Adaptation to Climate Change of Lowland Rice Farmers in Bukidnon, Philippines: A Micro-level Analysis

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Abstract

This study was conducted to analyze the determinants of taking adaptation strategies by lowland rice farmers on climate change and variability, and the impact of climate change adaptation on productivity using household data from 308 lowland rice farmers of selected barangays in Bukidnon. The analysis was complemented with an assessment of the extent of awareness and perception of lowland rice farmers, and the determinants of perception of farmers on climate change and variability. Using the bivariate probit analysis, the determinants of perception of climate change were sex, farm experience, farm size, flood and drought experience, climate information, adaptation information, and being in the south of Bukidnon. The Heckman probit analysis found that age, education, farm experience and access to adaptation information from any source were key drivers of adaptation. To account for endogeneity of the adaptation decision, a two-stage least squares (2SLS) procedure revealed that farmers who took yield-related adaptation strategies had better harvest compared to those farmers who did not take any adaptation measure to cope with the negative impacts of climate change. In the light of these findings, government policies, and strategic investment plans of both government and private institutions should ensure the provision of improved farmer education, extension services, affordable credit, off-farm employment opportunities, and irrigation facilities, not only to improve adaptation capabilities of lowland rice farmers but also their productivity.

Keywords: perception, adaptation, climate change, farm level productivity, two-stage least squares, Bukidnon

Introduction

Agriculture depends much on the environment in the process of providing the lives and livelihoods of millions who depend on it for food and subsistence. On the other hand, climate is the primary determinant of agricultural productivity. Climate change impact on agricultural inputs such as water for irrigation, amount of solar radiation for plant growth, and prevalence of pests can affect crop yield and types of crops that can be grown in some areas (Dhaka et al., 2010).

Agricultural production is still the main source of livelihood for the people of Bukidnon. Of its total land area, 92% is utilized for agricultural production. There is a dominance of subsistence farmers in the province who are vulnerable to the negative impacts of climate change and variability. The Intergovernmental Panel for Climate Change (IPCC) reports that smallholder and subsistence farmers in developing countries are among those who suffer the most from climate change impacts (IPCC, 2007). Since climate change affects food security in terms of availability, accessibility, utilization, and stability, the negative impacts it brings may lead to a decline in labor productivity, increase in poverty, and increase in mortality rates.

Rice is one of the major crops produced in Bukidnon. Rice farming is said to be threatened by climate change because of higher temperatures and changing rainfall patterns. Acute water shortages combined with thermal stress could adversely affect rice productivity despite the positive effects of elevated carbon dioxide in the future. Crop diseases such as rice blast, and sheath and culm blight of rice could become more widespread (Jaranilla-Sanchez et al., 2007). These changes in the climate will greatly affect millions of Filipino farmers and household members who depend on rice farming for food and income.

It is a fact that climate change and variability have been observed in the past and will continue to change in the future. In the climate change literature, vulnerability studies have shifted the focus of research from estimation of impacts, to the understanding of farm-level adaptation and decision-making. It is in this line that there is a need to understand how farmers perceive climate change and how they identify potentially useful adaptations to counter the effects of these changes. Adaptation to climate change is necessary, in addition to mitigation of climate change, to avoid unacceptable impact of anthropogenic climate change (IPCC, 2007). Furthermore, there is a need for studies on climate change and agriculture so as to provide micro perspective on the issue of adaptation and food security.

Thus, to better understand the adaptation strategies taken by these rice farmers, it is necessary to know whether these farmers perceive that climate indeed changed. In doing so, a critical analysis of the reasons underlying adoption and non-adoption will aid in the identification of important determinants of perceiving climate change, choosing any of the adaptation options available, and the impact of these choices on food productivity of the rice farmers.

Objectives of the Study

This study was conducted to analyze the determinants of actual adaptation strategies to climate change and variability made by lowland rice farmers, and the effect of adaptation on their production at the farm-level.

Specifically, it aimed to:

1. assess the extent of awareness and perceptions of lowland rice farmers on climate change and variability;
2. identify the determinants of perception of lowland rice farmers on climate change and variability;
3. analyze the farm-level adaptation strategies to changing climate conditions;
4. determine the factors that significantly affect farm-level adaptation strategies to climate change in the context of lowland rice farmers; and
5. assess the impact of climate change adaptation on lowland rice production at the household-level.

Review of Related Literature

This part of the paper presents both theoretical concepts and empirical studies on the different aspects of this research so as to meet the objectives outlined in the previous chapter.

Approaches to Assessing Perception, Adaptation, and Productivity to Climate Change in Agriculture

Research on climate change can be conducted by either using the top-down approach or the bottom-up approach. The top-down is a scenario-based approach where adaptations are assumed and are invariably treated as primarily technical adjustments to the inputs identified, while the bottom-up approach explores actual adaptation behavior based on the analysis of decisions made by the farmer in the face of variable conditions (Gbetibouo, 2009). Accordingly, the top-down approach can be found in spatial analysis, climate impact modelling, and Ricardian studies. For example, simulation results using 10 different climate scenarios on the effect of climate change on the yield of rice and corn in Bukidnon showed that the yield tend to decrease, with greater percent change and higher coefficient of variation in rice compared to corn (Lansigan and Salvacion, 2007). On the other hand, the bottom-up approach employs survey data analysis, in-depth interviews, and focus group discussions with farmers and other farm experts. Referring to Bryant et al. (2000), Gbetibouo (2009) pointed out that studies using the bottom-up approach have raised new research questions on how farmers perceived change and variability; have identified climate properties deemed to be important in making decisions; and have generated the types of adaptive measures that can be anticipated. Mengistu (2011), used focus group discussion (FGD) to generate and assess information on the perception of farmers on climate change, its related hazards, vulnerable groups of the community, and existing coping strategies in a farming community in Ethiopia.

Micro-level analysis of adaptation focuses on tactical decisions farmers make, which are influenced by a number of socio-economic factors that include household characteristics, household resource endowments, access to information, and availability of formal institutions for smoothening consumption (Nhemachena and Hassan, 2007). Accordingly, at the farm-level, decisions are made over a very short time and are usually influenced by seasonal climatic variations, local agricultural cycle, and other socio-economic factors.

