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Climate Change Adaptation

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ECONOMICS OF CLIMATE CHANGE ADAPTATION

AGRICULTURE SECTOR ANALYSIS FOR VIET NAM

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FOREWORD

Climate change, including climate variability, is having detrimental effects on human well-being across the developing world. Increasing temperatures, changing rainfall patterns, rising sea levels and increasing frequency and intensity of extreme weather events are adversely affecting ecosystem functions, water resources, food security, infrastructure and human health. Moreover, climate change-driven impacts are predicted to become increasingly severe. Conscious of the need to adapt and to prepare for future, more severe impacts, countries are eager to understand how best to address the challenges they face in the most cost effective and efficient manner.

The Capacity Building Programme on the Economics of Climate Change (ECCA) was a three-year programme launched in 2012 supported by the United Nations Development Programme (UNDP) and the United States Agency for International Development (USAID). It included a series of technical training sessions interspersed with mentor-assisted, in-country applied research to enable trainees from ten countries in Asia to master key economic concepts and tools for adaptation planning and decision-making. ECCA addressed a consensus reached during a regional stakeholder consultation that a more comprehensive approach to mainstreaming climate change risks into planning processes was needed to ensure economically efficient climate change strategies at the sector, sub-national and national levels. The innovative programme aimed to identify and strengthen gaps in the economics of adaptation, an area that is critical for helping countries formulate national adaptation plans and access climate finance.

The programme targeted mid- and senior-level public sector officials from planning, finance, environment and other key ministries responsible for formulating, implementing and monitoring climate change programmes. They were grouped into multi-disciplinary country teams. The country teams participated in four regional workshops, each spanning a period of five days, which provided training on theory and the practical application of cost-benefit analysis, and introduced participants to modelling and forecasting based on sector analysis. Each regional training was interspersed with fieldwork application guided by microeconomists who served as mentors to the country teams. Together, these two principal programme components provided building blocks to guide participants through the theory, principles and application techniques of microeconomic analysis as related to climate change adaptation.

This report was prepared for the consideration of decision-makers in Viet Nam by the Viet Nam country team together with their economics mentor and ECCA project staff. With this training and hands-on experience, it is expected that the members of the country teams will play pivotal roles in mainstreaming climate considerations into future development planning, ultimately seeking to institutionalize these important analytical skills.

The training activities have contributed to a key area of technical assistance required by countries. This contribution is in line with the United Nations Framework on the Convention of Climate Change's (UNFCCC) guidelines for countries on the National Adaptation Plan (NAP) process, a process established under the Cancun Adaptation Framework (CAF) to help countries identify their medium- and long-term adaptation needs.

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The core team in Viet Nam was led by Thuy Truong as the economics mentor and includes Ms. Nguyen Thi Hien Thuan; Ms. Pham Thi Dung; Ms. Diep Pham; Mr. Ho Cong Hoa; Mr. Tung Hoang; Mr. Hoang Tung; Mr. Ngo Minh Tuan; Mr. Nguyen Truong Giang (ECCA Focal Point); Ms. Bui Thi Thu Hien; Ms. Nguyen Hoang Thuy; Ms. Nguyet.

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EXECUTIVE SUMMARY

The Capacity Building Programme on the Economics of Climate Change Adaptation (ECCA) is supported by United Nations Development Programme's (UNDP) Global Environmental Finance Unit, within the Bureau of Policy and Programme, Sustainable Development Cluster. It is rolled out in collaboration with the United States Agency for International Development's (USAID) Adapt Asia-Pacific Programme. The centrepiece of this project is a capacity-building programme aimed at strengthening the ability of technical officers from government ministries to understand the economics of adaptation as it relates to adaptation investment projects and medium- and long-term national, sub-national and sectoral development plans. The officers were selected from the Ministries of Planning and Finance, in addition to line ministries such as the Ministries of Environment, Agriculture, Water and Public Works, as well as several sub-national offices.

This report is prepared by a team of technical officers from Viet Nam and UNDP. The report sheds light on the vulnerabilities (in terms of economic costs) of the agriculture sector to climate change, taking a holistic approach that examines the impact of climate change on net revenue of farmers in the country. By using the net revenue per hectare of the farmers, rather than the yield of a particular crop, the report takes into consideration implicit adaptation efforts by farmers. The end goals of the report are threefold: (i) to estimate the economic costs and benefits of climate change impacts; (ii) to analyse the adaptation options available to the country; and (iii) to evaluate the potential impact of climate change on poverty rates in the country.

Understanding the economic costs and benefits of climate change at the micro and sectoral level requires detailed information of the sector and the potential vulnerabilities. While there have been numerous ad hoc reports aimed at understanding the impact of climate change on different economies, detailed data required for rigorous evaluation and understanding of the impact and optimal adaptation strategy are typically lacking. The results of this report and the policy responses proposed are based on detailed farm level information collected from this project. The data are representative of the agro ecological zones of the country and of farming livelihood in the country.

Viet Nam is located in South East Asia and is bound by the South China Sea to the east, Lao PDR and Cambodia to the west and China to the north. The agriculture sector plays a strategic role in the overall economy of the country. As the economy grows, the proportion of GDP from agriculture sector is declining. In 2015, agriculture still contributed 17 per cent of the GDP.[1] The main focus of the study is to examine questions such as 'what are the potential economic impacts of climate change on the agriculture sector? Given the projected nature and magnitude of these impacts, what key issues should policymakers be aware of when designing policy and strategic direction that will help the country's population better adapt to climate change?' A number of policy recommendations and conclusions could be drawn from the Economics of Climate Change Adaptation Viet Nam report.[2]

1 World Bank database, Agriculture, value added (% of GDP). http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?end=2015&locations=VN&start=2005&year_high_desc=false

2 Given the small but representative sample, the objective of this report is mainly to introduce a practical methodology on the economics of household adaptation.

This report sheds light on the vulnerabilities of the agriculture sector to climate change by examining the impact of climate change on net revenue of farmers in the country. By using observed net revenues per hectare of farmers, rather than concentrating on experimental data on yields of particular crops, a variety of adjustments that farmers make in response to a variety of actual determinants are taken into consideration, including climate. Consequently, the results provide an indication of the likely economic impact of climate change with and without adaptation.

Given that agriculture employs 47 per cent of that total population (as of 2013) climate change could have a direct impact of Viet Nam's labour market. In order for Viet Nam to increase the resilience of its agriculture sector, immediate actions need to be taken in order to anticipate climate change-induced impacts. Based on preliminary analysis, the report presents a set of policy recommendations that the Government and policymakers may wish to consider to address the challenges that farmers are likely to face as a result of climate change. Such recommendations include the development of new types of crops resistant to floods and droughts, particularly for the rain season. It is important that the Government strengthen research capacities to develop cultivars and techniques appropriate for local climates. Establishing early warning systems for extreme weather events as well as for droughts is also a necessary measure. Stronger extension support from input companies has also been effective. More generally, this report and the training that underpinned its preparation, represents a template that the Government of Viet Nam may wish to consider employing in the future as it prepares and refines climate policies and strategies for its main development sectors.

ACRONYMS

CMCC	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CMIP5	Coupled Model Intercomparison Project
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
IPCC	Intergovernmental Panel on Climate Change
NGO	non-governmental organisation
NR	net revenue
OLS	Ordinary Least Square
OPL	Official Poverty Line
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

INTRODUCTION

Climate change impacts across Viet Nam, as in other parts of the world, will affect the behaviour of economic agents and the outcomes of economic activities. Economists have developed models to study the impacts of climate change on the welfare of these economic agents, taking into account the agents' potential adaptation behaviours. These models have been helpful in forecasting economic outcomes and guiding against maladaptation.

In this report, a team of technical officers from Viet Nam and United Nations Development Programme (UNDP) estimate the impacts of climate change and analyse the adaptation strategies of economic agents in the agricultural sector of Viet Nam. The team analyses in particular how climate change will affect the net revenue and behaviour of farmers. The report provides insight into how changes in climate are likely to affect the welfare of local farms as well as the outcome of farms that are able to adapt to alternative and plausible climate regimes. Climate change impacts on the agricultural sector is important in the context of Viet Nam's pursuit of Sustainable Development Goals especially with regards to goals on poverty because it is a key component of the economy. The sector employs nearly half of the labour force (46.8 per cent as of 2014) (WDI, 2016). Any adverse impacts on the agriculture sector will therefore have significant implications on efforts that are underway to address poverty reduction and tackle inequality. The analysis contained in this report is based on primary data collected in 21 out of the 63 provinces in Viet Nam, spanning all the eight agro-ecological zones of the country.

The report is structured as follows. The first section 'Country Overview' provides a country overview on the geography and the agro-ecological zones in the context of relevance to the agriculture sector and likely climate change impacts. Application – Description of the Data introduces the survey and dataset and provides some brief summary statistics. Section 3 presents the models used to evaluate both the impact of climate change on agriculture and the adaptation behaviour of farmers. In Evaluating Climate Change Impact and Agriculture, the team presents the econometric model used to evaluate the impact of climate change on agriculture. The analyses include three components. First, the team applies the Ricardian model (a technique developed in the economics literature) to examine the impacts of climate change on net revenue of farmers (under current climate as well climate change conditions). Second, the team analyses the climate change adaptation strategies of the farmers. Finally, the team examines the impacts of climate change on farmers' choices of crops. The last chapter includes recommendations and conclusions.

COUNTRY OVERVIEW

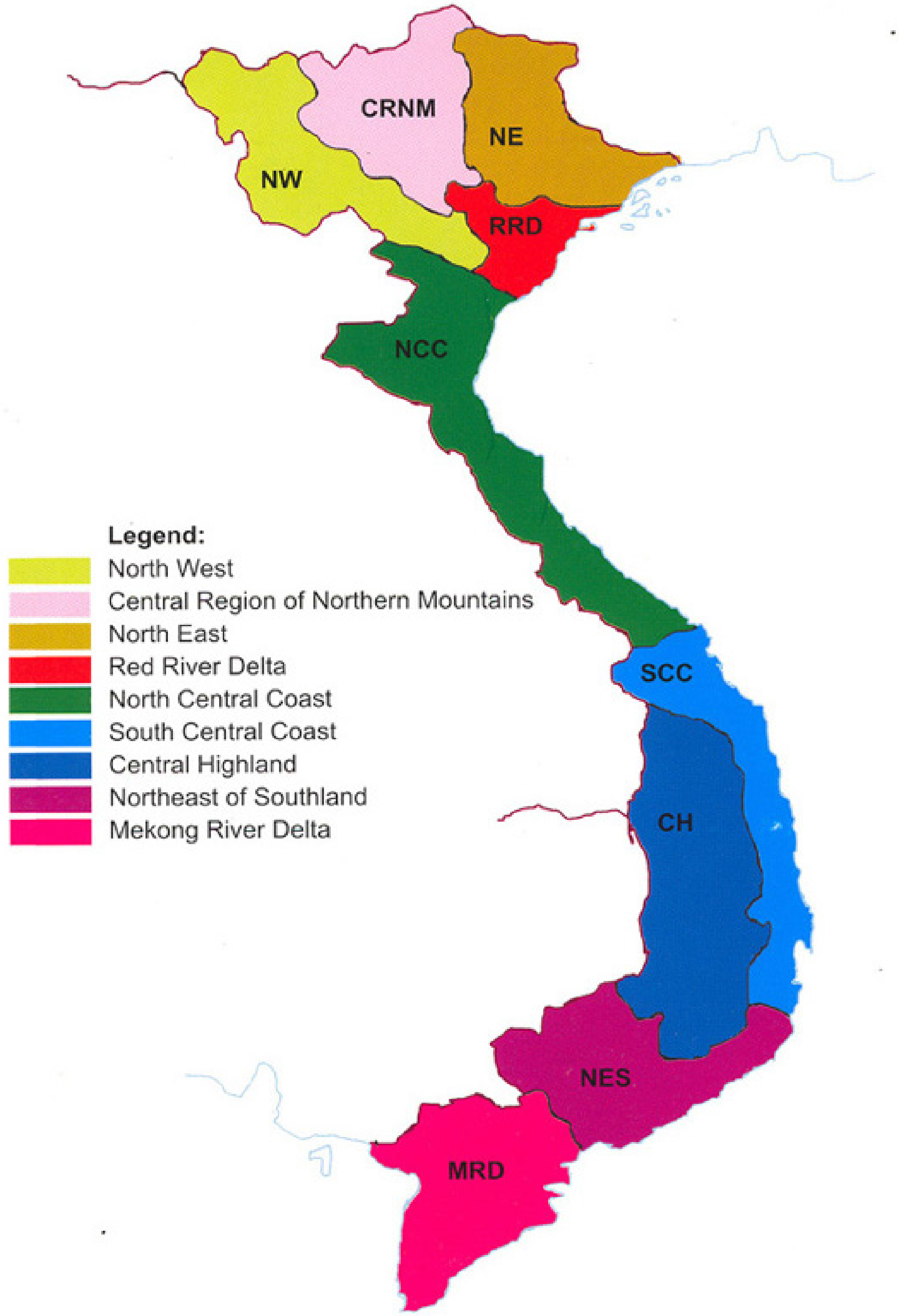
GEOGRAPHIC DESCRIPTION

Viet Nam is divided into the highlands and the Red River Delta in the north, and the Central Mountains (the Truong Son), the coastal lowlands in the central region, and the Mekong River Delta in the south (FAO, 2006). The elevation drops from the northwest to the southeast, reflecting the flows of the major rivers. Viet Nam has a dense river network, with 2,360 rivers over 10 km long. Its two largest rivers are the Red River in the northern region and the Mekong River in the southern region. These two rivers supply soils and nutrients for agricultural land. The river network also supplies over 310 billion cubic meters of water every year (Water Environment Partnership in Asia, n.d.). Despite the abundance of water, only about 20 per cent of the land is arable. The hills, which mainly are low hills, make up three-quarters of the total area; and the lowlands under 1,000 m accounts for 85 per cent of the total area (Averyanov et al. 2003).

The topography of the country is diverse, including such features as hills, mountains, plains, and coastline. Most of Viet Nam's mountains are relatively low and can be found in a 1,400 km range that extends from the northwest to the northeast. The tallest mountains are mainly located on the west and northwest, including the highest mountain in Indochina, Fansipan (3,143 m). The plains account for a quarter of the total land. On these plains, there is a chain of small deltas with a total area of 15,000 km2. There are two vast and fertile deltas as well, one in the north that covers 16,700 km2 and another one in the south that covers 40,000 km2.

In Viet Nam, there are nine main agro-ecological areas stretching from north to south, classified by topography, soils and climate (FAO, n.d.). The main agro-ecological zones are depicted in Figure 1.

Figure 1: Agro-ecological zones of Viet Nam

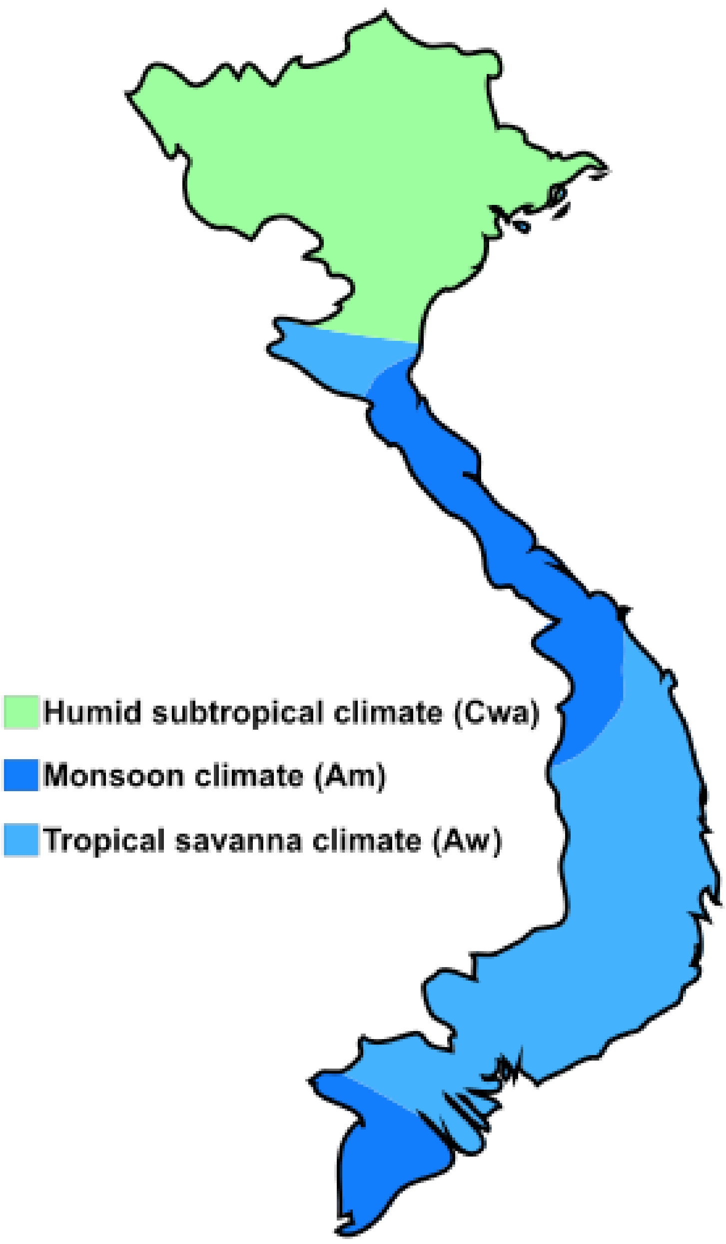


Source: FAO (2006).

CLIMATE

Viet Nam is located in the tropical belt and is hot and humid throughout the year. The climate of the country can be divided into three zones – a northern region, a central region, and a southern region. The climate of the country varies across the three regions. The climate is humid subtropical in the northern region, tropical monsoon in the central region, and tropical savannah in the southern region (Figure 2). Due to the country's varied terrain, Viet Nam has several sub-climate regions. Lao Cai Province in the northern region and Lam Dong Province in the southern region, for instance, have a temperate climate, whereas Son La province in the northern region enjoys a continental climate.

