spring peanut:

……
……

+ Summer-Autumn peanut:

……
……

+ Summer-Autumn bean:

……
……

+ Cassava:

……
……

+ Other (Specify):

……
……

19. Productivity of major crop in 2016?

Crop type	Area (m^2)	Total productivity (kg)	Compared to 2015	
			Increase	Decrease
Spring rice				
Summer-Autumn rice				
Spring peanut				
Summer-Autumn peanut				
Summer-Autumn bean				
Cassava				
Other (Specify)				

20. If productivity increase/decrease, what is the reason?

+ Spring rice:

……
……

+ Summer-Autumn rice:

……
……

+ Spring peanut:

……

……

+ Summer-Autumn peanut:

……

……

+ Summer-Autumn bean:

……

……

+ Cassava:

……

……

+ Other (Specify):

……

……

21. Household's estimated income in 2016?

Income source	Amount (VND million)
Cropping cultivation	
Livestock	
Aquaculture	
Forestry	
Non-farm	
Off-farm	
Other (Specify)………………………..	

22. Did extreme weather events affect cropping cultivation of household in?

[ ] Yes [ ] No [ ] Cannot estimate [ ] Have no answer

23. If yes, how is damaged level?

Indicator	Spring rice	Summer rice	Spring peanut	Summer peanut	Summer bean	Cassava
Decrease in yield (kg)						
Increase in seedling cost (VND thousand)						
Increase fertilizer cost (VND thousand)						
Increase labor cost (VND thousand)						
Increase irrigation cost (VND thousand)						
Other (specify)						

24. Did family apply adaptive strategies to extreme weather events in cropping cultivation?

Spring rice	[ ] Yes	[ ] No
Summer rice	[ ] Yes	[ ] No
Spring peanut	[ ] Yes	[ ] No
Summer peanut	[ ] Yes	[ ] No
Summer bean	[ ] Yes	[ ] No

25. If yes, what are the adaptive strategies?

Option	Spring rice		Summer rice		Spring peanut		Summer peanut		Summer bean	
	(1; 0)	‘000đ	(1; 0)	‘000đ	(1; 0)	‘000đ	(1; 0)	‘000đ	(1; 0)	‘000đ
Change crop variety										
Change cultivated method										
Change cultivar type										
Adjust farming agenda										
Update meteorological information										
Improve irrigation infrastructure										
Intercropping										
Get advices of extension workers										
Other (Specify)										

26. Information sources for adaptive options?

[ ] Training courses
[ ] Public media (TV, radio...)
[ ] Propaganda of local authorities and extension workers
[ ] Learn from relatives and neighbors
[ ] Other (Specify)…………………………………………………………………………….

PART III. USING METEOROLOGICAL INFORMATION TO ADAPT TO CLIMATE CHANGE IN AGRICULTURAL PRODUCTION AND WILLINGNESS TO PAY FOR SEASONAL FORECAST BULLETIN

3.1. Using meteorological information status in climate change adaptation

27. Following weather forecast news?

[ ] Daily update
[ ] Unusual update (1 time per week or less)
[ ] Do not care for weather forecas news

28. If update, what is benefit of weather forecast news?

[ ] Decease damaged level in agricultural production
[ ] Reduce production cost
[ ] Support for pest and disease prevention
[ ] Other (Specify) ……………………………………………………………………

29. Source of weather forecast news?

[ ] National weather forecast news (TV, radio….)
[ ] Nationally agricultural weather forecast news
[ ] Provincial weather forecast news
[ ] Weather forecast news at district level
[ ] Internet
[ ] Learn from relatives and neighbor

[ ] Other (Specify)……………………………………………………………………

30. If update, how is quality of weather forecast news?

[ ] Exact

[ ] Medium

[ ] Inexact

[ ] Cannot valuate

31. Did family use meteorological information to adjust agricultual production to cope with extreme weather events?

[ ] Yes [ ] No

32. If yes, what is the adjustment?

[ ] Change planting date
[ ] Change time for applying fertilizer
[ ] Shift time for spraying pesticides
[ ] Adjust harvesting calendar
[ ] Change cultivated form
[ ] Improve irrigation infrastructure
[ ] Other (Specify)…………………………………………………………

33. What is benefit of using meteorological information to adjust agricultural production to cope with extreme weather events?

[ ] Increase crop yield

[ ] Reduce production cost

[ ] Reduce adaptation cost

[ ] Other (Specify)...

3.2. Willingness to pay (WTP) level for seasonal forecast bulletin

34. Have you known meteorological station in My Loi village?

[ ] Yes [ ] No

35. How do you think about the importance/necessity of this meteorological station?

[ ] Necessary/Important
[ ] Normal
[ ] Unnecessary/Unimportant
[ ] Have no answer

36. Do you hear/known seasonal forecast bulletin of ACIS project?

[ ] Yes [ ] No

37. How do you evaluate the importance/necessity of this bulletin?

[ ] Necessary/Important
[ ] Normal
[ ] Unnecessary/Unimportant
[ ] Have no answer

Scenario:

"Seasonal forecast based on meteorological information of specifically climatic zone has been proven having many advantages for climate change adaptation. This forecast will help farmers adjust efficiently and effectively their agricultural practices in the context of adaptation to climate change. Through agricultural production activities adjustment, farmers may reduce losses resulted from extreme climate events in agricultural production. However, getting seasonal forecast based on meteorological information of specifically climatic zone is costly. The cost includes expense of setting up meteorological station at specifically climatic zone. It also consists of payment for the people who is responsible for collecting meteorological information and making seasonal forecast. ICRAF's project has made seasonal forecast based on collected meteorological information at the district level since August 2015. Are you willing to pay for making this kind of seasonal forecast? Note that your payment will affect your income!"

38. Are you willing to pay **VND 20,000/30,000/40,000/50,000/60.000** per month for seasonal forecast bulletin?

[ ] Yes [ ] No

39. If yes (in question 38), are you willing to pay **VND 30,000/40,000/50,000/60,000/70.000** per month for seasonal forecast bulletin?

[ ] Yes [ ] No

40. If yes (in question 39), what is the highest level of payment?.................... VND/month

41. If no (in question 38), are you willing to pay **VND 10,000/20,000/30,000/40,000/50.000** per month for seasonal forecast bulletin?

[ ] Yes [ ] No

42. If yes (in question 41), what is the reason?

[ ] Provision of seasonal forecast bulletin is goventment task

[ ] Cannot recognize benefits of seasonal forecast bulletin

[ ] Do not believe in quality of seasonal forecast bulletin

[ ] Other (Sprcify)…………………………………………………………………………..

43. If yes (in question 38, 39 and 41), what is the reason?

[ ] To reduce damaged level in agricultural production

[ ] To reduce adaptation cost

[ ] To have suitably adaptive plan

[ ] Other (Specify)………………………………………………………………………....

44. Comments for improving quality of seasonal forecast bulletin?

....
....
....
....

Thank you very much for your cooperation!!!