In agriculture, adaptation to climate change can take place at the farm, national, regional and global levels. According to Hassan and Nhemachena (2008), farm-level adaptation depends on technology, soil types, and the capacity of farmers to detect climate change and take necessary actions.

One set of approaches under the partial equilibrium models for analysing adaptation to climate change is the group of discrete choice models. The use of these models is based on its conceptual similarities with agricultural technology adoption and other related models.

The probit and logit models are the most commonly used empirical models involving decisions whether to adopt or not to adopt. Gbetibouo (2009) used a multinomial logit model to examine the determinants of adaptation to climate change and variability of farm households in the Limpopo Basin, South Africa. Nhemachena and Hassan (2007) employed the multivariate probit model to analyze factors influencing the choice of climate change adaptation options in South Africa.

It must be noted that technology adoption decisions by farmers requires two steps. The Heckman selection model is usually employed to correct selection bias generated during the decision making process. Maddison (2007) employed the Heckman two-step procedure to analyze perception of and adaptation to climate change in South Africa. Similarly, Deressa et al. (2010) adopted the Heckman two-step procedure to analyze the perception and adaptation to climate change in the Nile Basin of Ethiopia. Also, Gbetibouo (2009) used the Heckman sample selection method to study the factors that affect the perception of and adaptation to climate change in South Africa.

Yu et al. (2010) estimated a yield function for rice in Vietnam and examined how farmers could increase yield through intensified input use and improved public provision. In their study on the impact of climate change and adaptation on food production in Ethiopia, Yesuf et al. (2008) used both pseudo-fixed effects and two-stage least squares (2SLS) econometric approaches to control unobserved heterogeneity and endogeneity so as to have robust results and conclusions. On the other hand, Di Falco et al. (2011) estimated a simultaneous equation model with endogenous switching to account for heterogeneity of the decision to adapt and for the unobservable characteristics of farmers and their farms, in a study on adaptation and its impact on the food productivity of farm households in Ethiopia.

Awareness and Perception of Farmers on Climate Change and Variability

The awareness of farmers to change in climate variables like temperature and precipitation is important in adaptation decision making (Maddison, 2007). In a study of farmers in Southeast Nigeria, majority of the farmers do not agree that farming contributes to climate change, but were aware of climate change and its effects on agriculture (Enete et al., 2011). Across the ten countries studied in Africa, Maddison (2007) found out that a significant number of farmers perceived and believed that temperature had increased and rainfall levels had decreased. Results of the study of Nhemachena and Hassan (2007) in Southern Africa indicated that most farmers report that long-term temperature is increasing, and there are pronounced changes in the timing of rains and frequency of droughts.

In two case studies done by the John J. Carroll Institute on Church and Social Issues (2009), some of the observed changes in climate as reported by the rice farmers in the Philippines were: delays in the rains for more than ten years in Nueva Ecija, and the weather has become so unpredictable that there are still rains in December until March when the rainy season is only up to November; rice farmers from Iloilo observed changes in the local climate where heavy rains do not seem to stop, resulting to more pests and insects.

Furthermore, in the Philippines, farmers have reported a number of abnormalities related to climate change in terms of resurgence of pests and diseases in rice, corn and fruit trees. Rice farmers have reported the reappearance of a very destructive disease called ‘tungro’ (Lasco et al., 2011).

It is said that agriculture is not only at risk to climate change but it is also an agent of environmental and climate change. Agriculture contributes about half of the global emissions of two of the most potent non-carbon dioxide greenhouse gases: nitrous oxide and methane (Worldbank, 2008). From the International Panel on Climate Change (IPCC) report, methane emissions from rice production occurred mostly in South and East Asia, where it is a dominant food source (Smith et al., 2007). The report added that in South Asia, most of the increase in emission is due to the expanding use of nitrogenous fertilizers and manure in order to meet the demand for food as a result of rapid population growth. Irrigated paddy and burning of biomass are responsible for producing most agricultural nitrous oxide and methane emissions (Worldbank, 2008).

Technology Adoption and Adaptation to Climate Change in Agriculture

According to Carr (2001), the decision to adopt or reject as a process begins when the individual first learns about the existence of the innovation, forming and attitude towards it, deciding to adopt or reject, implement or use it, and finally to confirm the decision. The reasons why farmers do not adopt to improved technologies as outlined by Doss (2003) are: they are not aware of technology and its benefits; inavailability of technologies or not available when needed; and, technologies are not profitable given the allocation constraints of resources across agricultural and non-agricultural activities. According to Maddison (2007), a survey of the literature identified general themes concerning adoption of new technologies: it is linked to resource scarcity and price changes; it is affected by capital or savings constraints; rate of adoption is affected by learning costs; technology adoption and risk aversion are linked. Examples to this are lack of improved seeds, lack of access to water for irrigation, lack of correct knowledge of modern adaptation strategies, lack of capital, lack of awareness and knowledge of climate change scenarios are the barriers to adoption of modern techniques for combating climate change.

It is posited that the goal of an adaptation measure should be to increase the capacity of a system to survive external shocks or change. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007a). The Fourth Assessment Report further establishes adaptation practices as actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate (Adger et al., 2007). Traditional and newly introduced adaptation practices can help farmers to cope with both current climate variability and future climate change.

If farmers learn gradually about the change in climate, in the same manner they will also learn gradually about the best techniques and adaptation options available (Maddison, 2007). Moreover, farmers learn about the best adaptation option through learning by doing, learning by copying, and learning from instruction. In addition, Gbetibouo (2009) noted that farmers can be influenced by the perception of their peers, values in their communities, and professional associations.

Farmers are into organic agriculture as an adaptation strategy to counter the effects of farming practices that contribute to climate change. According to FAO (2008), in this type of agriculture, farmers use organic manures, legume production, wide crop rotation, rejection of synthetic fertilizers, and plant protection agents with less or no use of fossil fuel, thus, maintaining soil fertility.

Jaranilla-Sanchez et al. (2007) referring to Lasco et al. (2005), recommends a variety of adaptation options to the perceived impacts of climate change on Philippine agriculture: development of stress-tolerant varieties, development of new farm management techniques, adaptive design and development of efficient farm tools and implements, improvement of post- harvest technologies, and design and installation of a management information system.