Figure 2: The climate zones in Viet Nam

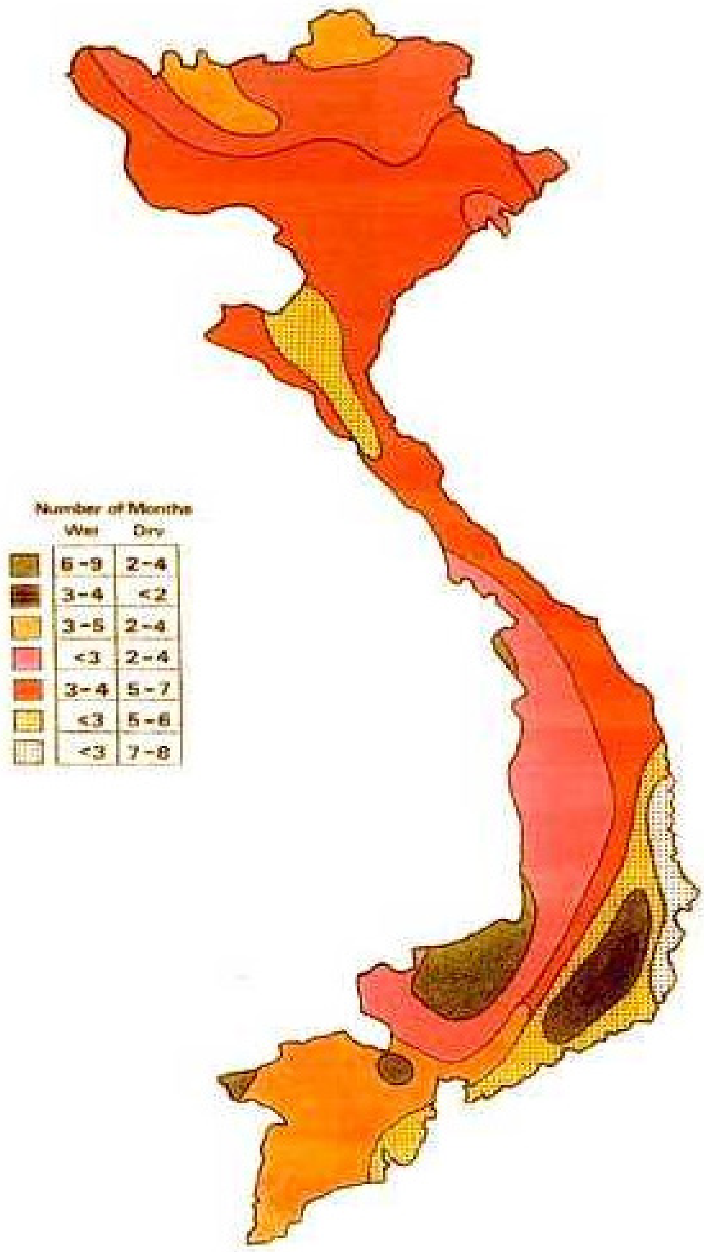


Source: Köppen-Geiger Classification.

CLIMATE SEASONS

Each of the three regions has slightly different seasons. In the southern region, there are two different seasons, a rainy season from November through April and a dry season from May to October. The northern region has four distinct seasons. The hot and rain season occurs from April to October, with the wettest period in July and August. The dry season runs from November to March, with the driest months being December and January. In the central region, the dry season occurs from November to April. Figure 3 shows the number of wet and dry months in the different regions of Viet Nam.

Figure 3: Number of wet and dry months in Viet Nam



Source: FAO, 2006.

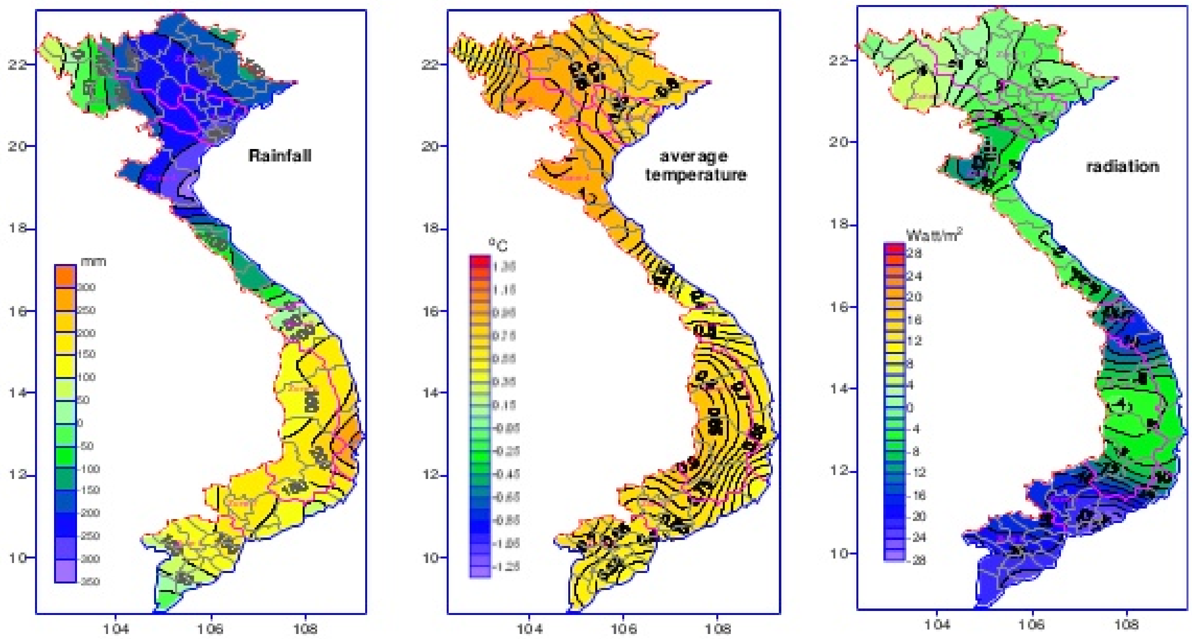
RAINFALL

Over the period of 1911-2000, the average annual rainfall throughout country ranged from 1,500 to 2,000 mm, and the humidity level ranges between 84 per cent and 100 per cent throughout the year. During La Niña climate conditions, in the northern climate zone there has been a decrease in annual precipitation, whereas in the southern zone there has been an increase (Thang, 2016). On average, precipitation in Viet Nam decreased by 2 per cent during the period 1958-2007 (FAO, 2011).

TEMPERATURE

Over the period of 1961 to 2010, the lowest temperatures in each region of Viet Nam had an increasing trend. Increased temperature was recorded at the Truong Sa meteorological station of 0.7°C per 10 years. There was an increase in the number of hot days up to 7.85 days per ten years at Tuyen Hoa station, Quang Binh Province (Field et al., 2012). Over the last 50 years, average annual surface temperature in Viet Nam has increased by 0.5°C to 0.7°C, as seen in Figure 4 (VACC, 2009). The mean temperature ranges from 21°C to 27°C and is higher in the southern parts of the country. Overall, the average annual temperature in the plains is slightly higher than in the highland and mountainous regions. The temperature drops to its lowest level (about 5°C on average) during the winter months of December and January, while it rises to its highest levels (more than 37°C on average) during April. In the summer, the average temperature is about 25°C. In some parts of the northern region, the temperature goes to 0°C and there is some snowfall (Government of Viet Nam, nd.).

Figure 4: Changes of precipitation, temperature, and solar radiation, 1971-2007

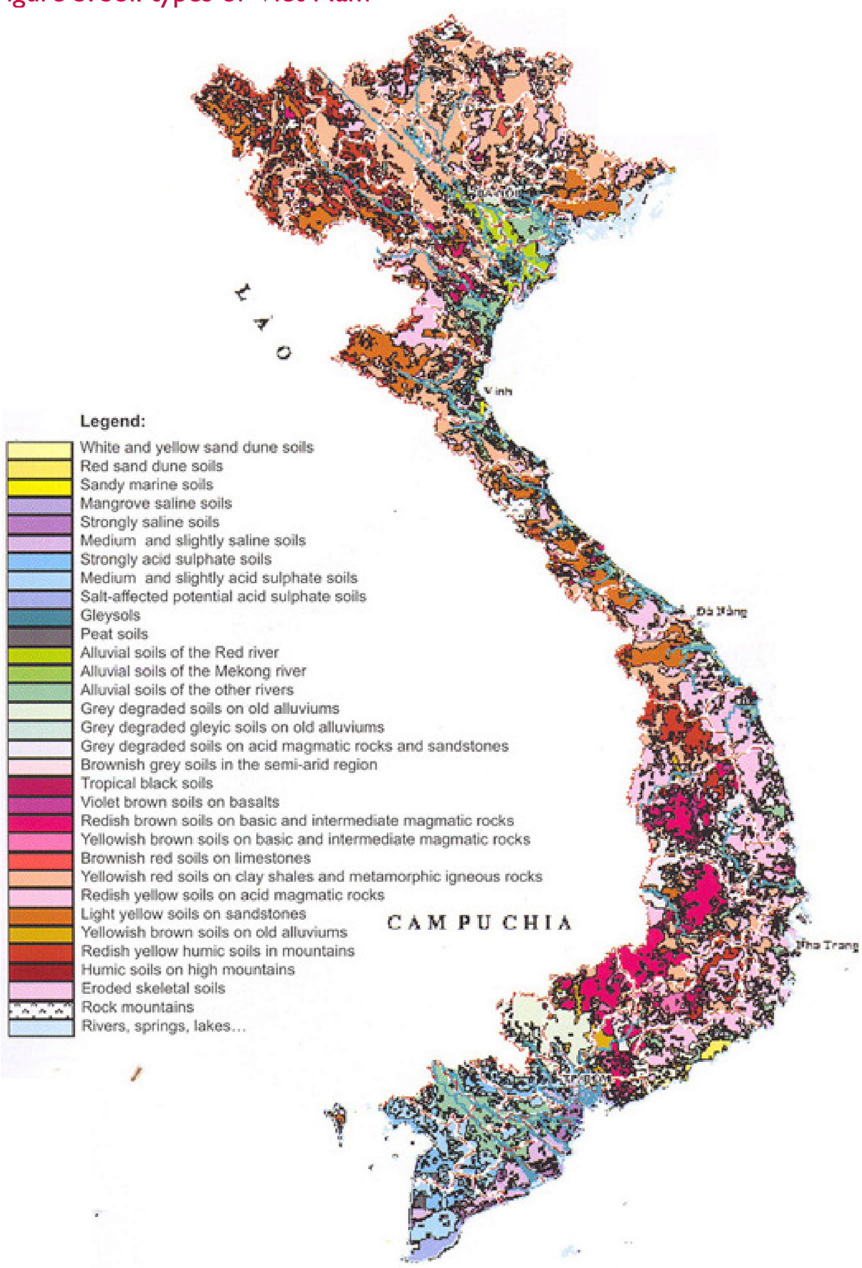


Source: Tingju and Trinh (2010).

SOILS IN VIET NAM

Soils in Viet Nam span 14 groups and 31 soil units. The three main soil groups are *mountainous and hilly* soils, and *delta* soils (FAO, 2006). The soils in the mountainous and hilly group are mostly *ferralitic* (14.2 million ha), *acrisol, alisol* (or red) (3.1 million ha). These soils degrade quickly and tend to be acidic with low fertility. They can be used for afforestation, for the expansion of perennial crops, and fruit crops. Separately, the soils in deltas are mostly *alluvial* soils (3.4 million ha), *marine sandy* soils (0.5 million ha) and *gley* soils (0.5 million) (IPNI n.d.). These soils are very fertile and are effective for intensive cultivation. Figure 5 shows the soil map of Viet Nam in more detail.

Figure 5: Soil types of Viet Nam



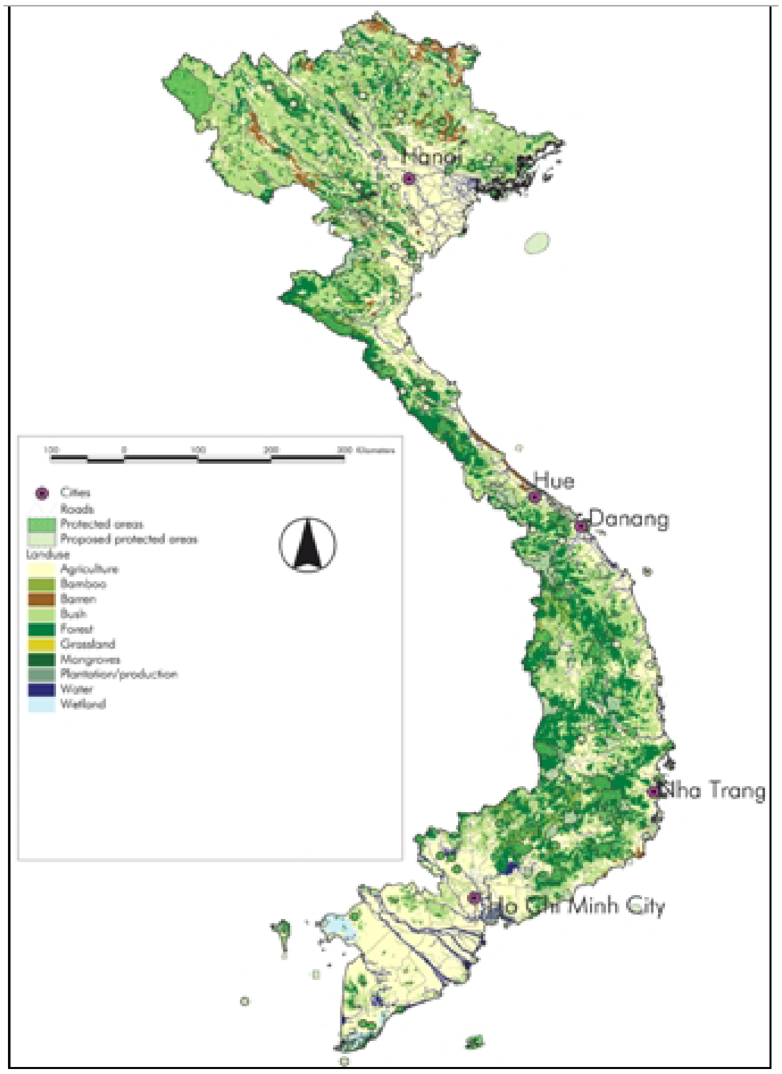
Source: Centre of Database Establishment for Environmental Resources in Viet Nam, Geography Institute, 1999.

AGRICULTURE IN VIET NAM: CURRENT ROLE AND SITUATION ANALYSIS

Viet Nam is a lower middle income country with income per capita of US$5,628.95 per year in 2014. The mean annual GDP growth in the period from 2002 to 2014 was 6.37% (WDI, 2016). The country's score on the human development index (HDI) in 2014, at 0.666, ranked 116th out of 188 countries and territories (UNDP, 2015). Viet Nam's HDI is below the mean HDI value of 0.71 for nations in East Asia and the Pacific.

The agricultural sector is an important foundation for economic development in Viet Nam. Half of all employees in the country work in the agricultural sector, which accounted for an average of about 20 per cent per cent of GDP from 2002-2014 (WDI, 2016). The GDP share of the agriculture sector dropped slightly from 18.38 per cent in 2013 to 18.11 per cent in 2014 (WDI, 2016). Farms are mostly small scale, with an average farm size of 0.8 ha, and there are few large commercial farms. Within the agricultural sector, the sub-sector of paddy continuously plays an important role, while the sub-sectors of livestock and plantation (i.e. tea, coffee, rubber, pepper) have recorded positive growth in recent years.

Figure 6: Land use map of Viet Nam



Source: icem.

Agricultural land use in Viet Nam can be divided into two types, one for short-term cultivation (e.g. rice, corn, potato, cassava) and another for the long-term cultivation (e.g. tea, coffee, rubber, pepper). The three cultivation seasons for rice and other short-term plants are spring (*Dong xuan*), winter (*Thu dong*) and autumn (*He thu*). In recent years, farmers have begun to plant a smaller area in paddy crops and instead plant of longer-cultivation industrial crops, generally because the price of these crops has increased (General Statistics Office of Viet Nam, 2016).

VULNERABILITIES TO CLIMATE CHANGE

Due to Viet Nam's long coastline and deltas in coastal areas, the country is one of five countries to be most affected by the negative impacts of climate change (e.g. floods, salt intrusions, and drought) (e.g. World Bank, 2015; Dasgupta et al 2010). Viet Nam's vulnerability score, which measures the country's sensitivity and ability to adapt to climate change, is 0.446, 106 out of all countries and territories (GAIN, 2015).[3]

The anticipated problems from climate change in Viet Nam stem from a combination of the increase in temperature, rising sea level, and increasing variability of rainfall (Dzung et al., 2014). Over the past 50 years, the mean temperature in Viet Nam has increased between 0.5°C and 0.7°C (IPONRE, 2009). Based on a simulation method for investigating the impact of climate change on food production, the temperature is projected to increase by 0.3°C to 2.5°C by 2070 (Asian Disaster Preparedness Center, 2003). Johnston et al. (2010) project that this increase in temperature will decrease agricultural output due to a greater presence of pests and diseases.

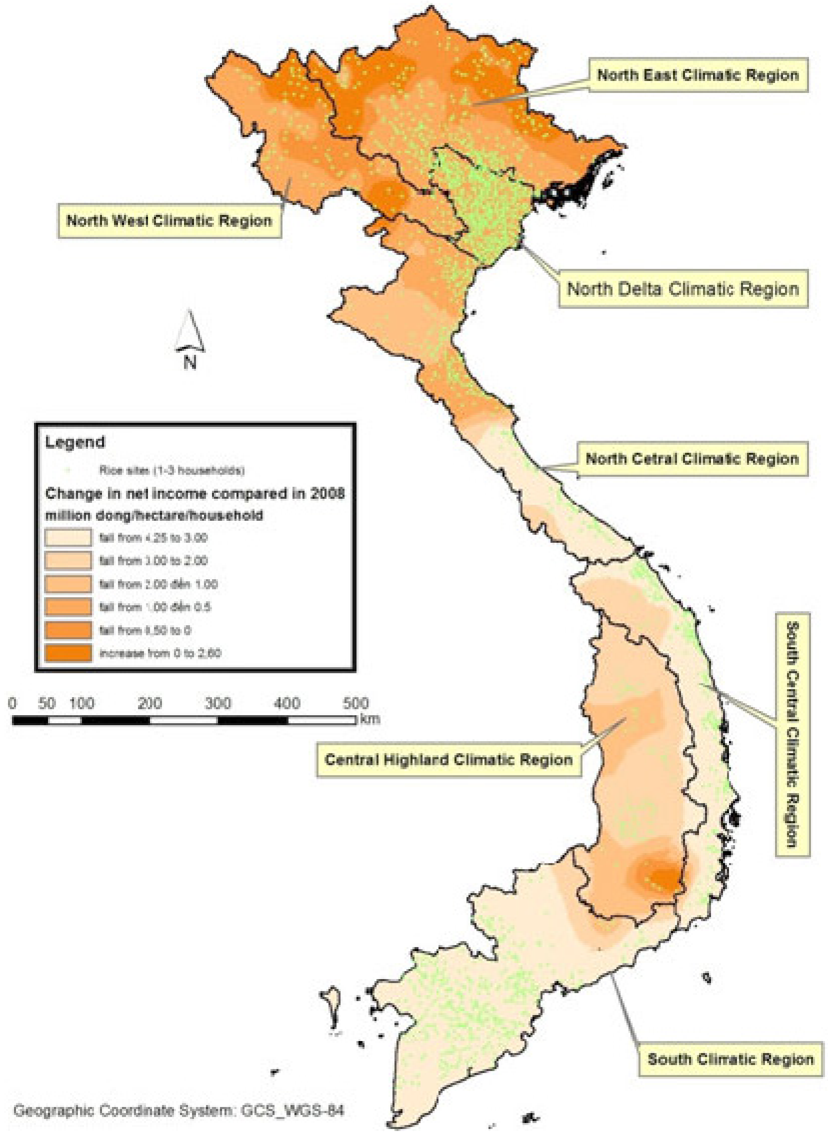
PADDY SUB-SECTOR

Viet Nam's agriculture, the country's food security, and rural households' livelihoods all rely on rice farming (Vu and Glewe, 2008). Many other countries rely on rice from Viet Nam as well given that the country is the second largest rice exporter in the world (FAO, 2016). Approximately 50 per cent of all rice grown in Viet Nam, and 90 per cent of the total rice export, is grown in the Mekong Delta.

According to the Viet Nam's Assessment Report on Climate Change, the cultivation areas in the Mekong and Red Deltas will be influenced by the extent of salt water intrusion from rising sea levels. Moreover, flood inundation and droughts could happen more frequently because of the variability of rainfall intensity (IPONRE, 2009). According to research conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Viet Nam, rice production is projected to decrease 15 per cent by 2050 owing to climate change.

3 The high vulnerability score and high readiness score of Viet Nam place it in the upper-right quadrant of the ND-GAIN Matrix. It is in the process of responding effectively to climate change, but the adaptation needs and urgency to act are greater. Viet Nam is the 77th most vulnerable country and the 82nd least ready country.

Figure 7: Predicted climate change impacts



Source: Pham, 2012.

PLANTATION CROPS

The plantation sector relies on tea, coffee, pepper, and rubber, all of which are high-value crops, are mainly planted in the Central Highlands of the country. This region will be significantly affected by adverse climates in the future. In particular, its rivers and channels are predicted to become exhausted in the future, which would lead to disadvantages for plantation crops. Annual run-off projections for 2070 for the Red River and the Mekong River are expected to increase. An increase in the range of 5.9 per cent to 19 per cent is expected for the Red River and from 4.2 per cent to 14.5 per cent for the Mekong River, respectively. Droughts have been increasingly frequent over the past 50 years, particularly in the Northern mountainous area and the Red River Delta. Frequent droughts events and flood retention volume of reservoirs below the intended level has contributed to the lowest water level of the Red River recorded in 2004.[4] Floods, especially flash floods, will remain a perpetual threat

4 See www.ais.unwater.org/ais/pluginfile.php/597/mod_page/content/79/Vietnam.pdf

in the rain season. Moreover, higher temperatures are expected to give rise to pests and diseases to crops and livestock (IPONRE, 2009).

LIVESTOCK SECTOR

The primary livestock and poultry species in Viet Nam are chicken, duck, buffalo and beef cattle. Further increases in temperature will have a direct effect on livestock, by decreasing water availability and increasing the occurrence of natural diseases. Using IPCC AR4 simulation data for climate in the future, Viet Nam's climate change vulnerability profile indicates that the annual average temperature in all regions will increase by 1.3°C to 1.6°C, 1.6°C to 1.9°C, and 1.9°C to 2.2°C for 2050, 2070 and 2100, respectively.

POSSIBLE IMPACTS OF CLIMATE CHANGE ON THE DIFFERENT AGRO-ECOLOGICAL ZONES OF VIET NAM

The following is based on IPCC AC4 scenario, Special Report on Emission Scenarios (SRES) scenarios of greenhouse gas emission trends (Viet Nam Assessment Report on Climate Change, 2009).

NORTH EAST AND NORTH WEST

In the North East and North West regions, the hot season is projected to grow longer and the cold season, shorter in all regions. Fewer cold fronts will penetrate into the North East through the North West. The temperature in the next decades will be higher than the baseline of temperature in the previous decades. Since the increased temperature will lead to increased evaporation, water shortages are projected to become more common and the frequency and intensity of droughts are projected to rise. It is highly likely that, as a result, there will be negative effects on the productivity and quality of both crops and livestock.

RED RIVER DELTA

Similar to the North West and North East regions, cold fronts will become less frequent in the coming years. The average temperature will be higher than the baseline level of the previous decades, which may cause the evaporation rate to rise. By 2070, rainfall in the Red River is expected to increase within the range of 5.8 per cent to 19 per cent. Low-flow changes are expected to change in the range of -10.3 per cent to 14.5 per cent. The decline of annual run-off will be more severe for low-flow periods. It is also very likely that there will be more droughts in the future, which will increase the production costs of crops (IPONRE, 2009).

In addition, tropical cyclones are predicted to become more intense and more frequent. The stormy season may become unstable and arrive before June and last until November or December. The sea level is projected to rise between 0.5 and 0.6 cm per year, a faster rate than previous years. This sea level rise will cause seawater to penetrate further into the Red River Delta, and it will decrease the area of mangrove in the coastal areas.

NORTH CENTRAL COAST AND SOUTH CENTRAL COAST

The sea level along Viet Nam's coastline is expected to rise about 0.5-0.6 cm per year, leading to a reduced area of mangrove forests and further coastal erosion. This will also cause difficulties for fishermen, because it would lead to a decrease in fish population. The frequency and intensity of tropical cyclones penetrating into the central coast delta is projected to rise in the coming decades. Moreover, the stormy season, which begins before August and last until December, will fluctuate more significantly. The amount of annual rainfall in the Central Coast delta will increase in the coming decades, while the amount of drizzly rain could decrease in the North Central Coast in particular.

Additionally, the average surface air temperature will increase in the coming decades, and the quantity and duration of extreme climate spells (i.e. high temperatures) will increase. The hot and dry westerly wind season may arrive earlier and end later. Evaporation rates will increase, contributing to an increased frequency and intensity of droughts. As a result, droughts and water shortages will become serious problems, affecting the agricultural sector and normal life.

SOUTHERN COASTAL AND CENTRAL HIGHLANDS

The southern coastal region will also experience more frequent and intense tropical cyclones and less frequent cold fronts. The normal surface air temperature is projected to be higher than in previous years. Moreover, the hot season will grow longer in middle and low mountainous areas, while the cold season in middle and high mountainous areas may be shorter. In terms of precipitation, rainfall will rise in the rain season and will become more variable in the dry season. Meanwhile, areas of highest rainfall will concentrate in some centres (i.e. Bao Loc and Phuoc Long) and lowest rainfall areas will be Ayunpa and Dak Lay. In addition, evaporation rates will increase in comparison with past decades, contributing to a rise in the frequency and intensity of droughts.

These changes will directly influence the socio-economic activities in the Central Highlands. In particular, the volume of the annual currents of rivers may decrease in the coming years, and flash floods will continue to be a permanent threat in some areas during the rain season. However, there may be water shortages due to droughts, leading to a reduced productivity and quality of agricultural production. There will be benefits to developing industrial trees in central places in which current conditions are below tropical standards.

SOUTHEAST AND MEKONG RIVER DELTA

Climate change issues in these regions will be similar to the regions discussed above, stemming from a combination of rising sea level, increased temperatures, and more intense and more frequent tropical cyclones. These issues will affect the socio-economic activities in the south of Viet Nam. Future precipitation trends are expected to increase in the range of 4.2 per cent to 14.5 per cent, by 2070 (ISPONRE, 2009). Moreover, higher temperatures will cause higher rates of evaporation, which will lead to stronger demands for irrigation water and higher production costs. Importantly, salinity intrusion will be a serious problem in the Mekong River Delta, which will affect the productivity as well as quality of rice crops.

APPLICATION – DATA DESCRIPTION

SAMPLING

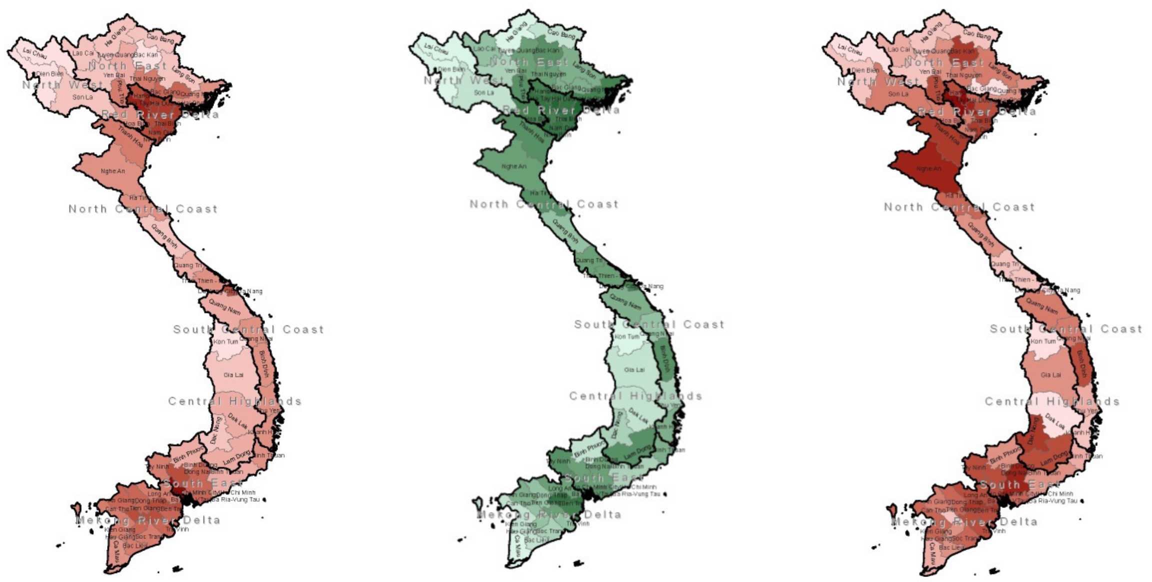
This case study of Viet Nam is part of a larger project that involves an additional eight countries including Sri Lanka, Bangladesh, Thailand, Nepal, Cambodia, Lao PDR, Indonesia, and Mongolia. Data in each country was collected by national teams. The countries are part of the UNDP-USAID Capacity Building Programme on the Economics of Climate Change Adaptation.

Table 1: Agro-ecological zones of Viet Nam

No.	Zone	Number of provinces	Area (million ha)
1.	North West	6	10.2
2.	North East	9	
3.	Red River delta	11	1.2
4.	North-central coast	6	5.2
5.	South Central Coast	6	7.5
6.	Central highlands	5	5.6
7.	South East	8	2.4
8.	Mekong River delta	13	4.0

Source: Author's calculation based on General Statistics Office of Viet Nam (2013).
Note: *The figure represents the combined area of North East and North West.

Figure 8: The eight agro-ecological zones of Viet Nam, shaded by population density, cropping productivity, and livestock productivity



Source: Calculated and generated from Statistical Yearbook of provinces in Viet Nam (2013).

In each country, the team surveyed households that were involved in at least one of the two agricultural activities, growing crops and raising livestock.

Survey locations were selected to cover each of the ago-ecological zones present across Viet Nam in the context of agriculture production. In each location, the Viet Nam country team surveyed 18 households. The number of surveyed locations and households are presented in Table 2.[5]

Table 2: Number of surveyed households

Agro-ecological zone	Number of provinces	Number of surveyed districts	Number of surveyed households
North West	6	2	36
North East	9	2	36
Red River Delta	11	3	54
North Central Coast	6	2	36
South Central Coast	6	2	36
Central Highlands	5	1	18
South East	8	3	54
Mekong River Delta	13	4	72
Total	64	19	342

The following procedure was used to choose households:

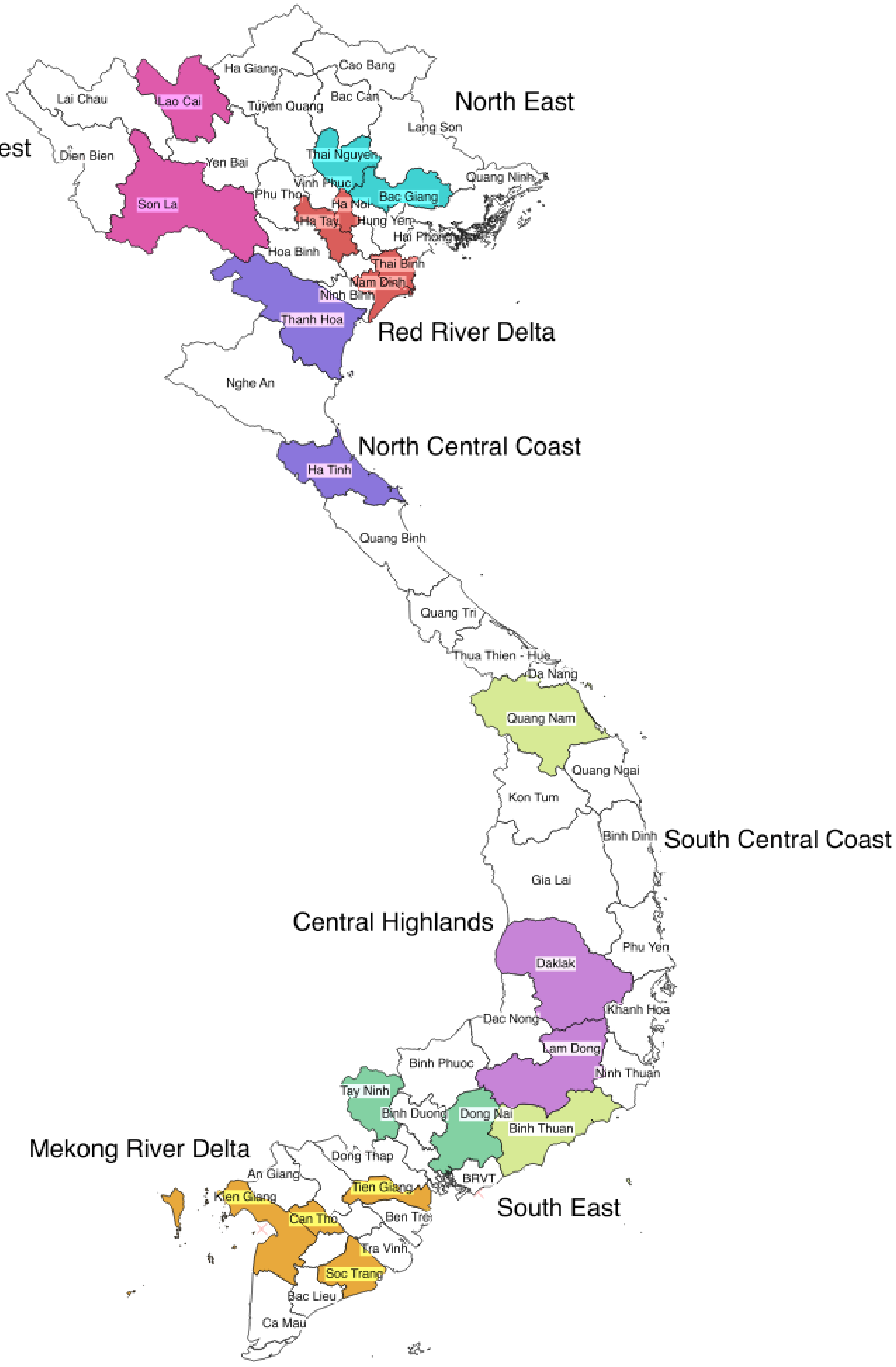
1. The team chose the provinces to be surveyed. The provinces are considered to be the survey locations.
2. In each chosen province/location, the team chose one district, taking into consideration that the district should be relatively representative for the province.
3. In each chosen district, the team randomly selected three villages.
4. In each village, the team surveyed six households that were clustered.

As a result of this procedure, the team surveyed 18 households in each district.

The selected agro-ecological zones are presented in Table 2. The selected provinces are summarized and shaded in Figure 9.

5 Please note that climate change adaptation options vary by ecological zone, particularly for the agriculture sectors. Precision of estimates can be improved with more sample but the data was collected to be representative of the agro-ecological zones and should be representative at that level.

Figure 9: Selected provinces for the survey



Out of the 342 surveyed households, the team obtained 323 usable questionnaires, of which 306 cover households with cultivation activities.

Figure 10: Locations of households used in the survey

INFORMATION COLLECTED IN THE QUESTIONNAIRE

Data from households were collected using a questionnaire that was administered by a Vietnamese team. The questionnaire was designed to collect the following information:

1. Past experience on climate change, communications and adaptation response: The team collected data on farmers' perceptions of climate change and on farmers' current sources of information.

2. Detailed farming area information: The team asked about farm planting area, fallow land area, and the division of plots by crop and other livelihoods by the household.

3. Household information: The team collected detailed information on the farm occupations of those in each household, the level of technology within each household, the gender roles within each household, and each household's access to basic infrastructure. The team also inquired about the level of education of the head of household.

4. Components needed to calculate net revenue of the farmer (crop and livestock): The team gathered information on labour available to the household, the type of crops grown by each farmer, the growing season of different crops, the cost and amount used of different inputs (such as fertilizer, pesticide, seed, irrigation and machinery), and the relevant, parallel information for livestock farmers.

5. GPS locations for geo-spatial information and analysis: The team kept detailed records of where each survey was conducted.

6. Detailed information on extension services: The team collected information on extension services provided by private extension groups, non-government organizations (NGOs), central government agencies, cooperatives and local government, in the hope of eliciting potential policy tools available to help aid adaptation.

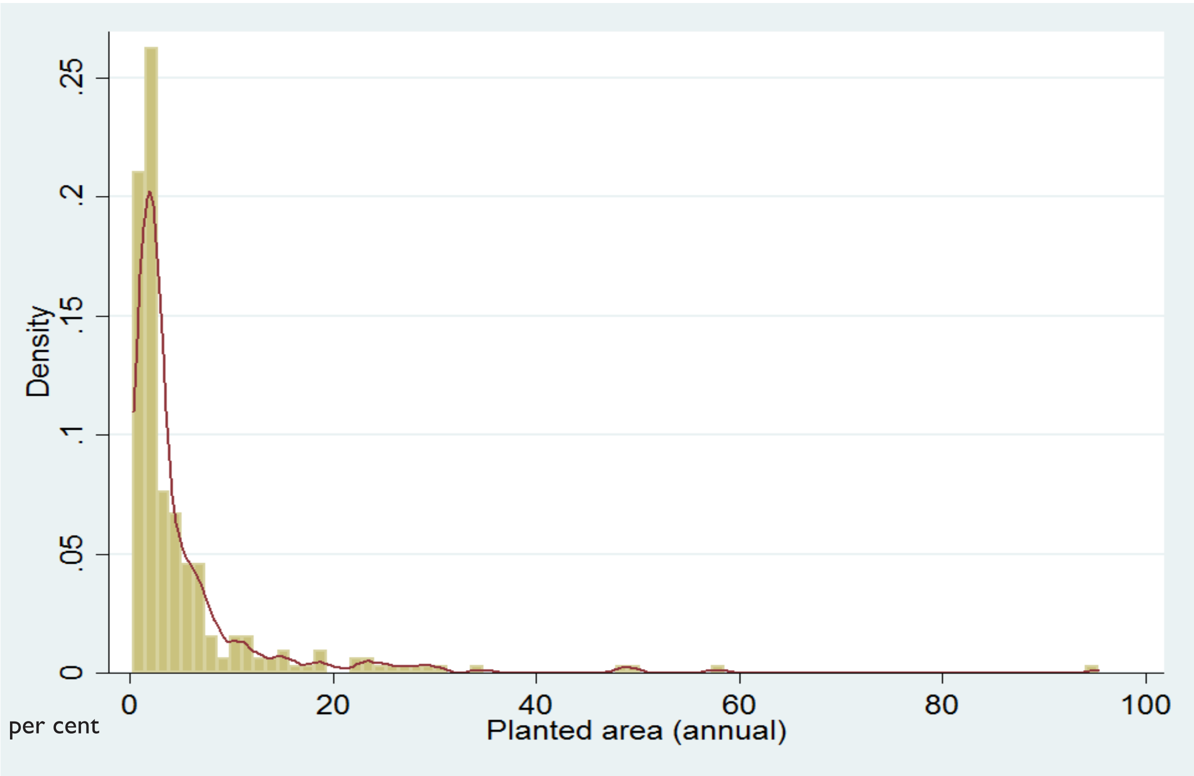
As shown in Table 3, the households in the survey have about 27 years of farming experience ranging from one year to 60 years. The average household size is four, ranging from one to 13. The heads of household have an average of 7.5 years of education with access to electricity by almost all the households. In terms of access to information and telecommunication technology, the majority (96 per cent) of the respondents have a telephone, although only 20 per cent have a computer and 15 per cent have access to the Internet.