Adaptation Strategies of Rice Farmers in the Philippines

Mitin (2009) documented case studies in the Philippines and found out that rice farming communities in Luzon adopted autonomous adaptation strategies: delaying rice planting for four months and planted alternative crops; and planned adaptation strategies with the aid of the Department of Agriculture: cloud seeding, provision of shallow tube wells, and identified alternative drought-resistant crops. In addition, rice farmers in Southern Mindanao adopted organic farming so as to reduce socio-economic impacts and agricultural losses due to climate change.

A study of rice farmers in Camarines Sur found out that they have been shifting to high-yielding and/or early maturing varieties, changing planting dates, diversifying crops, and taking non-farm jobs to cope with the effects of rainfall variability and extremes (Cuesta and Rañola, 2009).

From the studies conducted by the John J. Carroll Institute on Church and Social Issues (2009), the following biophysical and economic adaptation measures were adopted by rice farmers from Isabela and Iloilo: use water pump and shallow tube for irrigation, change rice varieties, adjust planting spacing, perform synchronous planting, plant multi-purpose tree species, change planting calendar, practice contour and organic farming, borrow from traders and neighbors, engage in other agricultural production, seek off-farm jobs, and sell assets.

Philrice (2011) reported that rice varieties which are adaptive to climate change are saline resistant varieties for irrigated lowlands, drought resistant varieties, and submergence-tolerant varieties. The agency recommends the following technologies or best practices that can reduce the greenhouse gas emissions from rice fields: practice mid-season drainage, adopt alternative wetting and drying or controlled irrigation, avoid water logging in off-seasons, practice direct seeding, use temporary vegetative cover, improve nitrogen use efficiency, use chemical fertilizers and nitrification inhibitors, use rice varieties with low methane emission potential, improve tillage practices, improve crop residue management, enhance carbon impounding and use farm waste and biomass.

Determinants of Perception and Farm-level Adaptation Strategies to Climate Change

The perception or awareness of climate change and taking adaptive measures are influenced by different socio-economic and environmental factors (Enete et al., 2011).

Econometric investigation by Maddison (2007) revealed that experienced farmers are more likely to perceive climate change. Age of the farmer and farming experience are positively and significantly related to perception to climate change (Dhaka et al., 2010). Age of the farmer may negatively or positively affect technology adoption depending on the location or technology (Teklewold et al., 2006).

According to Gbetibouo (2009), educated farmers are more likely to perceive that rainfall does not have significant trend in the long-run. Education of the household head has a positive relationship with adoption of technology (Lin, 1991). Farmers with higher levels of education are more likely to adapt to climate change (Dhaka et al., 2010; Eñete et al. 2011).

Farm households with larger household sizes are more likely to adopt agricultural technology and use it more intensively (Croppenstedt et al., 2003). According to Gbetibouo (2009), household size enhances adaptive capacity to climate change.

Studies examined by Pattanayak et al. (2002) found that households with a higher proportion of males are more likely to adopt agroforestry technologies. Female-headed households are more likely to take up climate change adaptation strategies (Hassan and Nhemachena, 2007). But, Deressa et al. (2011) found that gender of the head being male has a positive influence on adaptation.

Wealth has a positive association to the perception of farmers on climate change (Deressa et al., 2010). Farmers with the best access to capital will adopt first while the capital-poor may not adopt the technology (Foltz, 2003). According to Norris and Batie (1987), income has a significant and positive influence on conservation expenditures. Increase in non-farm income will lead to increased adoption and intensity of use of technology (Onyenweaku et al., 2007). Wealth is one of the factors that increases adaptive capacity to climate change (Gbetibouo 2009).

Farm size has a positive effect on adoption of an agricultural technology (Onyenweaku et al., 2007). Farm size negatively affects the use of one, or a combination of the identified coping strategies by farmers (Deressa et al., 2010). On the other hand, Dhaka et al. (2010) found out that larger farms are more likely to adapt to climate change.

Social capital is an important player in information exchange (Isham, 2000). According to Deressa et al. (2011), number of relatives in the village positively influences the perception of climate change.

The number of extension visits per year is positively associated with technology adoption (Adeoti, 2009). Access to information through extension increases the probability of taking up adaptation strategies (Nhemachena and Hassan, 2007; Maddison, 2007). Government extension, farmer-to-farmer extension and climate information increase the probability of adaptation to climate change (Di Falco et al., 2011).

Research in the adoption of agricultural technologies indicates that there is a positive relationship between availability of credit and adoption of the given technology (Pattanayak et al. 2002). Access to credit can influence adaptation to climate change (Gbetibouo, 2009; Deressa et al., 2011).

Impact of Climate Change and Adaptation on Food Production

A number of studies tried to investigate the impact of climate change and climate related adaptation measures on agricultural production. Increasing temperature during summer and winter reduces net revenue per hectare, whereas increasing precipitation during spring increases net revenue per hectare (Deressa, 2007). Temperature level seems not to explain variations in yield levels but precipitation has a positive contribution to food production, but too much rain may affect food production negatively in the study sites in low-income countries (Yesuf et al., 2008).

The study of Yu et al. (2010) found that adaptation measures like chemical fertilizer application and irrigation expenditure for paddy field significantly increase rice production. According to Yesuf et al. (2008), climate change adaptations can have a significant impact on food production. Adaptation to climate change increases food productivity, where farm households who actually adopted an adaptation strategy tend to be more productive than those who did not take adaptation measures to effects of climate change (Di Falco et al., 2011). Accordingly, if those farmers that did not take adaptation measures had adopted, those farmers can produce the same output as the farm households that actually adopted.

More use of production inputs: seeds, fertilizer, manure and labor tend to increase food production (Yesuf et al., 2008). Same results were revealed by Di Falco et al. (2011) but only labor and fertilizers significantly affect productivity of farm households that did not adapt. In addition, the studies cited also found out that some household and farm characteristics, increase food production (Yesuf et al., 2008; Di Falco et al., 2011).

The findings of the different studies regarding the influence of each of the explanatory variable on the response variables presented in this section are summarized in Table 1. The results of the different studies cited earlier together with theories in technology adoption and economics were used as the bases for formulating the hypotheses in this study.

Conceptual Framework

This section starts with a discussion on a model of farm-level adaptation to risk influences, and is heavily drawn from Tarleton and Ramsey (2008). Accordingly, there are four influences which can be identified to climate change risks: social and cultural influences, political-economic influences, environmental influences, and technological influences. Social and cultural influences include community demographics and dynamics, educational levels and opportunities, and generational histories. Political-economic influences include community prices, input costs, mortgage and lending rates, agricultural support programs, and level of taxation. Climate change and weather variability, crop diseases, and depletion of soil quality and quantity are under environmental influences. Crop variety availability and mechanical innovations are included in technological influences.

Patttanayak el al. (2002) came up with five general categories which can influence technology adoption in agriculture: farmer preferences, resource endowments, market incentives, bio-physical factors, and risk and uncertainty. Accordingly, farmer preferences are proxied by socio-demographic variables; resource endowments include land, labor, livestock and savings; market incentives involve prices, availability of markets, transportation, and potential income losses or gains; bio-physical factors are those associated with the physical production process associated with farming; risk and uncertainty include fluctuations of commodity prices, projected output, rainfall, and tenure insecurity.

Adaptation to climate change can be framed within the standard theory of technology adoption. The investigation of climate change and adaptation and its potential impact on food production can be modelled in the setting of a two-stage framework. In the first stage, one can model a representative risk

(1)

averse farm household to implement a set of climate change adaptation strategies if it generates maximum expected utility from final wealth at the end of the production period, given the production function and land, labor, other resource constraints and perception on long-term changes in climate. A latent variable, A^*, represents an optimal mix of adaptation measures undertaken by the representative farm household is given by

$$A_i^* = X_i\alpha + \varepsilon_i$$

The vector *X* represents household characteristics, land and other farm characteristics and climate variables that affect the expected benefits of adaptation, α is a vector of parameters, and ε_i is the household-specific random error term. Here, households choose adaption 1 over adaptation 2 if $E[U(A_1)] > E[U(A_2)]$.

Accordingly, adaptation to climate change is a two-step process involving perception and adaptation stages. In the first step, the respondent perceived whether there was a change in climate or not; and in the second step, respondent adopts an adaptation strategy, given that he or she perceived that there was climate change. The process gives rise to a sample selection bias since the adaptation step is a sub-sample of the first step. That is, the second step sub-sample is non-random and differs from those who did not perceive climate change. Therefore, it is appropriate to use the Heckman maximum likelihood two-step procedure in order to correct the selectivity bias. Following Deressa et al. (2010), the Heckman sample selection model assumes that there exists an underlying relationship which consists of the latent equation given by Equation (1). That is,

$$A_i^* = X_i\alpha + \varepsilon_{1i} \quad (2)$$

Here, only the binary outcome given by the probit model is observed as

$$A_i^{probit} = (A_i^* > 0) \quad (3)$$

The dependent variable is observed only if the observation *i* is observed in the selection equation

$$A_i^{select} = (Z_i\beta + \varepsilon_{2i} > 0) \quad (4)$$

$\varepsilon_1 \sim N(0,1)$

$\varepsilon_2 \sim N(0,1)$

$$corr(\varepsilon_1, \varepsilon_2) = \rho$$

In Equation (2), *X* is a *k*-vector of explanatory variables which include different factors hypothesized to affect adaptation and in Equation (4), *Z* is an m-vector of explanatory variables which include different factors hypothesized to affect perception; β is the parameter estimate, ε_{2i} is an error term and ε_1 and ε_2 are error terms which are normally distributed with mean zero and variance one. Equation (4) is the selection model and Equation (2) is the outcome model. If $\rho \neq 0$, then Equation (2) produces biased estimates using standard probit techniques. Thus, the parameters must be estimated by the Heckman probit selection model.

In the second stage, the study models the effect of climate change and adaptation on food production using representation of the production technology. Here, adaptation measured by a dummy variable is entered into a standard household production function given by

$$Y_i = W_i\gamma + \mu_i \quad (5)$$

where Y_i is the quantity produced per hectare, W_i represents a vector of inputs, characteristics of farm households, climate factors and adaptation measures, γ is the vector of parameters, μ_i is the household-specific random error term. If an ordinary least squares (OLS) procedure is used to estimate the parameters of Equation (5), it might yield biased estimates because it assumes that adaptation is endogenous. Accordingly, adaptation to climate change may be voluntary and based on expected benefits. Also, unobservable characteristics of rice farmers and their farms may affect both adaptation decision and rice production. To account for endogeneity of the adaptation decision, a two-stage least squares (2SLS) procedure is employed in the estimation of the production function. Instrumental variables, specifically those related to information sources and social capital of the rice farmers, are tested for admissibility.

Methodology

Locale of the Study

Bukidnon has a total land area of 1,049,859 hectares, 92% of which is utilized for agricultural production. Rice is one of the major crops raised in Bukidnon which is considered the largest rice producing province in Northern Mindanao. The presence of irrigation facilities provided by the National Irrigation Administration (NIA) and some communal systems makes it possible for farmers to grow two crops of rice per year and even three in some areas. Although typhoons are not common in the province, droughts are considered to mainly affect water supply and rice production especially for fields not covered by the irrigation facilities.

Research Design

This research used a bottom-up approach in identifying the important determinants of adoption of the various adaptation strategies and production model identified in the study. All relevant information were elicited from the farmers themselves using a farm household survey. This process meets the requirement that farm household characteristics should be matched with use of adaptation strategies. The selected rice farmers were interviewed personally using a structured and pre-tested interview schedule.

Sampling Procedure

Barangays with lowland rice farmers were selected from three municipalities and a city in Bukidnon. The selection of these barangays was based on type of irrigation, and accessibility. In each municipality or city, at least two contiguous barangays were chosen, where one has an irrigation facility and the other has none. A total of 308 randomly selected rice farmers in selected barangays were the respondents in this study. The respondents for this study were selected using simple random sampling from the aggregated list of rice farmers of each selected municipality.