On average, the respondents owned 7.4 acres of land (2.96 ha) with the majority of planted crops in two seasons, while a few planted all the three seasons. The average annual planted area across the three seasons is 5.5 acres (Figure 11), with 2 acres left fallow, on average. A third of the farmers have less than 2 acres of planted area, while nearly 15 per cent of farmers planted more than 10 acres.

Table 3: Summary statistics on the households

Variable	Number of observations	Mean	Std. dev.	Min	Max
Experience	306	27.96	11.77	1	60
Household size (members)	306	4.03	1.75	1	13
Age of household (HH) head	306	52.86	10.75	23	94
Schooling years of HH head	306	7.46	3.21	0	16
Access to electricity (yes = 1)	306	1	0.06	0	1
Has telephone (yes = 1)	306	0.96	0.19	0	1
Computer (yes = 1)	306	0.2	0.4	0	1
Internet (yes = 1)	306	0.15	0.35	0	1
Extension local government	306	0.32	0.47	0	1
Extension input company	306	0.27	0.44	0	1

Figure 11: Distribution of annual planted area (ha)



Note: The team included a kernel density estimate to the graph.

Table 4 describes acreage planted by season. The spring season (which is from November/December to March/April) is when most planting occurs. The autumn season is also an important planting season, while very few households planted during the winter season. The seasonal data reveals the importance of having more than one season to grow crops. If there were just one season, Vietnam would have just 3 ha per farm. But with three seasons, Viet Nam has effectively 7.4 ha per farm. The greater number of growing seasons contributes to the high net revenue per ha (US$489).

Table 4: Planted area in acres and net revenue per acre

Variable	Obs	Mean	Std. Dev.	Min	Max
Planted area in spring	276	3.06	5.42	0.00	49.42
Planted area in autumn	276	1.94	4.29	0.00	47.69
Planted area in winter	276	0.54	1.47	0.00	9.88
Total planted area	276	7.36	13.74	0.36	148.26
Net revenue (USD/acre)	276	488.99	439.91	-366.39	2303.17

Table 5 summarizes the distribution of land by province. Not every province can grow crops in multiple seasons. Provinces that can take advantage of multiple seasons tend to have much greater acreage per farm such as Binh Thuan (12.8 ha), Can Tho (14.7 ha) and Kien Giang (29.6 ha). Some provinces can only support a single growing season and they tend to have much lower effective acreage per farm such as Dong Nai (4.1 ha) and Lam Dong (4.7)). But most provinces can at least support two seasons of crops.

Planted area also varies by type of crops grown and seasons, as summarized in table 6. Rice is the primary crop grown in Viet Nam accounting for 70 per cent of the effective acreage in the sample. It is evenly divided between the spring with 1.25 ha/farm and the autumn with 1.10 ha/farm with just 0.3 ha/farm in the winter. Cereal is the next most important crop by area, accounting for 14 per cent of the effective acreage in the sample. Similar to rice, the two largest seasons for cereal are the spring and autumn with just a small contribution in the winter. The remaining crops account for relatively less acreage: plantation (10 per cent), vegetables (5 per cent) and fruit (4 per cent). All the remaining crops primarily grow in the spring.

Table 5: Distribution of land size by province

Province	Variable	Observation	Mean	Min.	Median	Max.
Bac Giang	Planted area season 1	13	1.94	0.71	1.42	5.39
	Planted area season 2	13	0.42	0.00	0.44	1.07
	Planted area season 3	13	0.03	0.00	0.00	0.44
	Planted area total	13	2.40	0.98	1.96	5.83
Ben Tre	Planted area season 1	8	1.30	0.49	0.99	2.47
	Planted area season 2	8	0.59	0.00	0.25	2.47
	Planted area season 3	8	0.46	0.00	0.00	2.47
	Planted area total	8	2.35	0.74	1.36	7.41
Binh Thuan	Planted area season 1	10	5.21	0.99	4.57	14.83
	Planted area season 2	10	3.81	0.00	3.09	9.88
	Planted area season 3	10	3.81	0.00	3.09	9.88
	Planted area total	10	12.82	2.47	9.88	34.59
Can Tho	Planted area season 1	6	4.91	2.97	5.03	6.42
	Planted area season 2	6	4.91	2.97	5.03	6.42
	Planted area season 3	6	4.91	2.97	5.03	6.42
	Planted area total	6	14.73	8.90	15.09	19.27
Dak Lak	Planted area season 1	11	3.64	0.74	2.97	11.61
	Planted area season 2	11	1.91	0.00	1.24	7.41
	Planted area season 3	11	0.94	0.00	0.00	3.71
	Planted area total	11	6.49	2.97	4.94	19.03
Dong Nai	Planted area season 1	12	4.14	1.98	3.09	7.41
	Planted area season 2	12	0.00	0.00	0.00	0.00
	Planted area season 3	12	0.00	0.00	0.00	0.00
	Planted area total	12	4.14	1.98	3.09	7.41
Dong Thap	Planted area season 1	7	1.80	1.05	1.61	2.97
	Planted area season 2	7	1.72	0.80	1.61	2.97
	Planted area season 3	7	0.55	0.00	0.00	2.22
	Planted area total	7	4.07	1.85	4.45	6.67
Ha Noi	Planted area season 1	17	0.93	0.53	0.89	1.78
	Planted area season 2	17	0.92	0.53	0.89	1.78
	Planted area season 3	17	0.14	0.00	0.00	0.89
	Planted area total	17	1.99	1.07	1.78	4.00
Ha Tinh	Planted area season 1	17	0.89	0.49	0.86	1.36
	Planted area season 2	17	0.88	0.49	0.86	1.36
	Planted area season 3	17	0.00	0.00	0.00	0.00
	Planted area total	17	1.77	0.99	1.73	2.72
Kien Giang	Planted area season 1	13	15.38	0.00	13.59	47.69
	Planted area season 2	13	13.92	1.24	12.36	47.69
	Planted area season 3	13	0.29	0.00	0.00	3.71
	Planted area total	13	29.58	2.72	27.18	95.38

Table 5: Distribution of land size by province (cont.)

Province	Variable	Observation	Mean	Min.	Median	Max.
Lam Dong	Planted area season 1	15	4.68	1.73	3.21	9.88
	Planted area season 2	15	0.00	0.00	0.00	0.00
	Planted area season 3	15	0.00	0.00	0.00	0.00
	Planted area total	15	4.68	1.73	3.21	9.88
Lao Cai	Planted area season 1	16	2.01	0.27	1.70	4.60
	Planted area season 2	16	0.24	0.00	0.00	1.07
	Planted area season 3	16	0.06	0.00	0.00	0.44
	Planted area total	16	2.30	0.53	2.29	5.93
Nam Dinh	Planted area season 1	17	1.01	0.36	0.89	2.67
	Planted area season 2	17	1.01	0.36	0.89	2.67
	Planted area season 3	17	0.13	0.00	0.00	0.62
	Planted area total	17	2.14	0.71	1.78	5.34
Quang Nam	Planted area season 1	17	0.71	0.25	0.74	1.36
	Planted area season 2	17	0.71	0.25	0.74	1.36
	Planted area season 3	17	0.05	0.00	0.00	0.62
	Planted area total	17	1.47	0.49	1.54	2.72
Soc Trang	Planted area season 1	11	4.86	1.93	3.21	11.86
	Planted area season 2	11	4.86	1.93	3.21	11.86
	Planted area season 3	11	2.96	0.00	2.25	8.03
	Planted area total	11	12.68	5.78	9.64	24.09
Son La	Planted area season 1	17	3.41	0.00	1.73	15.20
	Planted area season 2	17	3.40	0.30	2.47	12.36
	Planted area season 3	17	0.03	0.00	0.00	0.25
	Planted area total	17	6.84	2.97	5.56	15.57
Tay Ninh	Planted area season 1	13	7.46	0.74	4.08	49.42
	Planted area season 2	13	1.62	0.00	0.74	5.68
	Planted area season 3	13	0.00	0.00	0.00	0.00
	Planted area total	13	9.08	0.99	5.93	49.42
Thai Binh	Planted area season 1	16	0.68	0.18	0.62	1.51
	Planted area season 2	16	0.67	0.18	0.62	1.51
	Planted area season 3	16	0.08	0.00	0.00	0.81
	Planted area total	16	1.44	0.36	1.25	3.20
Thai Nguyen	Planted area season 1	16	0.86	0.36	0.85	1.60
	Planted area season 2	16	0.63	0.00	0.53	1.60
	Planted area season 3	16	0.14	0.00	0.00	0.80
	Planted area total	16	1.63	0.44	1.47	3.20
Thanh Hoa	Planted area season 1	18	0.89	0.18	0.86	3.09
	Planted area season 2	18	0.97	0.18	0.86	3.09
	Planted area season 3	18	0.41	0.00	0.37	0.99
	Planted area total	18	2.27	0.53	2.15	6.18

Table 5: Distribution of land size by province (cont.)

Province	Variable	Observation	Mean	Min.	Median	Max.
Tien Giang	Planted area season 1	6	2.32	1.48	1.72	4.94
	Planted area season 2	6	1.50	0.00	0.74	4.94
	Planted area season 3	6	1.50	0.00	0.74	4.94
	Planted area total	6	5.33	1.48	3.09	14.83
Total	Planted area season 1	276	3.06	0.00	1.33	49.42
	Planted area season 2	276	1.94	0.00	0.79	47.69
	Planted area season 3	276	0.54	0.00	0.00	9.88
	Planted area total	276	5.54	0.36	2.47	95.38

Table 6: Land size by primary crops grown

Crops	Variable	Obs.	Mean	Min.	Median	Max.
Rice	Planted area season 1	444	1.25	0.00	0.40	19.30
	Planted area season 2	444	1.10	0.00	0.36	19.30
	Planted area season 3	444	0.31	0.00	0.00	4.00
	Planted area total	444	2.65	0.14	0.90	38.60
Cereal	Planted area season 1	115	1.00	0.00	0.43	6.15
	Planted area season 2	115	0.81	0.00	0.40	5.00
	Planted area season 3	115	0.39	0.00	0.14	4.00
	Planted area total	115	2.20	0.20	1.30	14.00
Vegetables	Planted area season 1	73	0.74	0.05	0.40	4.00
	Planted area season 2	73	0.38	0.00	0.29	2.75
	Planted area season 3	73	0.10	0.00	0.00	1.50
	Planted area total	73	1.22	0.05	0.96	5.00
Fruit	Planted area season 1	49	1.10	0.11	0.80	3.00
	Planted area season 2	49	0.26	0.00	0.00	2.30
	Planted area season 3	49	0.07	0.00	0.00	2.00
	Planted area total	49	1.43	0.25	1.00	6.50
Plantation crops	Planted area season 1	73	1.84	0.00	1.00	20.00
	Planted area season 2	73	0.39	0.00	0.00	5.00
	Planted area season 3	73	0.11	0.00	0.00	4.00
	Planted area total	73	2.34	0.18	1.30	20.00
Total	Planted area season 1	754	1.21	0.00	0.44	20.00
	Planted area season 2	754	0.86	0.00	0.35	19.30
	Planted area season 3	754	0.27	0.00	0.00	4.00
	Planted area total	754	2.33	0.05	0.97	38.60

Gross revenue is calculated by multiplying the price times the quantity of each crops sold and summing across all crops and seasons. Net revenue is gross revenue minus the costs of production. All major costs of production are included except the cost of household labour provided by the farm family. Net revenue is estimated per acre of annual planted area.[6] The average net revenue is US$489 per ha, ranging from – US$366 to US$2,303. Approximately 6.5 per cent of the households used in the analysis had a negative net revenue in the year of the survey, i.e. their costs exceeded their revenues.

Table 7 reveals the distribution of gross revenue and cost for farmers in Viet Nam depending on whether they were profitable or not. Farmers with losses had slightly higher costs ($100/ha) than farmers with profits. The farmers with losses, however, had $560 lower gross revenues than farmers with profits. It is likely that the farmers with losses suffered a major setback in yields that year from either bad weather or pests.

Table 7 also gives a perspective on the gross revenue and costs of farmers. Gross revenue averaged US$842/acre across the sample. Costs averaged US$352/acre. The highest cost item was fertilizer ($258/acre), followed by hired labour (US$55). It should be noted that this cost did not include own labour. Machinery cost ($37/acre) for irrigation was almost free of charge at US$3/ha.

Table 7: Revenue and cost distribution of farmers by profit and loss

Profit distribution	Variable	N	Mean	Min.	25th percentile	Median	75th percentile	Max.
Loss	Net revenue	13	-144.4	-366.4	-253.4	-115.8	-51.0	-1.2
	Gross revenue	13	302.4	6.8	172.7	293.2	440.2	534.5
	Hired labour	13	42.6	0.0	0.0	0.0	34.1	293.2
	Fertilizer cost	13	305.8	91.6	214.8	321.2	399.1	467.3
	Irrigation cost	13	1.49	0.00	0.00	0.38	2.26	8.17
	Machinery cost	13	96.8	3.1	19.2	33.8	119.6	450.3
Positive profit	Net revenue	263	520.3	25.9	274.2	406.5	554.5	2 303.2
	Gross revenue	263	868.1	172.1	524.6	643.8	841.1	4 798.2
	Hired labour	263	55.1	0.00	0.00	7.1	61.4	1 151.6
	Fertilizer cost	263	255.2	0.00	141.8	183.7	251.7	1 406.3
	Irrigation cost	263	2.9	0.00	0.3	1.3	3.0	100.3
	Machinery cost	263	34.5	0.00	6.4	15.1	45.2	277.6

A large proportion of the households perceive long-term shifts in climate conditions. Approximately 90 per cent were aware that there was a long-term shift in temperature and precipitation. Almost two-thirds of households (63%) observed a change in drought frequency. Many farmers (88 per cent of those surveyed) indicated a change in the incidence of crop pests and diseases. Few farmers (28 per cent) noticed changes in the frequency of flooding. Overall, the level of awareness on changes in climate is fairly high in the sample.

6 Net revenue data for 30 farms were discarded because of problems measuring input costs.

From those who noticed a temperature change, 98 per cent reported that temperature had increased, while 2 per cent reported a decrease. Regarding precipitation, most (85 per cent) reported an increase, while 15 per cent reported an increase. Among the farmers who reported a change in flood frequency, 70 per cent said it decreased, while 30 per cent said it increased. Almost all farmers who reported a change in the frequency of droughts and pests said the frequency had increased. Table 8 summarizes these statistics on the awareness/perception on climate change in the sample. Statistics on the awareness and perception on climate change by eco-zones. Based on the findings, the awareness the temperature is increasing and precipitation is lower in nearly all provinces. Households have noticed flood frequency change and in most of the provinces, they reported a decrease. Similar answers were found for pest change, with stronger results for increase in almost all provinces of Viet Nam.

Table 8: Number of farmers who perceived long-term shifts in climate conditions

	Temperature change			**Precipitation change**			**Drought frequency change**			**flood frequency change**			**Pest change**		
Province	Re-sponse	In-crease	De-crease	Re-sponse	In-crease	De-crease	Re-sponse	In-crease	De-crease	Re-sponse	In-crease	De-crease	Re-sponse	In-crease	De-crease
Bac Giang	2	14	16	4	12	16	5	11	16	12	4	16	0	16	16
Ben Tre	1	7	8	0	8	8	4	4	8	8	0	8	1	7	8
Binh Thuan	2	16	18	0	18	18	8	10	18	13	5	18	4	14	18
Can Tho	0	6	6	1	5	6	3	3	6	3	3	6	1	5	6
Dak Lak	1	16	17	1	16	17	1	16	17	15	2	17	2	15	17
Dong Nai	1	17	18	1	17	18	4	14	18	18	0	18	5	13	18
Dong Thap	0	7	7	1	6	7	5	2	7	5	2	7	1	6	7
Ha Noi	1	17	18	1	17	18	9	9	18	18	0	18	1	17	18
Ha Tinh	1	17	18	1	17	18	5	13	18	9	9	18	0	18	18
Kien Giang	3	12	15	3	12	15	5	10	15	15	0	15	0	15	15
Lam Dong	1	16	17	1	16	17	3	14	17	17	0	17	3	14	17
Lao Cai	1	15	16	1	15	16	7	9	16	12	4	16	0	16	16
Nam Dinh	1	18	19	1	18	19	7	12	19	11	8	19	2	17	19
Quang Nam	0	19	19	1	18	19	2	17	19	3	16	19	1	18	19
Soc Trang	1	10	11	2	9	11	7	4	11	11	0	11	0	11	11
Son La	2	17	19	3	16	19	10	9	19	8	11	19	8	11	19
Tay Ninh	2	15	17	8	9	17	11	6	17	17	0	17	5	12	17
Thai Binh	2	16	18	1	17	18	6	12	18	15	3	18	0	18	18
Thai Nguyen	0	19	19	4	15	19	4	15	19	8	11	19	2	17	19
Thanh Hoa	1	17	18	5	13	18	7	11	18	10	8	18	2	16	18
Tien Giang	0	9	9	1	8	9	8	1	9	6	3	9	2	7	9
Total	23	300	323	41	282	323	121	202	323	234	89	323	40	283	323

Note: N=306.

As revealed in Table 9, 39 per cent of the farmers responded to the shift in temperature by making investments in irrigation, such as buying sprinklers or groundwater pumps. About 34 per cent of the sample chose only one crop adaptation strategy, such as changing crop dates, crop types or crop varieties, where "varieties" include hybrid crops.[7] Roughly 27 per cent of farmers reported not taking any action, even though they noticed climate is changing.

7 Hybrid rice and other crops are common in Viet Nam with research from the International Rice Research Institute (IRRI). In addition to introducing several rice varieties of IRR in Viet Nam, other activities include strengthening the Cuu Long Delta Rice Research Institute with UNDP assistance, and also several research projects undertaken jointly by the IRRI with institutions in Viet Nam on hybrid rice, insect infestation, potassium deficiencies in soils affecting yields and rice based farm research. See Lee (1994); and IRRI (n.d.)

Table 9: Reported climate change adaptation responses

Climate change adaptation response	Response	
Irrigation investment	120	39.22
Crop date, type and variety	104	33.99
No adaptation	82	26.8
Total	306	100

In the following sections, a description of the modelling exercise of the impacts of climate change on the agriculture sector is outlined. The results of attempts to predict how farmers are likely to adapt their behaviours, given predicted changes in temperature and precipitation, is also described.

EVALUATING CLIMAGE CHANGE IMPACT AND ADAPTATION

One of the approaches used in the economics literature for evaluating the impacts of climate change on farmers' economic outcome is the Ricardian approach, named after David Ricardo's 1815 work.[8] This approach is based on the observation that land rents capture the long-term productivity of the farm. The approach in the context of climate change evaluates performance of farms across landscapes, capturing the impacts of spatial variations in climate attributes and other factors (including input prices and soil quality), where the value of the land reflects the present value of future stream of net farm revenue.

The Ricardian approach is useful for evaluating the impact of climate change because climate change affects productivity and farm net revenues. The main advantage of this model is that it accounts for adaptation to climate change implicitly because each farmer has adjusted to the climate they live in. One other advantage, given the difficulty in obtaining data on many economic variables over time, is that it does not require data collection over time but only across space, where climate attributes vary. Clearly, obtaining revenue data for more than one year is highly desirable. The Ricardian approach depends on cross-sectional variation of climate, examining farmers who are exposed to different climates. That is possible in Viet Nam by sampling from across the country. The remaining concern is that other variables that affect net revenue and that also vary over space are controlled for. The authors control for soil, terrain, farm size and household characteristics in this study. Additional advantages of this approach include the flexibility of the model and its ease of implementation.

There are, however, a number of limitations to this approach. One drawback is the potential for omission of relevant variables, which is present in all cross-sectional analysis. Another drawback is data-related: the model requires detailed information on the farm in order to calculate net revenue. This information includes the value of all the inputs and any inefficiencies of the land and labour prices/markets that may distort prices.

The model used in the analysis is represented by Equation 1:

8 One of the first applications of this method to measure climate change impact is Mendelsohn et al. (1994). Since then the method has been applied extensively in climate change impacts analysis in numerous countries across the world including Africa (Kurukulasuriya et al.,2006; Seo et al., 2005) and many more.

$$NR = \beta_0 + \beta_1 C + \beta_2 C^2 + \beta_3 S + \beta_4 Z + \varepsilon \text{ ---- (1)}$$

Where *NR* is the net revenue of the farmers, *C* represents the climate attributes (temperature and rainfall), *S* captures characteristics of the soil, *Z* includes all other factors that may be of importance to determine the *NR* of the farm, and $\mathcal{E}$ is the error term. The quadratic term for climate is included to capture the nonlinear relationships of climate attributes. The value of the net revenue of the farmer is obtained by calculating the total revenue (farm gate price multiplied by quantity sold by the farmer) less the total cost of production (cost of hired labour, fertilizer, pest and seed, irrigation, and machinery).

The econometrics model that underpins the Ricardian approach allows to make appropriate inferences about the relationship between net revenue and its key determinants. As a first step in understanding this relationship, net revenue of the farmers and key exogenous variables that capture climate is modelled; seasonal variables are used for this purpose. Next, other variables that also matter in explaining differences in the revenue apart from temperature and precipitation is added to the model. Some of these key variables include the education levels of the farmer, the location of the farm, and the characteristics of the soil. After controlling for these factors, the climate variables provide a good representation of the determinants of net revenue of farmers in the country based on the data collected.

Once a model that satisfactorily explains the variation in net revenue in the sample is determined (applying different model diagnostics and robustness tests and ensuring adequate model specification by adequately controlling for potential nonlinearities in the relationship), it is then used to predict changes in net revenue given changes in climate, holding everything else in the model constant. The model is then used to estimate the difference in net revenue under alternative climate change scenarios from estimates of net revenue under current climate conditions. This captures the economic effect of climate change. The model can then be used to make inferences on policy recommendations based on anticipated changes in temperature and precipitation.

EXPLAINING CLIMATE CHANGE IMPACT ON AGRICULTURE IN VIET NAM

The team estimated Equation 1 using ordinary least square regression, where the net revenue is measured in US$/acre. Four different models are estimated in order to understand the factors that determine net revenue in the survey data. The first model, the base one, only includes nonlinear seasonal climate (with quadratic term). In Model 2, we add the soil variables. Model 3 includes key farm characteristics that might explain net revenues. Model 4 combines all the variables including quadratic terms for temperature and precipitation. The estimates of the four models are presented in Table 9.

The model diagnostics show that the model behaves well, explaining about 28 per cent to 30 per cent of the observed variations in net revenue.

There are several control variables in the regression in Table 10. Farms with more planted areas have lower net revenue/ha. This effect gets smaller as the farm gets larger. The farm size results is most likely due to the omission of own labour as a cost in the net revenue function. Smaller farms tend to use a higher proportion of own labour, which is not priced in this analysis. The only soil variable that is significant is clay soil, which is associated with a lower net revenue. The included household characteristics are also insignificant. Education, age, gender and experience have no effect on net revenue, nor does access to Internet or telephone.

Table 10: Estimates of the net revenue function

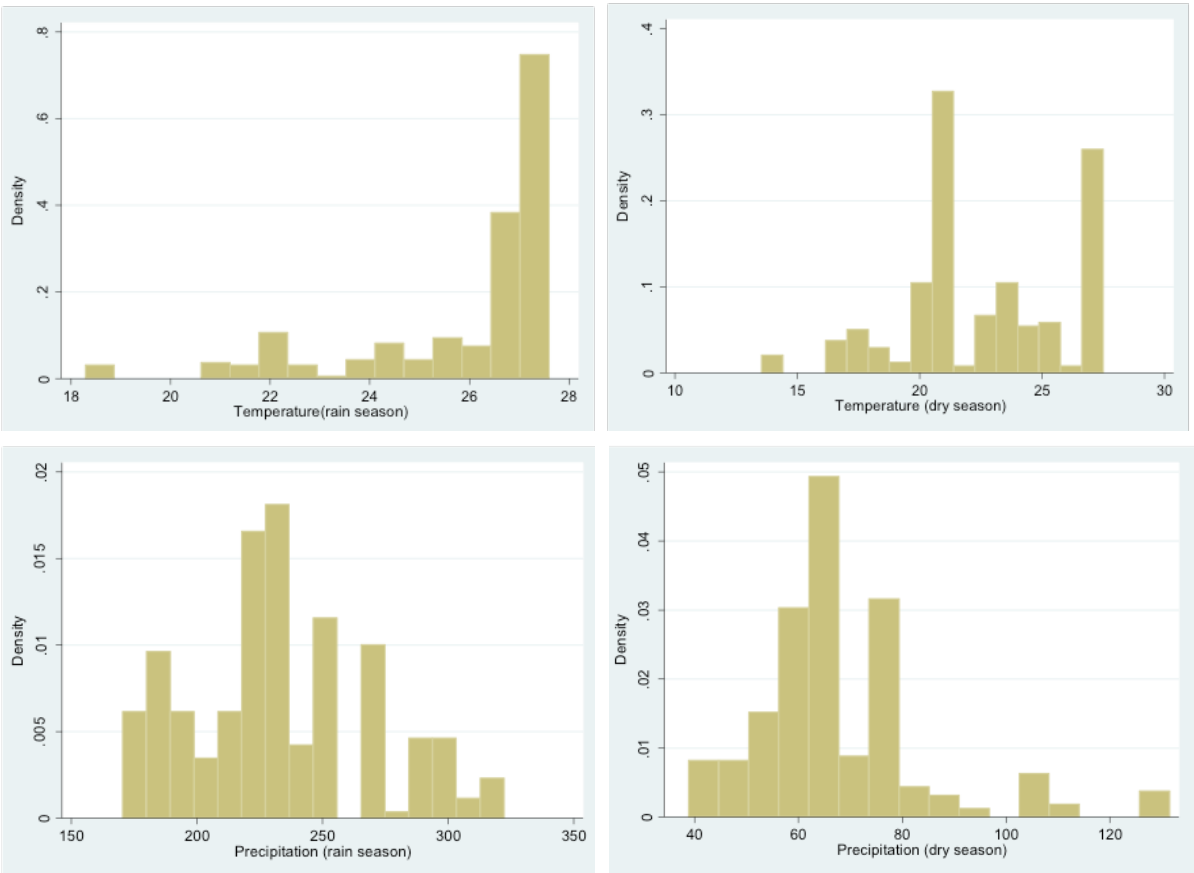
Variable	(1) Base model	(2) Base with soil	(3) Base with other control	(4) Base, soil and control
Precipitation rainy	-13.32	-13.50	-11.22	-12.31
	(14.57)	(14.10)	(15.46)	(15.05)
Precipitation rainy sq.	0.02	0.02	0.02	0.02
	(0.03)	(0.03)	(0.03)	(0.03)
Precipitation dry	12.07	11.99	11.14	11.72
	(14.54)	(14.39)	(15.25)	(15.11)
Precipitation dry sq.	-0.05	-0.05	-0.04	-0.05
	(0.09)	(0.08)	(0.09)	(0.09)
Temperature rainy	-1,525.1***	-1,493.3***	-1,389.8***	-1,415.8***
	(356.4)	(489.1)	(402.1)	(523.5)
Temperature rainy sq.	28.26***	27.73***	25.50***	26.12**
	(7.12)	(9.54)	(8.10)	(10.27)
Temperature dry	786.1***	709.5***	752.5***	699.9***
	(160.134)	(262.453)	(169.895)	(267.227)
Temperature dry sq.	-15.43***	-13.78**	-14.73***	-13.59**
	(3.431)	(5.478)	(3.650)	(5.587)
Farm area (acre)	-10.28**	-10.89**	-10.31**	-10.94**
	(4.92)	(4.82)	(5.11)	(4.98)
Farm area (acre) sq.	0.08	0.09*	0.08	0.09*
	(0.052)	(0.052)	(0.054)	(0.053)
Education			0.68	1.36
			(7.282)	(7.398)
Household head age			14.96	13.57
			(11.18)	(10.93)
Household head age sq.			-0.14	-0.13
			(0.10)	(0.10)
Household head male			4.38	15.71
			(66.16)	(65.32)
Telephone			-47.66	-61.73
			(153.10)	(150.17)
Experience			0.06	-0.07
			(2.76)	(2.74)
Internet			80.36	79.52
			(84.48)	(84.85)
Clay soil		-102.2**		-110.26**
		(49.25)		(52.03)
Sandy soil		-174.0		-165.9
		(244.38)		(243.4)
Flat land		-91.3		-72.7
		(230.6)		(229.7)
Steep land		-166.4		-147.8
		(235.7)		(233.7)
Constant	12,691.2***	13,260.4***	10,852.3**	11,990.7**
	(3,945.2)	(4,341.9)	(4,565.1)	(4,877.7)
Observations	275	275	275	275
R-squared	0.28	0.29	0.29	0.30

Robust Notes: Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively

The primary focus of this analysis was to determine the extent of the influence of temperature and precipitation on net revenue of the farmers in Viet Nam. After testing a number of alternative definitions of seasons, temperature and precipitation is based on the two seasons discussed above: the rain season (June – November) and the dry season (December – May). We should note that the dry season in Viet Nam is also the coldest season in the country. The climate data used in the analysis is from the current (1950 – 2000) climate data from WordClim's website at the 10 arc-minutes, which are the finest spatial data available. [9]

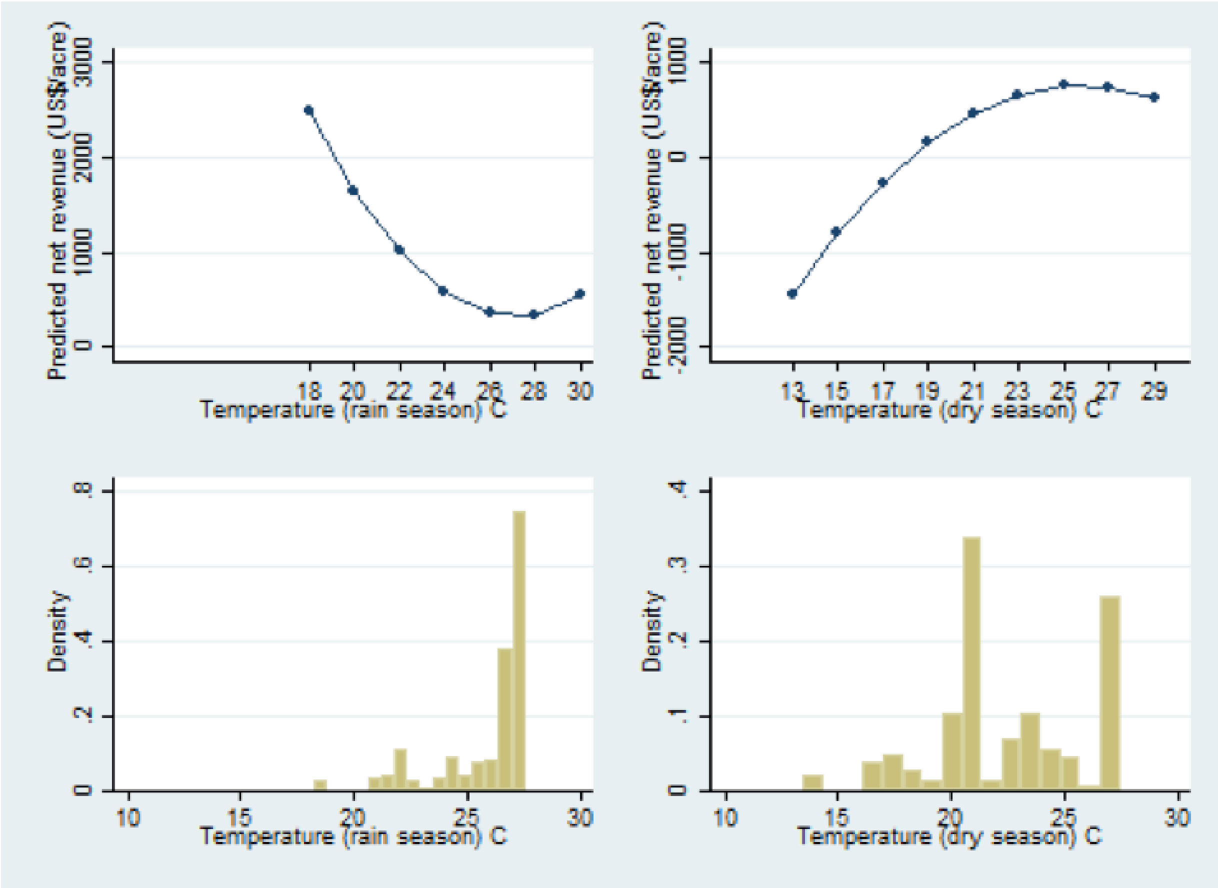
The result for temperature shows that, as expected, if it gets warmer in the rain season, net revenues will decrease. By contrast, higher temperature in the dry season (which is cooler than the rain season) would result in higher net revenues. Figure 13 shows the estimated relationship between temperature and net revenue. The effect of temperature in the rain season, however, levels off beyond 26°C, which will have implications for understanding the impact of climate change – at the current mean temperature of 26°C, additional increase in temperature may not significantly increase net revenue. It should be noted that it is the sum of the effects that are relevant, given that the net revenue is measured per acre per annum.

Figure 12: Distribution of current temperature and precipitations in dry and rain season



9 www.worldclim.org/current

Figure 13: Impact of temperature on net revenue (NR) in rain and dry seasons (top and bottom, respectively)



Turning to precipitation, additional precipitation during the rain season will negatively impact net revenue until it flattens out around 330 mm/month. This indicates that the current precipitation is enough and an increase may result in either a crop loss or an increase in drainage costs.

The precipitation of the dry season shows the opposite trend. During this season, increased precipitation up to 130 mm/month will result in an increase in net revenue. The average precipitation in the dry season currently is about 70 mm/month, which shows that more precipitation in this season will increase revenue.

Figure 14: Impact of precipitation on net revenue (NR) in rain and dry seasons

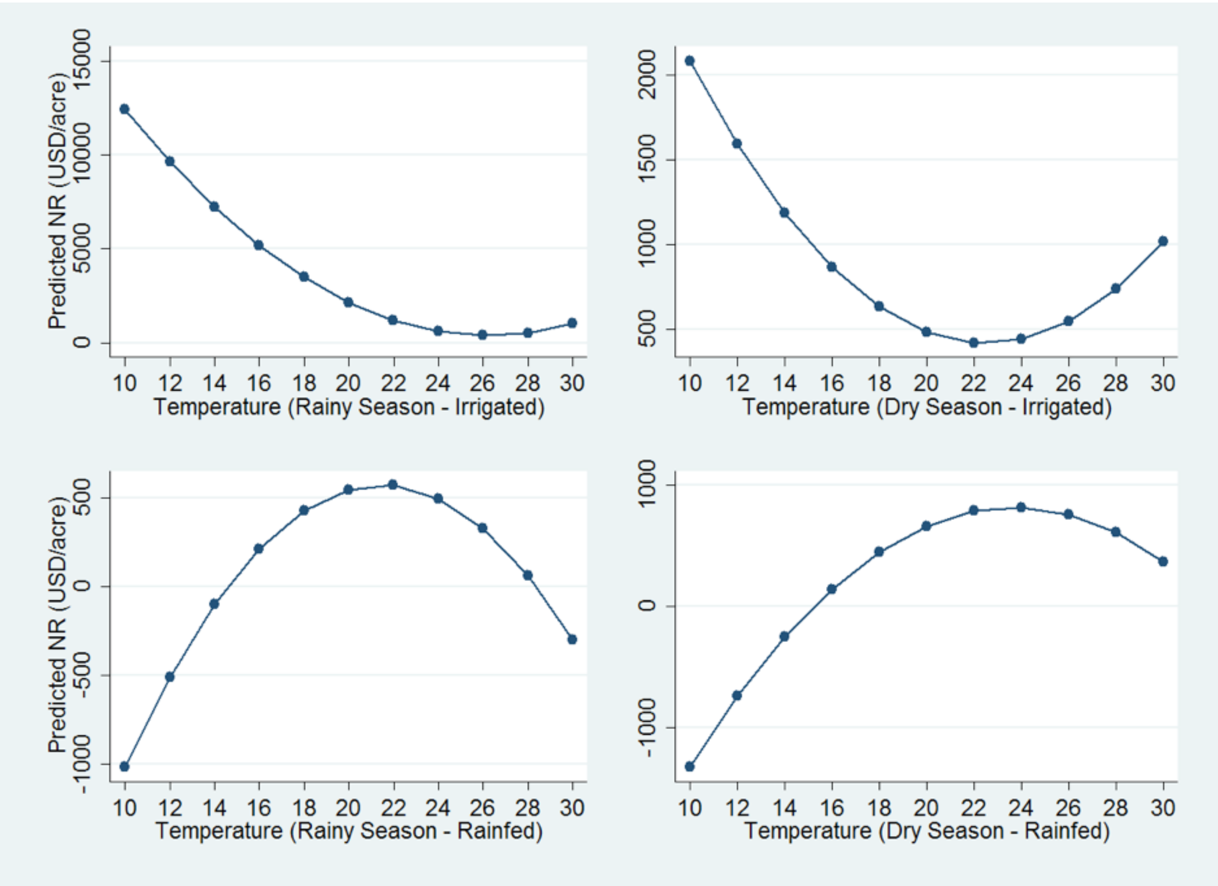


Table 11 presents the marginal effects of climate variable on net revenue, calculated at the sample mean. At the sample mean, a 1°C increase in temperature in the rain season would result in a loss of about US$62/acre. By contrast, a 1°C increase in temperature during the dry season would result in an increase of net revenue by about US$87/acre. A one mm increase of precipitation during the rain season would result in a loss of nearly US$4.0/acre and an increase of US$5.5/ha in the dry season. Adding these values across seasons together suggest a small gain from warming in Viet Nam and a small gain from more rainfall. The annual marginal effect of 1°C uniform warming would be a $25 gain. The annual marginal effect of another mm/mo of rainfall would be a US$1.4 gain.