Research Instrument

The structured questionnaire that was used in the interview of rice farmers included data on their awareness and perception of climate change, adaptation strategies, factors associated with these adaptation strategies, and production data. The choice of the explanatory variables in the model was based on technology adoption and economic theories, and literature review on adaptation studies. The production data was based on the average of the last two cropping seasons of 2011. To reduce cognitive burden on the side of the respondents, detailed data on production inputs were collected at different stages of production: land preparation, planting, pest management, and harvesting. Labor was disaggregated in each of the different stages and aggregated again to represent total labor in adult days. Secondary data on rainfall and temperature were obtained from nearby weather stations and collection sites of the different municipalities and city included in the study.

Statistical and Econometric Analyses of Data

The survey data were subjected to exploratory analysis to check for the distribution of each outcome variable, missing values, potential outliers, and assumptions necessary for the statistical and econometric models to be used in the different testing procedures.

Descriptive statistics such as proportions, means and standard deviations were estimated. Appropriate statistical and econometric methods were employed to descriptively and analytically evaluate the determinants of adaptation options. The chi-square test was used to compare proportions. Specifically, the study employed econometric tools like the bivariate probit model, Heckman selection probit model, ordinary least squares (OLS), and two-stage least squares (2SLS) procedure, to examine the characteristics that best explain variations in the measures of perception and adaptation level to climate change, factors that influenced such decisions, and the impact of these variables on rice production.

Results and Discussion

Table 1 presents the frequency distribution of the awareness of some climate change issues of the surveyed farmers. More than three-fourths (76.0%) of the rice farmers reported that they heard about climate change and variability, but less than a quarter (22.7%) said that they were invited to a meeting or seminar on climate change. According to Maddison (2007) and Gbetibouo (2009), awareness of changes in climate attributes among farmers, like temperature and precipitation, is necessary for deciding whether to adopt or not to adopt an adaptation strategy. It is interesting to note that these farmers were not aware that some of their rice farming practices can contribute to climate change.

As to the direction of change of some climate change variables over the last ten years as perceived by the farmers, 74.0% and 81.5% of the farmers believed that temperature and precipitation increased, respectively. As shown in Table 2, only 10.1% believed that temperature had decreased, and 15.9% said

Table 1. Awareness of climate change issues of lowland rice farmers in Bukidnon, Philippines

QUESTIONS ON AWARENESS OF CLIMATE CHANGE	NO N(%)	YES N(%)
Have you heard of climate change before?	74 (24.0)	234 (76.0)
Where you invited to attend a seminar or meeting on climate change?	238 (77.3)	70 (22.7)
Which activities do you think would contribute to climate change?		
Continuous flooding of rice fields	227 (73.7)	81 (26.3)
Burning of rice straw	39 (12.7)	269 (87.3)
Application of fertilizer	160 (51.9)	148 (48.1)

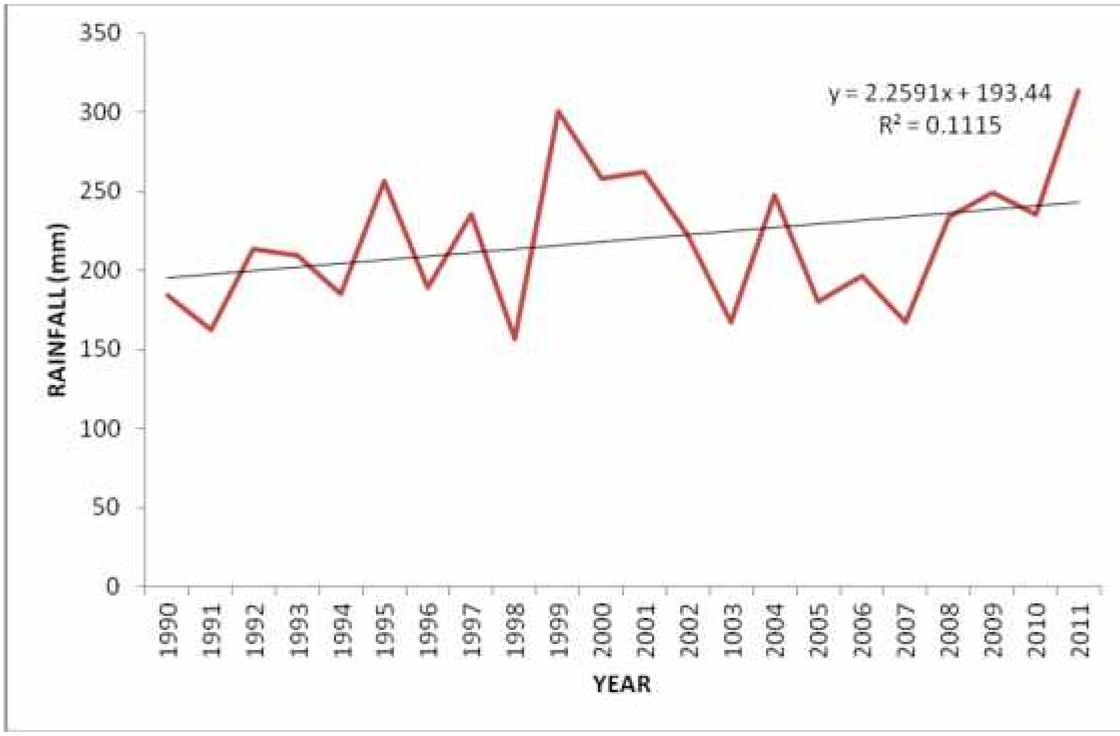
Table 2. Perceived direction of change of climate change phenomena of lowland rice farmers in Bukidnon, Philippines

PHENOMENA	DECREASING (%)	NO CHANGE (%)	INCREASING (%)
Temperature	10.1	15.9	74.0
Precipitation	2.9	15.6	81.5
Erratic rainfall pattern	3.2	18.2	78.6
Pests and diseases	12.0	16.6	71.4
Weeds	6.8	35.4	57.8

that temperatures did not change. Same pattern of opinion can be seen for precipitation and in the number of erratic rainfall patterns. The John J. Carroll Institute on Church and Social Issues (2009) reported that rice farmers in Nueva Ecija perceived that the weather has become unpredictable, while farmers in Iloilo observed changes in the local climate where heavy rains do not seem to stop.