Table 11: Marginal effects of climate variables on net revenue

	(1)	**(2)**	**(3)**	**(4)**
Variables	**Base model**	**Base with soil**	**Base with control**	**Base, soil and control**
Precipitation rain season	-4.34***	-4.04**	-4.21**	-4.02**
	(1.66)	(1.97)	(1.70)	(2.01)
Precipitation dry season	5.21	5.33	5.21	5.46
	(3.97)	(4.30)	(4.10)	(4.46)
Temperature rain season	-60.51**	-56.21*	-68.27**	-62.04*
	(26.77)	(33.86)	(30.66)	(34.62)
Temperature dry season	90.61***	87.97***	88.16***	87.12***
	(13.36)	(20.14)	(14.14)	(20.70)

Notes: Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

TOTAL IMPACT OF TEMPERATURE AND PRECIPITATION

The analysis then focused on the effect of changes in annual temperature and precipitation on annual net revenue. The hypothesis tested was whether an increase in temperature would have a negative impact, while an increase in precipitation would have a positive impact on net revenue. In addition, the analysis focused on determining the combined effect of changes in precipitation and temperature on farm revenues.

Based on the predicted values of net revenue generated using Model 4, a 1°C increase in temperature would result in an increase of US$25 per acre of planted area, while 1 mm increase in precipitation will result in a gain of US$1.44 /acre. The total impact of a 1°C increase in temperature and a 1 mm increase in precipitation would be an increase of US$26.52 per acre. There is no significant impact on net revenue per acre for this scenario. These effects are captured in Table 12. The authors will explore the impact of climate change further when actual climate predictions are used instead of an arbitrary increase in temperature and precipitation.

Table 12: Aggregate marginal effects of changes in temperature and precipitation

Variables	(1) Base model	(2) Base with soil	(3) Base with control	(4) Base, soil and control
Cumulative temperature	30.10	31.76	19.88	25.08
	(26.816)	(33.251)	(30.188)	(34.249)
Cumulative precipitation	0.87	1.28	1.00	1.44
	(2.842)	(2.970)	(2.941)	(3.086)
Climate	30.97	33.04	20.88	26.52
	(27.638)	(33.442)	(30.976)	(34.484)
Observations	275	275	275	275

Standard errors in parentheses.

*** p<01. ** p<05. * p<0.1.

SEPARATING THE IMPACT BASED ON IRRIGATED AND NON-IRRIGATED FARM TYPE

One of the ways in which the agriculture sector can adapt to climate change impact is through irrigation. In this section, the team evaluates the differences in climate change impacts on the net revenue of irrigated farms and non-irrigated farms. While the majority of the farmers in Viet Nam use irrigation, there are clear differences in the net revenue per acre for irrigated and non-irrigated farms. Table 13 shows that the net revenue of rainfed farms (US$437.48/ha) is on average lower than the net revenue of irrigated farms (US$499.83/ha). Farmers who irrigate also have more planted area on average than those who do not. However, it is interesting that while the mean net revenue per ha is higher for irrigated farms, the median net revenue is higher for rainfed farmers. It appears that there are more low-valued rainfed farms than irrigated farms, which brings down the mean for rainfed farms.

Table 13: Summary statistics of net revenue (NR) and farm area by irrigated and rainfed farms

Farm type	Variable	Number of farms	Mean	25th percentile	Median	75th percentile
Irrigated	Net revenue (NR)/ha	228	499.83	259.39	388.01	549.15
	Farm area	228	5.74	1.48	2.31	5.51
Rainfed	NR/ha	48	437.48	170.96	408.44	524.58
	Farm area	48	4.60	2.29	3.64	6.05
Total	NR/ha	276	488.99	246.45	394.44	543.61
	Farm area	276	5.54	1.51	2.47	5.73

To understand the impact of climate on the two types of farms, Model 4 is estimated separately for the two sub-samples of irrigated and non-irrigated farms. Table 14 shows the marginal effects calculated from the estimated models. The marginal effect of an increase in temperature in the rainy season is similar for irrigated and rainfed farms. This is intuitive since less irrigation is carried out in the rain season. However, increased temperatures in the dry season are more beneficial for rainfed than the irrigated farms. However, precipitation in the winter season is more harmful to rainfed farmers than irrigated farmers since they can make up for it in the dry season. It is worthy to note that higher precipitation in the dry season is more beneficial to rainfed farmers than irrigated farmers. None of the marginal effects are significant because the distribution is flat around the mean.

Table 14: Impacts of climate change on farms (based on Model 4)

	(1) All farms	(2) Irrigated farms	(3) Non-irrigated farms
Temperature rain season	-4.042**	-2.517	-2.396
	(1.974)	(2.056)	(4.217)
Temperature dry season	5.327	3.319	10.651
	(4.297)	(4.340)	(14.841)
Precipitation rain season	-56.209*	19.176	-47.505
	(33.859)	(47.886)	(125.129)
Precipitation dry season	87.969***	12.683	85.951
	(20.142)	(18.641)	(114.081)
Observations	275	227	48

Notes: (***), (**) and (*) significant at 1%, 5% and 10% respectively. Standard errors are in parentheses. The same controls as in Model 7 also included in the regression but not reported.

If the relationship between NR and climate are plotted, it would yield a better representation of the interactions. Figure 15 presents the relationship between temperature in each season and net revenue for irrigated and rainfed farmers. The upper part of the figure presents the impact on irrigated farmers and lower part rainfed. The figure shows differences in the impact on the two type of farmers – in the rain season, higher temperature above average is partially good for irrigated farmer (marginal impact will not be significant). However, rainfed farmers are negatively impacted when temperature is above average (25.9 degrees) – they have little means to cope with the higher temperature like rainfed farmers do. However, in the dry season when the temperature is cooler, higher temperature above the average of 22.5 degrees is good for irrigated farmers, but not necessarily good for rainfed farmers, conditional on the same precipitation level in that season.

Figure 16 shows that of precipitation and NR. The relationship between precipitation and NR is similar for rainfed and irrigated farmers as expected in the rain season. The difference is in the dry season – more precipitation is good for rainfed farmers but not necessarily good for irrigated farmers given that they would have already invested in irrigation network for that season.

Figure 15: Impact of temperature on net revenue (NR) of irrigated and rainfed farmers

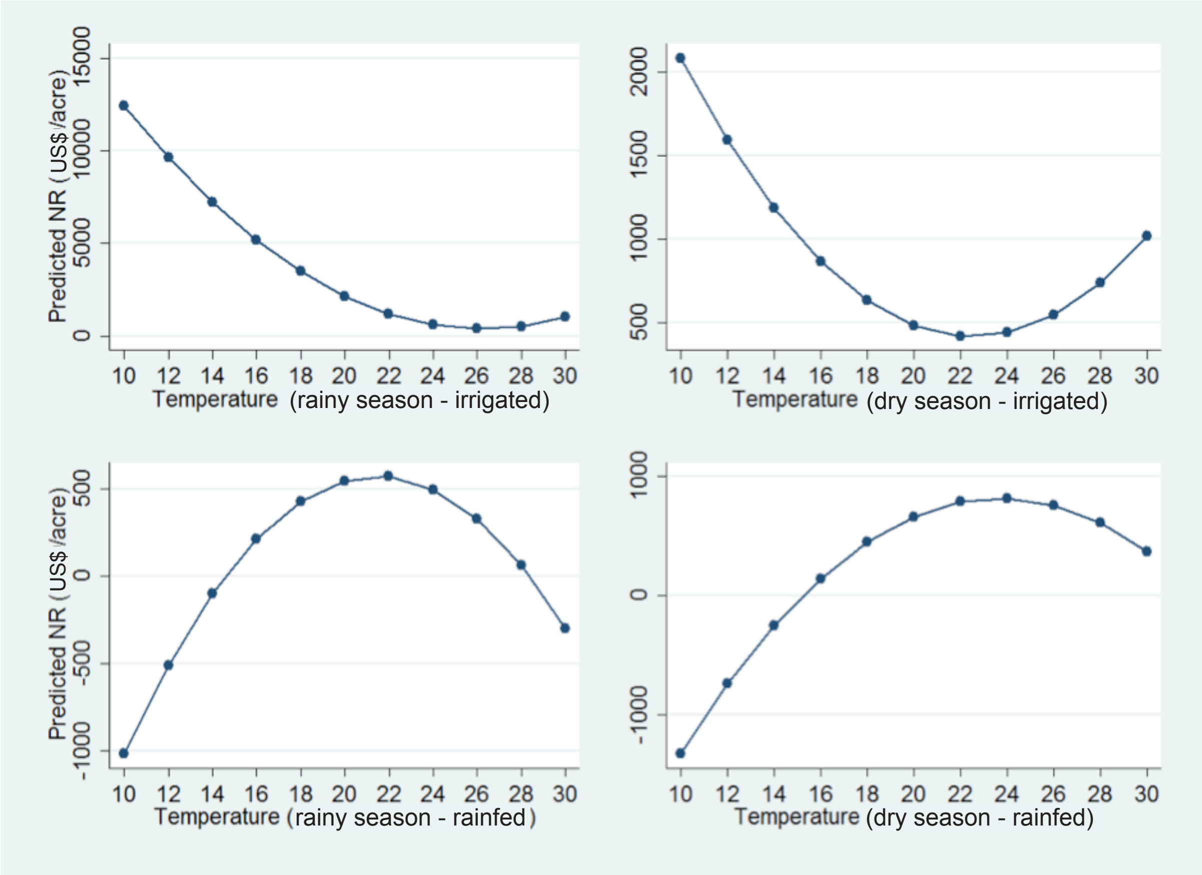


Figure 16: Frequency of temperature in dry and rain season, irrigated and rainfed farms

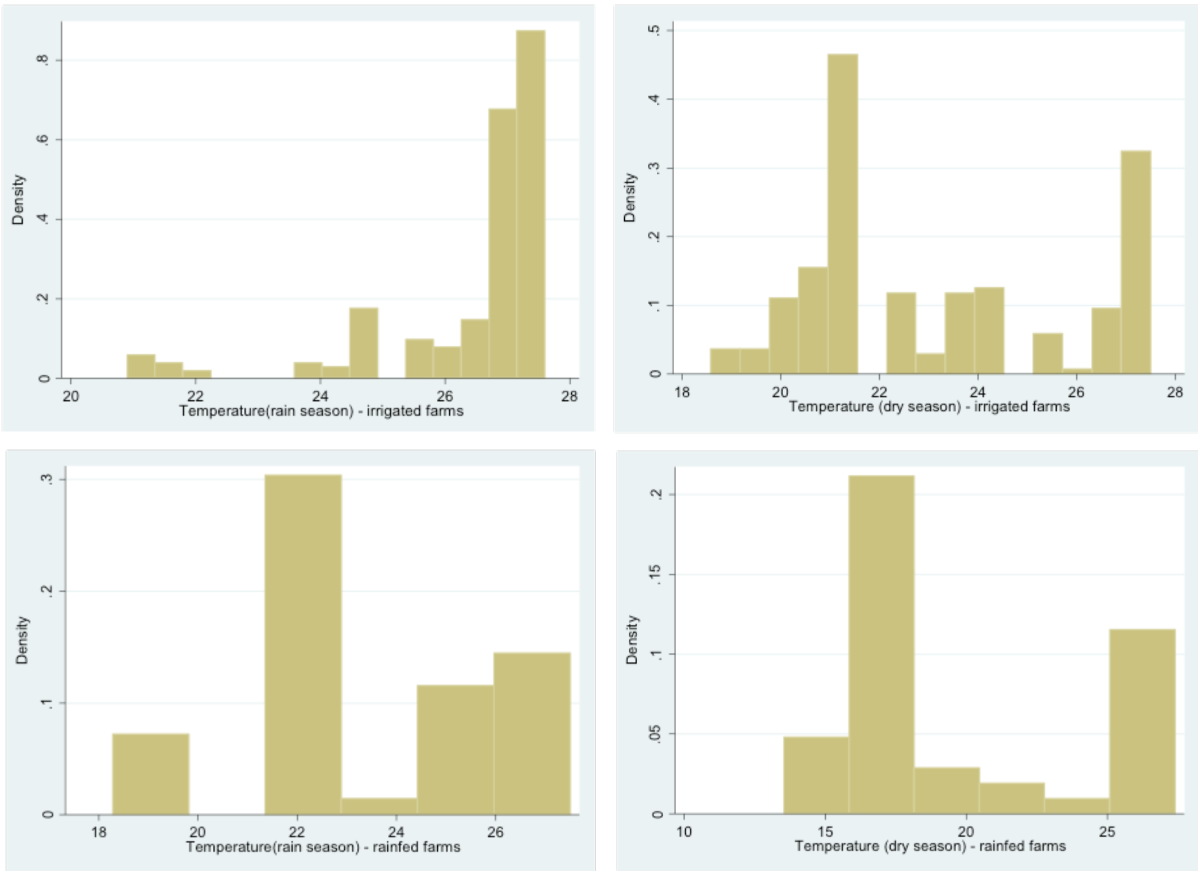


Figure 17: Impact of precipitation on net revenue (NR) of irrigated and rainfed farms

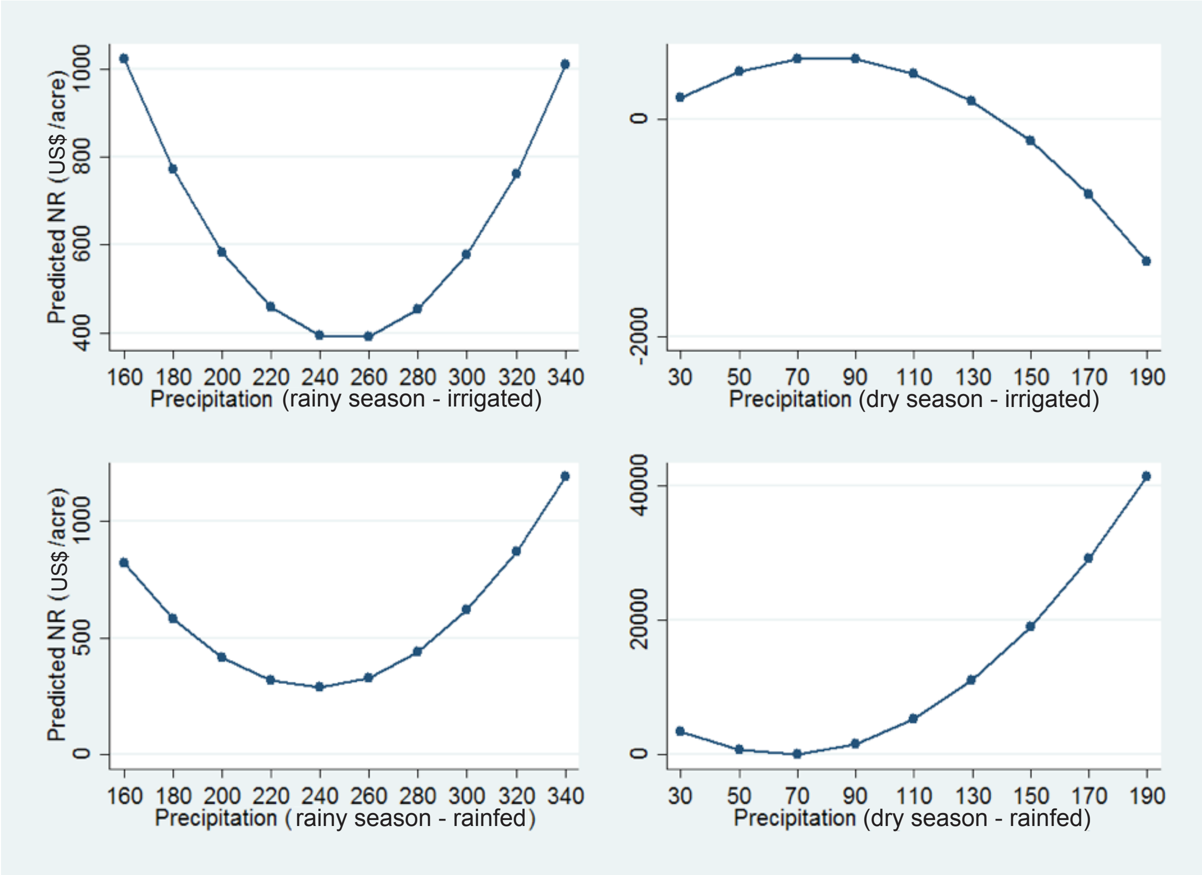
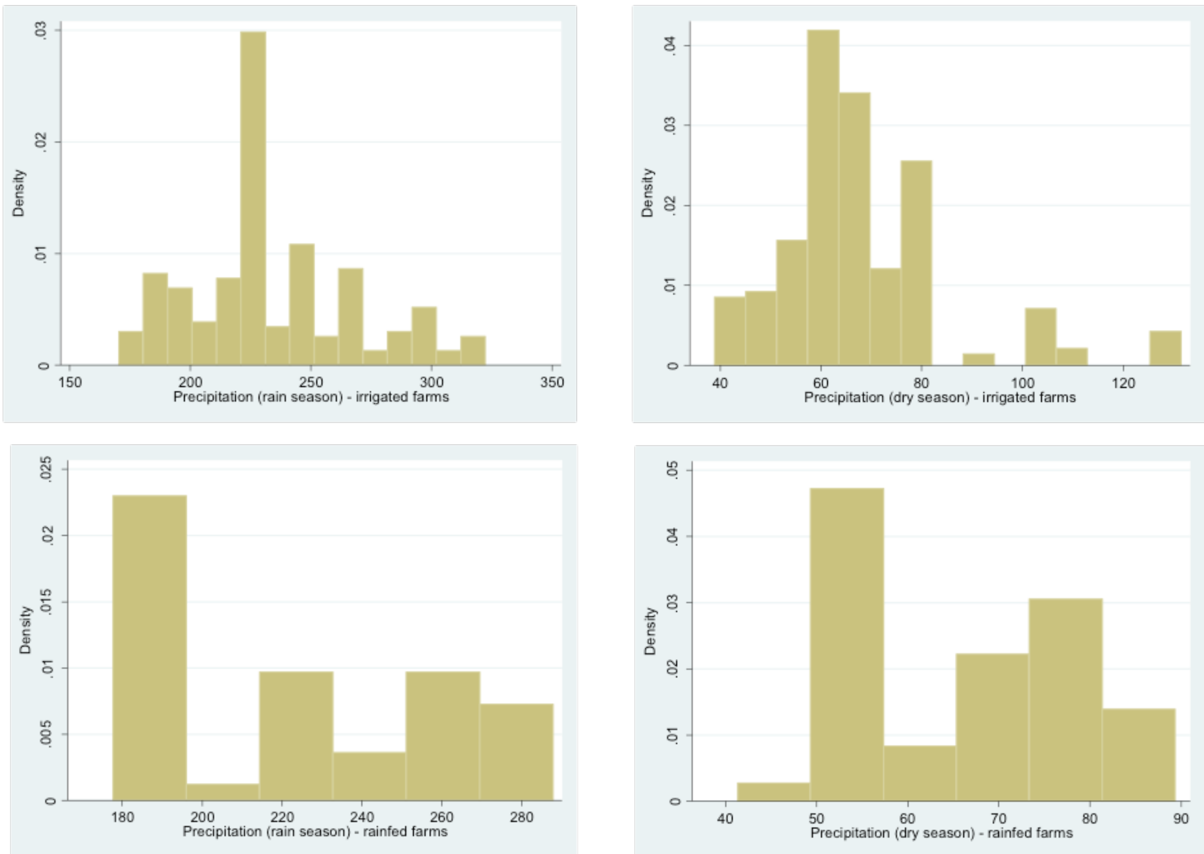


Figure 18: Frequency of precipitation in dry and rain season, irrigated and rainfed farms



ESTIMATING THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Finally, the impacts of future climate change scenarios on agriculture are calculated. Future changes in precipitation and surface temperature for each district are based on results from three coupled ocean-atmosphere General Circulation Models (GCMs). The data were downloaded from the Coupled Model Intercomparison Project (CMIP5) website (Taylor, Stouffer and Meehl, 2012).[10] Details of the three GCMS used in this study, and their associated institutions, are provided below. Simulated daily surface precipitation and mean temperatures from each model were averaged to produce estimates of monthly mean climatological changes (absolute temperature changes and relative percentage precipitation changes) for the periods 2031-2060, 2051-2080 and 2071-2100 (relative to the historical 1971-2000 period), The assumed emissions path is the Representative Concentration Pathway RCP8.5 (van Vuuren et al., 2011).[11] Note that RCP8.5 assumes a very high emission scenario that is on the very high end of plausible business-as-usual (no mitigation) scenarios. The temperature change by 2100 is assumed to be between 1.5°C - 4.5°C (IPCC) above pre-industrial level, which is 0.5°C - 3.5°C o above 2010 temperatures.

Table 15: Three coupled atmosphere-ocean models from the CMIP5 archive

Modelling Center (or Group)	Institute ID	Model Name
College of Global Change and Earth System Science, Beijing Normal University	GCESS	BNU-ESM
Canadian Centre for Climate Modelling and Analysis	CCCMA	CanESM2
Centro Euro-Mediterraneo per I Cambiamenti Climatici	CMCC	CMCC-CESM

Note: The CMIP5 archive provided precipitation and surface temperature data used to estimate average changes in each district, under an assumed RCP8.5 scenarios.[12]

Table 16: Annual climate change

	Climate projection	2031 - 2060	2051 - 2080	2071 - 2100
BNU-ESM	Temperature	1.52	2.46	3.22
	% precipitation	-4.20	-5.25	0.44
CanESM2	Temperature	1.94	2.90	3.90
	% precipitation	0.61	2.37	3.54
CMCC-CESM	Temperature	1.69	2.93	4.10
	% precipitation	5.30	4.98	3.02

10 CMIP5 Coupled Model Intercomparison Project, see http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html

11 The authors wish to acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP. Thanks are due to the climate modeling groups for producing and making available their model output. For CMIP the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison provides coordinating support and led development of software infrastructure in partnership with the Global Organization for Earth System Science Portals.

12 The authors acknowledge the World Climate Research Programme's Working Group on Coupled Modelling, which is responsible for CMIP, and thank the climate modeling groups for producing and providing their model output. For CMIP the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison provides coordinating support and led development of software infrastructure in partnership with the Global Organization for Earth System Science Portals.

Table 17: Projected change in temperature in °C by season

	Climate projection	2031 - 2060	2051 - 2080	2071 - 2100
Rainy season	BNU-ESM	1.55	2.44	3.29
	CanESM2	2.13	3.18	4.23
	CMCC-CESM	1.59	2.62	3.71
Dry season	BNU-ESM	1.49	2.49	3.16
	CanESM2	1.76	2.61	3.58
	CMCC-CESM	1.79	3.25	4.50

Table 18: Projected change in precipitation, by season (mm/day)

	Climate projection	2031 - 2060	2051 - 2080	2071 - 2100
Rainy season	BNU-ESM	1	4.4	8
	CanESM2	2.6	0.7	0.3
	CMCC-CESM	2.2	7.4	10.4
Dry season	BNU-ESM	-1.2	-2.4	-1.8
	CanESM2	-2.8	-2	-2.9
	CMCC-CESM	2.1	1	1.7

Table 19: Projected percentage change in precipitation, by season

	Climate projection	2031 - 2060	2051 - 2080	2071 - 2100
Rainy season	BNU-ESM	0.02	8.78	17.36
	CanESM2	7.18	5.35	10.87
	CMCC-CESM	3.89	13.35	18.10
Dry season	BNU-ESM	-8.42	-19.27	-16.48
	CanESM2	-5.97	-0.62	-3.79
	CMCC-CESM	6.70	-3.39	-12.05

In general, the climate change projections for Viet Nam shows temperature increasing by year across all seasons. However, there is also projected increase in precipitation even up to 2100 in the rain season. The only projected reduction in precipitation is in the dry season. Given that most of the farmers in the country already use irrigation, it is expected that climate change impact will be positive unless coupled with projections on water availability that may reduce impact of irrigation.

Using the results from our model combined with the climate projections, the team estimates the impact of climate change on crop farmers in Viet Nam. Specifically, the author estimates changes in net revenue if temperature and precipitation reach the levels projected for 2031-2060, 2051-2080 and 2070-2080.

For the climate projections of 2031-2060, the results for the full sample show no significant impact of climate change on net revenue. All three climate forecasts show increase in net revenue of between US$57 to US$320 per acre with large uncertainty surrounding the estimates as shown with the large standard errors. The impacts are harmful for rainfed farmers as expected given that precipitation is projected to fall in the dry season. In addition, the impacts are consistently higher for irrigated farms in 2051-2080 and 2070-2100. The impact of climate change on rainfed farms in Viet Nam is not statistically significant. Additional data may be needed to get a more precise estimate of the impact on rainfed farms.

Table 20: Climate (temperature and precipitation) projections and impacts on net revenue (based on Model 7)

Climate projection model	All farms	Irrigated farms	Non-irrigated farms
2031 - 2060			
BNU-ESM	56.99 (68.35)	82.76 (85.34)	-137.16 (371.00)
CanESM2	97.36 (88.46)	160.71 (112.04)	-231.16 (438.41)
CMCC-CESM	87.95 (76.71)	115.10 (95.33)	62.21 (241.78)
2050 - 2080			
BNU-ESM	124.80 (122.43)	266.74* (156.53)	-256.61 (634.23)
CanESM2	182.54 (148.47)	395.95** (192.87)	-353.14 (687.19)
CMCC-CESM	193.78 (154.13)	412.86** (199.99)	-202.57 (621.6)
2070 - 2100			
BNU-ESM	211.86 (171.45)	498.97** (225.38)	-492.08 (844.50)
CanESM2	295.77 (223.82)	755.53*** (300)	-531.56 (1009.98)
CMCC-CESM	319.87 (240.26)	840.41*** (325.17)	-614.55 (1104.28)

Note: (***), (**) and (*) significant at 1%, 5% and 10% respectively. Standard errors are in parentheses.

CLIMATE CHANGE AND POVERTY

Climate change can impact households through different channels, including changes in the production function and changes in price and consumption. Climate change has the potential to impact the productive assets and activities of farms in particular. These impacts are significant in least developed countries because most households in these countries are engaged in agriculture, which means that they are especially vulnerable to changes in climate.

The model used here does not explicitly analyse changes in price and consumption. Instead, the productive activities of farms are modelled. These activities contribute a large portion of the households' income and consumption. In this section, an estimate of the impact of climate change on income and income distribution in the country is presented.

According to the Ministry of Labour, Invalids and Social Affairs, the official poverty line (OPL) was estimated at VND700,000 (US$31.3) per capita per month in rural areas and VND900,000 (US$40.3) in the urban area. This amounts to about US$40 per person per month. Using an average household size of about four people, the OPL per household can be estimated as approximately US$1,920 per household each year. Below is the household income by decile, showing that the poor in the country are in decile groups 1 to 6.

Using the climate change impacts estimated in the previous section, together with an average household planted area of about 5.5 acres, the team estimates the changes in income that would be brought about by the climate changes projected by BNU-ESM for the period of 2030-2060. Table 21 shows that climate change would increase the income of farmers in decile group 7 under the current poverty line. These results apply to rainfed farms and for farmers whose income comes solely from agriculture.

Table 21: Current income groups and changes generated by 1°C increase in temperature

Decile	Range (USD)	Mean	Median	Range (USD)	Mean	Median
1	Less than 163	-112.40	17.88	Less than 518	256.14	309.08
2	170 – 354	270.16	281.33	521-777	647.06	637.35
3	358 – 519	435.33	435.49	790-1026	902.84	907.74
4	522 -694	604.49	608.88	1 045-1 236	1 148.79	1 152.15
5	703-968	825.16	820.05	1 280-1 644	1 446.01	1 436.18
6	973-1 574	1 269.82	1 227.57	1 711-2 449	2 049.25	1 969.91
7	1 577-2 227	1 928.55	1 965.25	2 504-3 653	3 044.51	3 035.94
8	2 251-3 763	2 921.95	2 862.10	3 727-5 722	4 500.15	4 331.61
9	3 794-6 606	5 061.10	5 199.48	5 801-10 186	7 433.99	6 955.35
10	6 872-37 368	13 287.32	10 345.35	10 220-55 628	19 739.78	16 226.83

ANALYSIS OF ADAPTATION BEHAVIOR

In the survey, farmers were asked about their perceptions of long-term shifts in temperature and rainfall on their land. Farmers were also asked a follow-up question on what kind of adaptations they have made for temperature shifts and rainfall. Farmers were asked to indicate if they: (i) changed planting dates; (ii) changed crop types; (iii) used different crop varieties (hybrid or genetically modified); and (iv) made irrigation investment (such as sprinkler or groundwater pump).

Among the crop farmers, 47.25 per cent of the respondents reported that they made investments in irrigation as a way of adapting to climate change, while 74.76 per cent either changed crop dates, crop types, or used different crop varieties. 52.44 per cent of the households used other adaptation strategies and finally, a small percentage (8.14 per cent) of the farmers did not adapt to climate change at all. The question, then, is, which factors determine the choice of adaptation by the farmers?

Table 22: Distribution of irrigation response to climate change

Province	Freq.	Percentage (%)	Cum.
Bac Giang	11	7.53	7.53
Ben Tre	7	4.79	12.33
Binh Thuan	13	8.9	21.23
Can Tho	4	2.74	23.97
Dak Lak	13	8.9	32.88
Dong Nai	10	6.85	39.73
Dong Thap	2	1.37	41.1
Ha Tinh	5	3.42	44.52
Kien Giang	4	2.74	47.26
Lam Dong	15	10.27	57.53
Lao Cai	2	1.37	58.9
Nam Dinh	2	1.37	60.27
Quang Nam	7	4.79	65.07
Soc Trang	4	2.74	67.81
Son La	5	3.42	71.23
Tay Ninh	12	8.22	79.45
Thai Binh	6	4.11	83.56
Thai Nguyen	13	8.9	92.47
Thanh Hoa	5	3.42	95.89
Tien Giang	6	4.11	100
Total	146	100	

Table 23: Distribution of cropping response to climate change

Province	Freq.	Percentage (%)	Cum.
Bac Giang	11	4.76	4.76
Ben Tre	7	3.03	7.79
Binh Thuan	10	4.33	12.12
Can Tho	6	2.6	14.72
Dak Lak	15	6.49	21.21
Dong Nai	12	5.19	26.41
Dong Thap	3	1.3	27.71
Ha Noi	18	7.79	35.5
Ha Tinh	10	4.33	39.83
Kien Giang	9	3.9	43.72
Lam Dong	14	6.06	49.78
Lao Cai	9	3.9	53.68
Nam Dinh	10	4.33	58.01
Quang Nam	14	6.06	64.07
Soc Trang	7	3.03	67.1
Son La	17	7.36	74.46
Tay Ninh	11	4.76	79.22
Thai Binh	16	6.93	86.15
Thai Nguyen	16	6.93	93.07
Thanh Hoa	12	5.19	98.27
Tien Giang	4	1.73	100
Total	231	100	

Table 24: Distribution of 'No response' to climate change

Province	Freq.	Percentage (%)	Cum.
Binh Thuan	3	12	12
Ha Tinh	3	12	24
Kien Giang	1	4	28
Lao Cai	4	16	44
Nam Dinh	6	24	68
Soc Trang	1	4	72
Son La	2	8	80
Tay Ninh	1	4	84
Thai Nguyen	1	4	88
Thanh Hoa	3	12	100
Total	25	100	

Adaptation choices are examined using the Multinomial Logit model with three adaptation options: irrigation adaptation, crop type adaptation against a baseline of no adaptation (business-as-usual).

Apart from perceived and objective climate, other hypothesis that was tested include whether the household involvement with cooperative societies and extension services had a positive effect on choice of adaptation option. However, very few farmers are members of input and output cooperative societies. The model controls for extension which is provided by local government (32 per cent) and input companies (27 per cent). Tables 22 to 24 summarizes households' behaviour by ecosystems and their adaptation options. In Lam Dong Province, 10.27 per cent of households are adapting through irrigation. In Thai Bing and Thai Nguyen Provinces, 6.93 per cent of the farmers are changing crops and in the province of Nam Dinh, 24 per cent of households do not adapt to climate change. The regression results for climate and these characteristics are presented in Table 25 and summarized below.

Table 25: Climate change adaptation model

Variable	Irrigation	Crop
Annual planted area (ha)	-0.036	-0.014
	-0.024	-0.02
Perceived temperature shift	17.8	17.837
	-1 270	-1 326.67
Perceived precipitation shift	0.252	0.401
	-0.582	-0.561
Temperature – rain	-0.440***	-0.003
	-0.129	-0.129

Table 25: Climate change adaptation model (cont.)

Variable	Irrigation	Crop
Temperature – dry	0.359***	-0.067
	-0.101	-0.101
Precipitation – rain	-0.021**	-0.005
	-0.01	-0.011
Precipitation – dry	0.019	-0.018
	-0.02	-0.02
Receive extension from local government	0.866**	0.553
	-0.436	-0.42
Farm output sell time (hours)	0.139	-3.786**
	-0.498	-1.838
Experience (years)	0.018	0.014
	-0.018	-0.017
Household size (members)	0.02	0.103
	-0.115	-0.107
Schooling years of HH head	0.180***	0.117*
	-0.063	-0.062
Telephone	3.253***	2.285**
	-1.193	-1.148
Internet	-1.415***	-1.118**
	-0.54	-0.517
Intercept	-15.418	-17.327
	-1 269.83	-1 326.67
LR Chi-square	138.71	
Observations	275	

Notes: (***), (**) and (*) significant at 1%, 5% and 10% respectively. Standard errors are in parentheses.

The results suggest the following:

Perceived climate change: The perceived shift in temperature and precipitation in general has no impact on the probability of adapting through either irrigation or cropping. This gives an indication that these two adaptation strategies are not farmer driven but more likely as a result of public adaptation that they are following.

Temperature and precipitation: An increase in temperature and precipitation in the rain seasons reduces the probability of adapting, while an increase in these variables during the dry season increases the likelihood of adaptation. Hence, farmers who face warmer and wetter rain season are less likely to adapt, while those who experience warmer and wetter dry season are more likely to adapt.

Farm experience: The influence of farmers' experience on the odds of adapting to climate change is insignificant. Farmers with more experience are not more likely to adapt.

Extension services: The results provide evidence that extension services from local government have influence on adaptation decisions in Viet Nam with some evidence that it increases the probability of investment in irrigation and reduces no adaptation.

Other variables: Farmers with higher schooling years are more likely to adapt. Other variables including experience, household size, and telephone do not have a statistically significant impact. Internet has a negative impact on adaptation – the role of Internet in the decision to adapt or not can be positive or negative depending on the kind of information that the farmer gets from the internet.

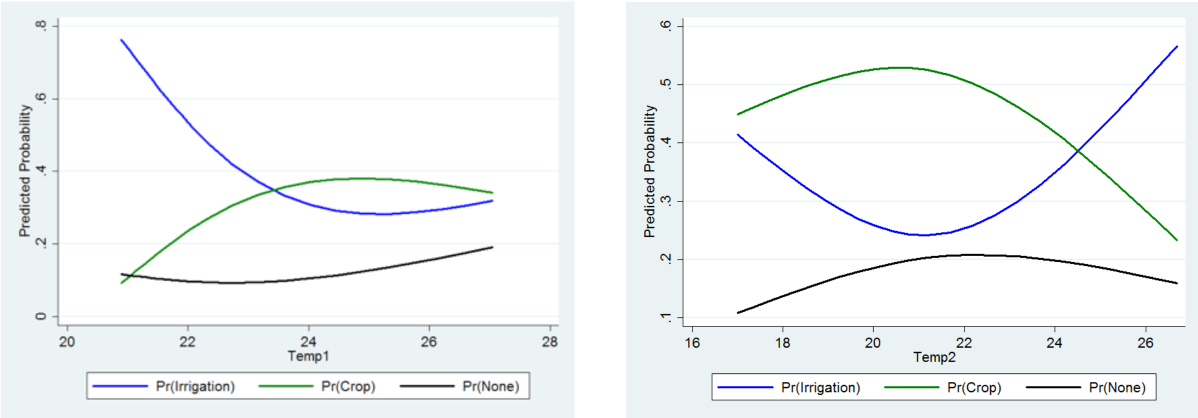
Table 26 presents the marginal effects for the variables included in the regression and their impact on choosing each of the adaptation alternatives, calculated at sample average. The result shows that higher temperature during the rain season increases the likelihood of choosing crop type adaptation and decreases the likelihood of choosing irrigation. In contrast, during the dry season, higher temperature decrease the likelihood of choosing crop type adaptation and increase the likelihood of choosing adaptation. Results show that higher precipitation during the rain season decreases the likelihood of choosing irrigation as adaptation alternative. Other factors that contribute to the choice of adaption are schooling years of household head, which increases the likelihood of irrigation adaptation. Farm output sell time (hours) reduces the likelihood of using the crop as an adaptation strategy.

Table 26: Marginal effects from the adaptation model

Variables	Irrigation	Crop	No Action
Annual planted area (ha)	-0.005	0.002	0.003
	(0.004)	(0.004)	(0.002)
Perceived temperature shift	1.078	1.290	-2.368
	(274.617)	(291.640)	(122.926)
Perceived precipitation shift	-0.002	0.046	-0.044
	(0.085)	(0.087)	(0.067)
Temperature – rain	-0.078***	0.051***	0.027*
	(0.015)	(0.017)	(0.015)
Temperature – dry	0.072***	-0.055***	-0.017
	(0.010)	(0.012)	(0.011)
Precipitation – rain	-0.003**	0.002	0.002
	(0.001)	(0.002)	(0.001)
Precipitation – dry	0.005*	-0.006*	0.000
	(0.003)	(0.003)	(0.002)
Receive extension from local gov.	0.090	0.003	-0.093*
	(0.056)	(0.057)	(0.051)
Farm output sell time (hours)	0.468**	-0.732**	0.264*
	(0.216)	(0.334)	(0.137)
Experience (years)	0.002	0.001	-0.002
	(0.002)	(0.003)	(0.002)
Household size (members)	-0.009	0.017	-0.009
	(0.016)	(0.016)	(0.013)
Schooling years of HH head	0.018**	0.001	-0.019***
	(0.008)	(0.009)	(0.007)
Telephone	0.312	0.051	-0.363***
	(0.229)	(0.237)	(0.109)
Internet	-0.121	-0.046	0.167***
	(0.082)	(0.084)	(0.058)
Observations	275	275	275

Notes: (***), (**) and (*) significant at 1%, 5% and 10%, respectively. Standard errors are in parentheses.