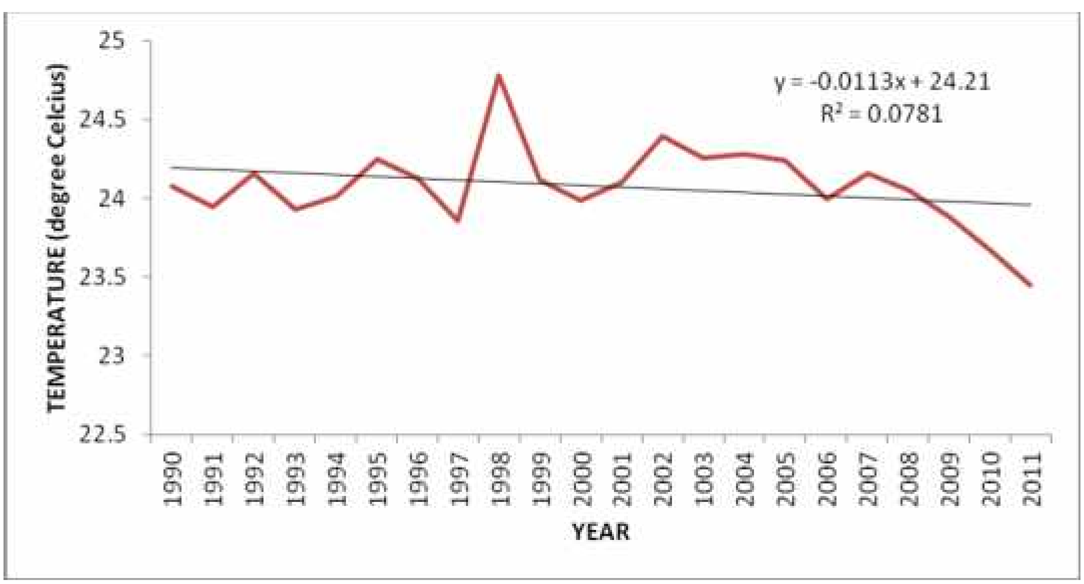
Using the data for rainfall and temperature as provided by Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) in Bukidnon from 1990 to 2011, the perception of the rice farmers seemed to be in accordance with the amount of rainfall but not with the behavior of temperature. The statistical data shown in Figures 1 and 2 seemed to indicate an increasing trend in rainfall but a decreasing trend in temperature. These observations may be different if site-specific data on these two climatic variables were available for the barangays considered in this study.

The figures in Table 3 classify the perception of climate change according to the number of years these farmers were engaged in rice farming. There is no significant difference in the proportion of farmers who perceived that precipitation had increased or decreased in the last 10 years. On the other hand, the chi-square test revealed that the proportion of younger farmers who were more likely to claim that there was a decrease in temperature was significantly higher than the other two older groups. As shown in Table 4, it can be inferred that the views between more educated and less educated farmers on precipitation did not differ significantly but their views on long-term changes in temperature differed significantly. According to Gbetibouo (2009), education seems to decrease the probability that farmers will perceive long-term changes in rainfall in South Africa.



Source: PAGASA Bukidnon Station

Figure 1. Rainfall trend in Bukidnon, Philippines from 1990 – 2011



Source: PAGASA Bukidnon

Figure 2. Temperature trend in Bukidnon, Philippines from 1990 – 2011

Table 3. Perceived change of rainfall and temperature by length of farm experience of lowland rice farmers in Bukidnon, Philippines

LENGTH OF EXPERIENCE	PRECIPITATION[a]			TEMPERATURE[b]		
	DECREASE	NO CHANGE	INCREASE	DECREASE	NO CHANGE	INCREASE
1 – 10 years	0%	19.7%	80.3%	19.7%	7.0%	73.2%
11 – 30 years	3.7%	13.8%	82.5%	6.3%	19.6%	74.1%
Above 30 years	4.2%	16.7%	79.2%	10.4%	14.6%	75.0%
Total	2.9%	15.6%	81.5%	10.1%	15.9%	74.0%

Notes: [a] $\chi^2 = 4.014, df = 4, p = .404$, [b] $\chi^2 = 14.344, df = 4, p = .006$.

Table 4. Perceived change of rainfall and temperature by level of education of lowland rice farmers in Bukidnon, Philippines

LEVEL OF EDUCATION	PRECIPITATION[a]			TEMPERATURE[b]		
	DECREASE	NO CHANGE	INCREASE	DECREASE	NO CHANGE	INCREASE
Primary	3.4%	16.2%	80.3%	15.4%	17.9%	66.7%
Secondary	1.6%	18.7%	79.7%	8.9%	17.9%	73.2%
Tertiary	4.4%	8.8%	86.8%	2.9%	8.8%	88.2%
Total	2.9%	15.6%	81.5%	10.1%	15.9%	74.0%

Notes: [a] $\chi^2 = 4.415, df = 4, p = .353$, [b] $\chi^2 = 12.347, df = 4, p = .015$.

The above results do not indicate whether the results are sensitive to other socio-economic factors of the surveyed rice farmers. Rather than running a probit model for each category of climate change perception, a bivariate probit model was used instead to analyze the determinants of the twin perception of change in both precipitation and temperature, since these two perceptions can be correlated. In the analysis, a dummy variable for the municipalities in Southern Bukidnon was included because almost a quarter did not perceive a change in rainfall or temperature. Experience in rice farming seemed to decrease the probability that the farmer will perceive long-term changes in temperature. Farmers with bigger farms were more likely to perceive long-term changes in both rainfall and temperature. Farmers with large farms, either owned or rented, may suggest that they are wealthy. Rice farmers with experience of flood and/or drought in the last five years were more likely to perceive that rainfall is increasing. Climate information from friends, neighbors, and fellow farmers increased the likelihood of perceiving long-term changes in the two climate variables. Adaptation information from any source was found to significantly increase the probability of perceiving a long-term change in rainfall. The dummy variable for location confirmed that being in the southern part of Bukidnon decreased the likelihood of perceiving climate change. Accordingly, areas in Southern Bukidnon have no pronounced maximum rain period and no dry season.