Figure 19: Predicted probability of adaptation and temperature



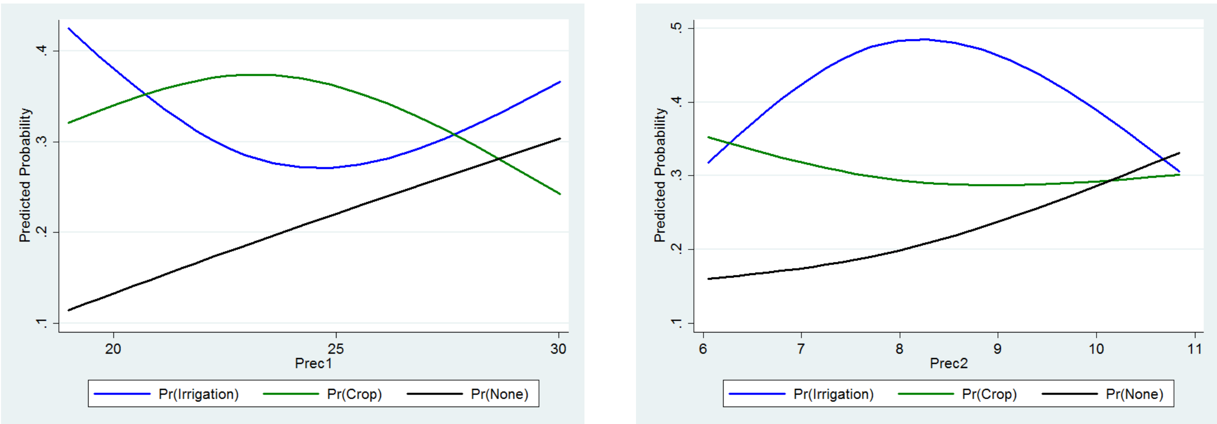
Rain season

Dry season

Figure 19 shows that the crop type adaptation in Viet Nam is temperature and season sensitive. The probability to choose crop adaptation peaks when temperature is about 20°C during the dry season and farmers shifts away from using crop as adaptation as it gets warmer. During the rain season, the probability of crop type adaptation continues to increase until it peaks when temperature is about 24°C and falling as it gets warmer in the season. Irrigation adaptation is more likely during the dry season and increases, as temperature increases when temperature is above 22°C. During the rain season, as temperature increases, the probability to choose irrigation adaptation decreases, up to about 24.5°C when the likelihood of irrigation increases.

Figure 20 shows that irrigation adaptation is sensitive to level of precipitation and season change. During the rain season lower precipitation, as precipitation increases, the likelihood to choose irrigation adaptation reduces but continues to increase beyond 250 mm precipitation. More precipitation in the rain season reduces the likelihood of using crop as an adaptation strategy. More rain increases the probability of no action. In the dry season the story is different, rainfall beyond 105 mm increases the likelihood of no action as the best strategy. However, before reaching this level of precipitation, probability of using irrigation investment is the highest. It reaches a peak around 85 mm with more rain reducing the likelihood of using irrigation.

Figure 20: Predicted probability of adaptation and precipitation



Rain season

Dry season

MODELLING REVEALED CLIMATE CHANGE ADAPTATION

Given that cropping is one of the major adaptation options, the team sought to understand which type of crops the farmers are likely to perform better as precipitation and temperature changes. The analysis examines the changes in probability of a farmer choosing a specific type of crop as climate changes.

The data is first organized to make use of information collected on each of the two plots that farmers typically used. The choice of crop for each plot per season is used. As a result, there are two observations per farmer with two plots. In addition, some farmers plant in the second and third seasons and thus make choices in each season on what to plant in each plot. Combining all the plots and seasons, there are 746 observations.

The crops are categorized into five groups: rice, cereal, vegetable, fruit, and plantation (including tea, coffee, cashew and other perennial crops). The majority (59 per cent) grow rice, 16 per cent cereal, 10 per cent vegetable, 9 per cent fruit and 10 per cent plantation.

The results of the multinomial logit model are presented in Table 27. The explanatory variables are similar to those used in the adaptation analysis model, controlling for seasons. The results show that temperature and precipitation both impact crop choice. The higher the precipitation in season 1, the higher the likelihood of choosing rice but no significant difference in the likelihood of choosing cereal. However, in season 2, precipitation only influences vegetables but no difference in likelihood of choosing the other crops. Precipitation is important in season 3 for fruit, reducing its likelihood relative to rice. Higher temperature reduces the likelihood of choosing rice – seasons with higher temperature will lead to lower choice of rice. As shown in Figure 21 as temperature increases during the rain season, the probability of choosing rice is higher and the probability of choosing fruit or vegetables is lower. During the dry season, the probability of growing plantation and cereal is higher up to about 22°C, when it starts to decrease. Figure 22 reveals that as precipitation increases during the rain and dry season, the probability of growing rice is higher. Growing fruits and cereals during the dry and rain seasons remains stable.

Table 27: Multinomial logit crop choice model

Variable	Rice (base)	Cereal	Vegetables	Fruit	Plantation
Farm Area		-0.136	-0.523**	-0.274**	-0.042
		(0.122)	(0.254)	(0.111)	(0.088)
Temperature (Rain)		-0.791***	-0.518**	-1.888***	-1.140***
		(0.261)	(0.241)	(0.363)	(0.280)
Temperature (Dry)		0.100	0.118	0.577***	0.458***
		(0.078)	(0.092)	(0.119)	(0.099)
Precipitation (Rain)		-0.100	0.136	-0.514***	-0.098
		(0.101)	(0.093)	(0.145)	(0.089)
Precipitation (Dry)		0.180	-0.139	0.515	0.211
		(0.197)	(0.176)	(0.349)	(0.192)
Altitude		0.001	-0.000	-0.010***	0.001
		(0.001)	(0.001)	(0.003)	(0.002)
Experience		0.021	0.008	-0.014	0.006
		(0.013)	(0.013)	(0.019)	(0.016)

Table 27: Multinomial logit crop choice model (cont.)

Variable	Rice (base)	Cereal	Vegetables	Fruit	Plantation
Household size		-0.243**	-0.038	-0.233**	-0.212*
		(0.102)	(0.076)	(0.116)	(0.110)
Education		0.083	-0.043	0.143**	0.068
		(0.055)	(0.048)	(0.071)	(0.056)
Telephone		17.663***	3.399***	15.227***	4.428***
		(1.121)	(1.191)	(0.767)	(1.359)
Internet		0.268	0.397	0.465	0.362
		(0.532)	(0.502)	(0.519)	(0.411)
Farm sell time		-1.255	0.688***	0.931***	0.024
		(0.767)	(0.226)	(0.326)	(0.307)
Extension local gov.		0.339	-0.069	-0.203	0.267
		(0.320)	(0.307)	(0.489)	(0.375)
Season 2 (Dummy)		-0.059	-1.818***	-3.330***	-2.950***
		(0.151)	(0.370)	(0.675)	(0.584)
Season 3 (Dummy)		2.864***	1.468***	-1.917**	-14.665***
		(0.338)	(0.383)	(0.830)	(0.347)
Constant		-0.338	4.446	29.277***	14.192**
		(5.625)	(5.957)	(10.467)	(6.983)
Observations	749	749	749	749	749

Notes: Robust Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

Table 28: Marginal effects from the crop choice model

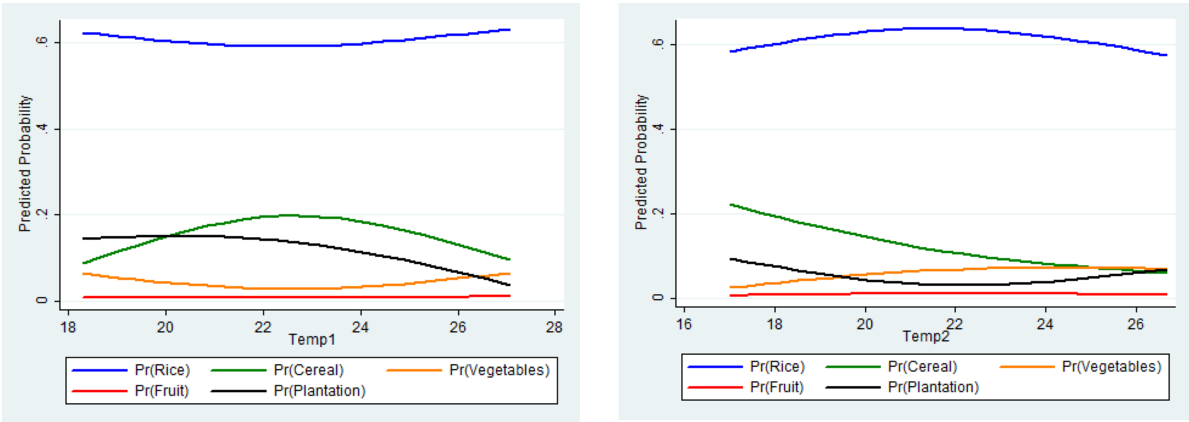
Variable	Rice (base)	Cereal	Vegetables	Fruit	Plantation
Planted area annual	0.034***	0.005	-0.031***	-0.011*	0.003
	(0.008)	(0.006)	(0.01)	(0.006)	(0.004)
Temperature	-0.016**	-0.017***	0.013***	0.020***	0.001
	(0.007)	(0.006)	(0.005)	(0.005)	(0.003)
Precipitation (cm)	0.033***	0.012***	0.004	-0.056***	0.008
Season 1	(0.01)	(0.004)	(0.005)	(0.02)	(0.005)
Season 2	-0.295***	-0.051	-0.096*	0.516***	-0.074***
	(0.067)	(0.053)	(0.051)	(0.058)	(0.018)
Season 3	-0.256*	0.172	0.046	0.018	0.019
	(0.14)	(0.123)	(0.092)	(0.107)	(0.038)
Experience	0.004**	-0.001	0.001	-0.001	-0.002**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Household size	-0.001	-0.01	0.007	0	0.005
	(0.01)	(0.008)	(0.005)	(0.005)	(0.006)
Education	-0.009	0.006	-0.006*	0.004*	0.004

Table 28: Marginal effects from the crop choice model (cont.)

Variable	Rice (base)	Cereal	Vegetables	Fruit	Plantation
	(0.006)	(0.005)	(0.003)	(0.003)	(0.004)
Telephone	-1.538***	1.493***	-0.295***	0.601***	-0.262***
	(0.168)	(0.142)	(0.079)	(0.083)	(0.099)
Internet	0.012	-0.027	0.014	0.004	-0.003
	(0.055)	(0.054)	(0.04)	(0.021)	(0.032)
Farm sell time	0.018	-0.12	0.076***	0.028**	-0.002
	(0.082)	(0.098)	(0.021)	(0.013)	(0.029)
Extension local gov.	-0.033	0.057*	-0.01	-0.023	0.009
	(0.038)	(0.031)	(0.023)	(0.019)	(0.025)
Observations	754	754	754	754	754

Notes: Standard errors in parentheses. (***), (**) and (*) significant at 1%, 5% and 10%, respectively.

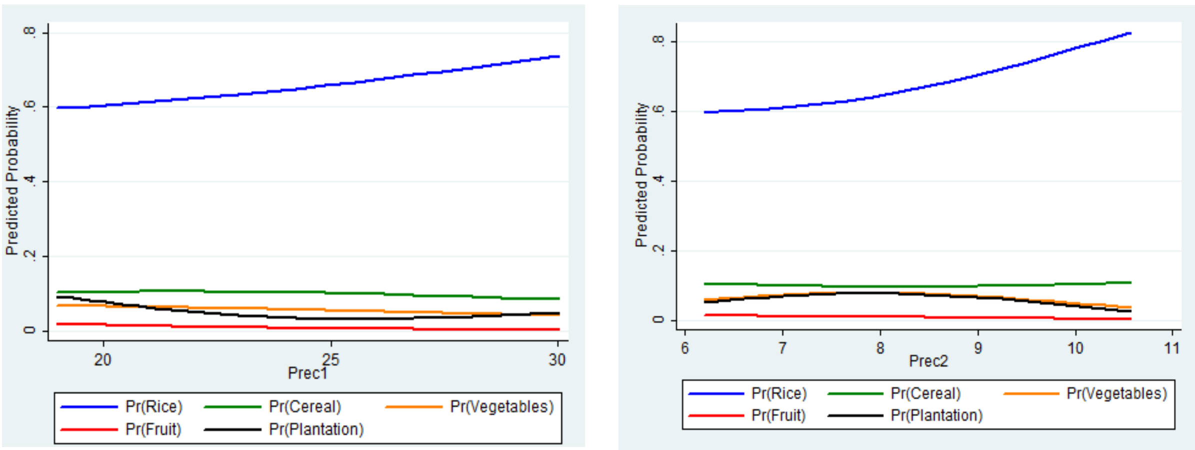
Figure 21: Predicted probability of growing crops at given temperatures



Rain season

Dry season

Figure 22: Predicted probability of growing crops at given precipitation (cm) levels



Rain season

Dry season

Households that have a telephone (as a proxy for social network) are less likely to grow rice and plantation. Instead, they tend to grow cereal and fruit. Longer distance to markets makes farmers more likely to grow vegetables and fruit and less likely to grow cereal. All other household characteristics have no effect on the crop choice.

In order to understand the effect of changes in temperature and precipitation on crop choice, the team calculated the marginal effects of a slight temperature increase and precipitation at the mean climate of the sample. A 1oC increase in temperature during the rain season reduces the probability of choosing cereal by 0.039 and fruit by 0.067 and plantation by 0.034 and increases the probability of growing rice by 0.148. Precipitation in the rain season increases the probability of growing vegetables by 0.016, while reducing the probability of growing fruit by 0.022

CONCLUSION AND POLICY RECOMMENDATIONS

Numerous factors contribute to the vulnerability of Viet Nam to climate change. The report focuses on the agriculture sector given its vital source of income, food and livelihoods for the communities. The main focus of the report is to examine questions such as 'what are the potential impacts of climate change on the agriculture sector? Given the projected nature and magnitude of these impacts, what key issues should policy makers be aware of when designing policy and strategic direction that will help the country's population better adapt to climate change? A number of policy recommendations and conclusions could be drawn from the Economics of Climate Change Adaptation Viet Nam report.

Key conclusions and recommendations that emerge from the analysis include the following:

- Farmers who use irrigation techniques earn US$62 per acre more than non-irrigated farms. The impact of climate change on rainfed and irrigated farms is also different. These impacts influence farmers' adaptation choices by increasing the probability to adapt through irrigation over crop type adaptation during the dry season, when temperatures are higher. In contrast, higher level of precipitation during the rain season decreases the likelihood to invest in irrigation as adaptation option.

- Policy responses such as extension support from local government is shown to be effective in increasing the probability of adapting through irrigation. It is important that government provides support directed at strengthening irrigation systems and improved water management, particularly in the dry season. Policy support responses that will allow farmers to build resilience of the agriculture sector during the rain season could encourage enhancing research capacities to develop cultivars and techniques appropriate to local shifts in climate.

- On the basis of assessments on the marginal impact of climate change on net revenue, it is clear that assistance in the form of extension services or cooperatives needs to be provided to farmers during periods of increased temperature and precipitation during the rain season. Results have been summarized in Table 29.

Table 29: Influence of climate variables on net revenue during rain and dry seasons, and total impact per annum

Seasons/climatic variables	Temperature	Precipitation
Rain season	An increase of 1°C above the mean would decrease net revenue by US$62.04 per acre.	A 1 mm increase in precipitation decreases net revenue by US$4.02 per acre.
Dry season	An increase of 1°C above the mean would increase net revenue by US$87.12 per acre	A 1 mm increase above the mean increases net revenue by US$5.46 per acre.
Total impact	An increase of 1°C would result in a gain of US$25 per acre.	An increase of 1 mm in each season would result in an increase of US$1.44 per acre.

- Based on climate projections, the team was able to analyse the impact of future changes in temperature and precipitation on farmers' net revenue. Results have indicated that temperature is expected to rise by 1.69°C in the 2031-2060, by 2.93°C in 2051-2081, and by 4.10°C in the 2071-2100 periods. The level of precipitation, as measured in percentage points, would grow in 2031-2060 by 5.30, in 2051-2081 by 4.98, and in 2071-2100 by 3.02 (based on CMCC-CESM estimator). Based on these projections, the impact on net revenue will be positive with increases of net revenue between US$57 to 320 per acre.

- The marginal effect of 1°C increase in temperature above the mean during the rain season would result in a loss of US$62.04 per acre, while during the dry season- in a gain of US$87.12 per acre. A one mm increase in precipitation during the rain season would result in a loss of nearly US$4.02 per acre. Given the OPL estimation of about US$40 per person per month, the total gain brought by shifts in temperatures and precipitation would be beneficial to farmers – more rain is projected in the rain season and irrigation is reducing the impact of less rain in the dry season. These results suggest that if the irrigation system fails then the impact will be devastating for farmers in the country and the poverty rate in Viet Nam would increase. Given the high dependence on the agriculture sector, action needs to be taken and policy response such as capacity building workshops and enhancing skills and knowledge for farmers so they could diversify employment opportunities and stimulate off-farm employment.

- The study suggested that cropping is one of the most preferred adaptation options in Viet Nam. Further analysis was performed to study the types of crops that are more likely to be invested in based on marginal increase of climatic variables. As precipitation increases by 1 cm in the rain season, farmers are more likely to invest in rice (increased probability of 3.3 per cent) and cereal (1.2 per cent) and will move away from fruit (-5.6 per cent). A one-degree increase in temperatures during the rain season increases the probability of growing plantation crops (0.1 per cent) and fruit (2.0 per cent) and reduced the likelihood of growing rice (-1.6 per cent) and cereal (-1.7 per cent). Farmers who own a phone (a proxy for social status) are more likely to invest in cereal and fruit. Finally, farmers who are located far away from markets would most likely grow vegetables and fruits.

- Given that agriculture employs 47 per cent of the total population (as of 2013) climate change could have a direct impact of Viet Nam's labour market. Immediate actions need to be taken in order to anticipate climate change induced impacts. Drawing implications for policy makers such as the development of new types of crops resistant to floods and droughts needs to be taken. It is important that the government provides support directed at strengthening research capacities to develop cultivars and techniques appropriate to local shifts in climate. Diversifying employment and economic opportunities away from farming and towards a more diversified economy will make Viet Nam more climate resilient. Establishing early warning systems for extreme weather events as well as for droughts is also a necessary measure. Stronger extension support from input companies has also shown to be effective.

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