Lowland rice farmers had adopted different adaptation strategies to cope with the effects of climate change. For those rice farmers who perceived changes in the climate for the past 10 years, the main adaptation strategies they had adopted are summarized in Table 6. These adaptation strategies were classified into yield related and non-yield related. The use of new rice varieties was adopted by 38.5% of the interviewed rice farmers to cope with the demands of declining agro-climatic conditions. Less than one-third (30.4%) of the farmers changed their planting calendars. Changing of planting dates was adopted by rice farmers in Camarines Sur as reported by Cuesta and Rañola (2009). Similarly, rice farmers from Isabela and Iloilo practiced synchronous planting to aid pest control management, as reported by the John J. Carroll Institute of Church and Social Issues (2009). Organic farming and planting of trees were adopted by 7.1% of the surveyed farmers. Almost a quarter (24.0%) of the rice farmers did not take any adaptation strategy to adjust to the effects of climate change. Only 42.4% of the farmers resorted into

Table 5. Estimates of the bivariate probit model on the perception of lowland rice farmers of climate change in Bukidnon, Philippines

VARIABLES	PERCEIVED CHANGE IN RAINFALL		PERCEIVED CHANGE IN TEMPERATURE	
	COEFFICIENTS	STANDARD ERRORS	COEFFICIENTS	STANDARD ERRORS
EDUCATION	0.2574	0.2880	0.2577	0.2534
EXPERIENCE	0.2959	0.2159	-0.6283**	0.2760
FARMSIZE	0.6871*	0.3627	0.9169***	0.3666
IRRIGATION	0.1495	0.2005	-0.0423	0.1957
FLOODDROUGHT	0.4539*	0.2455	0.3700	0.2397
CLIMATEINFO	0.9974***	0.3844	0.6866***	0.2545
ADAPTATIONINFO	0.5036***	0.2162	0.2755	0.2072
LOCATION	-0.6869***	0.2054	-0.4212**	0.2028
CONSTANT	0.0268	0.3329	0.9410***	0.3536
Log-likelihood: -211.44				
Rho = 0.6826				

Notes: $\chi^2(1) = 32.0647^{***}$, $p < .0001$.
*** significant at 1% level, **significant at 5% level, * significant at 10% level.

Table 6. Farm-level adaptation strategies adopted by lowland rice farmers in Bukidnon, Philippines

ADAPTATION STRATEGY	PERCENT
Yield related	
Used new rice varieties	38.5
Changed planting calendar	30.4
Others (organic farming and tree planting)	7.1
Did nothing	24.0
Non-yield related	
Borrowed from traders, friends, relatives, lending institutions	42.4
Planted other crops and raised livestock	16.3
Sold livelihood assets	11.7
Sought off-farm employment	1.4

borrowing of money, 16.3% resorted into planting of other crops and raised animals. Selling of household assets in dire times was adopted by11.7% of the surveyed farmers. A very small proportion (1.4%) of the interviewed farmers said that they sought for off-farm employment during climate extreme events. The surveyed communities are basically agricultural zones, thus off-farm jobs are not available.

An econometric analysis on the factors on climate change adaptation strategies taken by rice farmers, considered to be yield related, was carried out in this study. The Heckman probit model was employed and tested for its appropriateness compared to the standard probit model. The estimated coefficient of the Mill's ratio, λ, was statistically significant, implying the presence of selection bias, thus the appropriateness of the use of the Heckman probit model. Older farmers were less likely to take adaptation measures as compared to their younger counterparts. According to Teklewold et al. (2006), age of the farmer may negatively influence the decision to adopt a new technology. Education was found to be positively related with taking any of the yield related adaptation measures. Length of farming experience significantly increased taking up of an adaptation strategy. Experienced farmers have high skills in farming techniques and management,

Table 7. Estimates of the Heckman probit model of adaptation behavior of lowland rice farmers in Bukidnon, Philippines

EXPLANATORY VARIABLES	ADAPTATION MODEL		SELECTION MODEL	
	COEFFICIENTS	STANDARD ERRORS	COEFFICIENTS	STANDARD ERRORS
SEX	0.0113	0.0652	-0.5746*	0.3203
AGE	-0.0061**	0.0026	0.0167	0.0110
EDUCATION	0.1255**	0.0618		
EXPERIENCE	0.3214***	0.0727	-0.6765*	0.3666
HHSIZE	-0.0032	0.0129	-0.0121	0.0649
TENURE	0.0071	0.0533		
FARMSIZE	0.0164	0.0798	0.8794*	0.4857
FLOODDROUGHT	0.0014	0.0732	0.6751**	0.2794
CLIMATEINFO	0.0171	0.0724	0.8302*	0.4497
ADAPTATIONINFO	0.2117***	0.0758	0.5869**	0.2718
CREDIT	0.0657	0.0482		
IRRIGATION			0.9670	0.2662
RELATIVES			0.1471	0.4461
MEMBER			-0.0973	0.2516
LOCATION			-0.3903	0.2678
CONSTANT	0.6491***	0.1804	0.5501	0.8711
Lamda	-0.4248*	0.2516		

Notes: *** significant at 1% level, **significant at 5% level, * significant at 10% level

thus making them more adaptable to changing conditions in the farm (Gbetibouo, 2009). Rice farmers who had more access to adaptation information from any source were more likely to employ an adaptation measure to improve yield.

Both the ordinary least squares (OLS) and the two-stage least squares (2SLS) results are shown in Table 8 to compare and establish that adaptation to climate change is a potentially endogenous variable. Alternative forms were explored and the specification of a quadratic term for rainfall was found to be more robust. Tests for endogeneity, over-identification, and weak instrument test, all suggest the validity of the use of instrumental variables using two-stage least squares (2SLS) estimation. The pro duction function estimates tell consistent stories as far as expected signs of the explanatory variables are concerned for both model specifications. Also, the models have strong explanatory powers ($p < 0.001$). The explanatory variables, adaptation information and presence of relatives in the barangay were used as instruments in the implementation of the two-stage least squares (2SLS) procedure. The production inputs: seeds, fertilizer, pest management, and labor, all have signs consistent with predictions of economic theory and were all found to be statistically significant.

The results would show that more use of these production inputs tended to increase rice production in the study areas. Specifically, for every kilogram of seeds and fertilizer used, rice production increased by 1.85 and 1.47 kilograms, respectively. A one peso increase spent for pest management increased production by only 0.20 kilograms, and an increase in labor of one adult day increased rice production by 44.56 kilograms. Moreover, rice fields with irrigation systems, both communal and provided by the National Irrigation Administration, tended to produce 321.52 kilograms of rice per hectare more as compared to rainfed rice farms. These results on the contribution of the use of conventional inputs are similar to those impact studies of adaptation on food productivity conducted in Ethiopia (Yesuf et al, 2008; Di Falco et al., 2011).

The estimates of the two production models were found to significantly explain variations of rainfall in yields across rice farmers. An increase in rainfall resulted to an increase in rice

Table 8. Estimates of parameters of the production models of lowland rice farmers in Bukidnon, Philippines

	ORDINARY LEAST SQUARES		TWO-STAGE LEAST SQUARES[a]	
VARIABLES	COEFFICIENTS	STANDARD ERRORS	COEFFICIENTS	STANDARD ERRORS
SEX	221.87***	125.57	203.20	136.24
HHSIZE	70.12*	27.98	67.53**	30.31
IRRIGATION	447.54**	118.13	321.52**	143.90
SEEDS	1.95***	0.93	1.85*	1.01
FERTILIZER	1.59**	0.65	1.47**	0.71
PESTMANAGE	0.19**	0.06	0.20***	0.07
LABOR	38.91***	7.83	44.56***	8.97
RAINFALL	487.91***	90.15	503.51***	97.91
SQRAINFALL	-0.77***	0.14	-0.80***	5710.16
ADAPTATION	100.67	129.41	1023.23**	503.55
CONSTANT	-76265.30***	13935.00	-78988.70***	15147.60
R – squared	0.4023		0.3244	

Notes: [a]Hausman test: $\chi^2(1) = 4.4828^{**}$, $p = .0342$; Sargan over-identification test: $\chi^2(1) = 0.4957^{***}$, $p = .4814$; Weak instrument test $F(2,296) = 12.4080$.

*** significant at 1% level, **significant at 5% level, * significant at 10% level

produced by the farmers. A negative sign of the square of rainfall indicates that too much rain had an adverse impact on rice production in the study sites. Precipitation has a positive contribution to food production (Yesuf et al., 2008).

It is worthy to note that in the ordinary least squares (OLS) estimation, the coefficient of the dummy variable for adaptation was positive but statistically insignificant. This can mean that there is no significant difference in the quantity of rice produced per hectare by farmers that took adaptation measures with respect to the quantity produced by farmers that did not adapt. However, in the two-stage least squares (2SLS) model, the positive coefficient for adaptation is statistically significant. This would imply that rice farmers who adopted climate change adaptation measures had higher rice production than those who did not take any adaptation measure. Using the marginal effect of the estimate, rice farmers with climate change adaptation measures tended to produce about 1023.23 kilograms more rice per hectare than those farmers who did not take such measures. This increase in output would mean that the effect of climate change in the study areas will be reduced by about 29.9% if rice farmers employ adaptation strategies. This result highlights the importance of the inclusion of climate change adaptation in the analysis of the impact of climate change on rice production.

. Conclusions

Based on the objectives and results of the study, the following conclusions are generated:

The rice farmers have a high level of awareness of climate change and its link to agriculture, but are not aware that continuous flooding of rice fields and using of fertilizer can add to global warming and climate change. Though they have access to climate and adaptation information from other sources, they have little access to technical information and extension services related to farming and climate change from concerned institutions.

The farmers perceive that both rainfall and temperature are increasing over the years. The data from the government weather station in Bukidnon suggest an increasing trend in rainfall but a decreasing trend in temperature from 1990 to 2011.

The determinants of perception of climate change are sex, farm experience, farm size, flood and drought experience, climate information, adaptation information, and being in the south of Bukidnon.

The yield-enhancing adaptation strategies that are most likely to be adopted by the farmers are: use of new rice varieties, change of planting calendar, and organic farming. Adaptation strategies that will be adopted when farmers will experience crop failure include: borrowing from credit sources, selling of livelihood assets, planting other crops and raising livestock, and seeking for off-farm employment.

The adoption of adaptation strategies of rice farmers is dependent on age, education, farm experience, and access to adaptation information from any source

Farmers who are using more of the production inputs Farmers who took yield-related adaptation strategies have better harvest compared to those who did not take any adaptation measure to cope with the negative impacts of climate change.like seeds, fertilizer, pest management and labor will have better yields.

Recommendations

Based on the findings and conclusions made on the study, the following recommendations are suggested:

Farmers must be informed of the contribution of rice production to global warming and climate change. Partnership between government and non-government institutions should be encouraged to create different channels of learning that will promote farm-level adaptation strategies with effective participation of farmers in adopting best farming practices.

The Department of Agriculture should strengthen its efforts in promoting farm-level adaptation strategies and providing technologies and land management practices that could reduce the negative impact of agriculture on the environment. The government, through the National Irrigation Administration should provide irrigation facilities to other rice growing communities so as to provide rice farmers with available and accessible water for irrigation in their rice fields all year round.

Access to extension services ensures that farmers have the necessary information for making decisions and the means to take up important adaptation strategies. Thus, provision of extension support from concerned institutions in order to hasten adaptation is imperative. The academe and the Department of Agriculture must promote extension services that will address the issues of climate change especially in poor farming communities.

Credit can increase financial resources of farmers and their ability to meet transaction costs incurred in taking various adaptation strategies. For instance, availability of credit will enable farmers to finance farm inputs like fertilizer and improved seeds. In this light, affordable credit from government and private institutions is recommended.

The different Local Government Units should consider strategic investment plans that will support access to climate information, develop farm-level adaptation strategies, provide technology packages to augment farm income, and create opportunities for off-farm employment. Collection of rainfall and temperature data should be in place for all local agriculture offices since these climate variables are important for rice production. The importance of providing appropriate and timely information on future climate changes to farm communities will prompt farmers to take the necessary actions to avert the impacts of such changes.

The government in promoting programs for rural development should consider the top two agenda for policy makers and development agencies: preventing the effects of climate change and achieving food security. With the positive impact of adaptation on lowland rice production, policies must be framed in the context of reducing vulnerability of farmers to climate change and increasing productivity among rice farmers.

Future research should try to investigate the contribution of each adaptation strategy not only in improving rice production but in agricultural productivity as a whole. In addition, it should identify the most successful measures in mitigating the impacts of climate change on rice farming.

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