Effect of climate change on Thailand's agriculture: New results

Attavanich, Witsanu

Faculty of Economics, Kasetsart University

30 September 2017

Research Paper

Effect of Climate Change on Thailand's Agriculture: New Results

By

Witsanu Attavanich, Ph.D.

Funded by Department of Economics
Faculty of Economics
Kasetsart University
September 2017

Research Paper No. 25/2017

Research Paper

Effect of Climate Change on Thailand's Agriculture: New Results

By

Witsanu Attavanich, Ph.D.

Funding by the Department of Economics
Faculty of Economics
Kasetsart University
September 2017

Research Paper No. 25/2017

Contents

Acknowledgments **4**
Abstract **7**
1. Introduction **8**
2. Objectives of the Study **10**
3. Benefits from the Study **10**
4. Scope of the Study **11**
5. Literature Review and Theoretical Framework **11**
5.1 Literature Review 11
5.2 Theoretical Framework 22
6. Methodology **26**
6.1 Empirical Estimation 26
6.2 Climate Change Projection 27
6.3 Projections of Socio-Economic Conditions 28
6.4 Data Collection from Interview 28
6.5 Data 29
7. Empirical Results **37**
7.1 Effect of Climate Change on Thailand's Agriculture 37
7.2 Implications for Greenhouse Warming 47
7.2.1 Climate Change Impacts at the National Level 49
7.2.2 Climate Change Impacts at the Provincial Level 52
7.3 Interviewed Results 70
7.3.1 Impacts of Climate Change Related Policies on Working Operation 70
7.3.2 Driving the Policies Related to Climate Change 71
7.3.3 Obstacles of Driving the Policies Related to Climate Change 71
7.3.4 How to Solve the Problems 72
7.3.5 Discussion 72
8. Conclusions and Policy Implications **73**
8.1 Conclusions 73
8.2 Policy Implications 75
8.3 Future Research 76
9. References **77**

Table of Contents

Table 1. Description of Representative Concentration Pathways 28
Table 2. Description of variables 32
Table 3. Summary statistics of selected variables in the full sample 34
Table 4. Summary statistics of selected variables in the subsample of irrigated farms 35
Table 5. Summary statistics of selected variables in the subsample of rainfed farms 36
Table 6. Regression models explaining farm values in the full sample 39
Table 7. Regression models explaining farm values in the subsample of irrigated farms 41
Table 8. Regression models explaining farm values in the subsample of rainfed farms 43
Table 9. Marginal effect of climate variables in the full sample and subsamples 47
Table 10. Implications for greenhouse warming at the national level 51
Table 11. Implications for greenhouse warming on irrigated farms at provincial level under RCP2.6 53
Table 12. Implications for greenhouse warming on irrigated farms at provincial level under RCP4.5 55
Table 13. Implications for greenhouse warming on irrigated farms at provincial level under RCP6.0 57
Table 14. Implications for greenhouse warming on irrigated farms at provincial level under RCP8.5 59
Table 15. Implications for greenhouse warming on rainfed farms at provincial level under RCP2.6 62
Table 16. Implications for greenhouse warming on rainfed farms at provincial level under RCP4.5 64
Table 17. Implications for greenhouse warming on rainfed farms at provincial level under RCP6.0 66
Table 18. Implications for greenhouse warming on rainfed farms at provincial level under RCP8.5 68

Figures of Content

Figure 1. Ricardian function and bias in traditional production function studies......................... 23
Figure 2. Projected changes in seasonal mean temperature in 2041-2050 from the baseline 48
Figure 3. Projected percent changes in seasonal precipitation in 2041-2050 from the baseline .. 49

Acknowledgments

This research project was fully supported by a grant from the Department of Economics, Faculty of Economics, Kasetsart University, Thailand. Gratitude is expressed to: the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives; and Thai Meteorological Department for providing data for this research study.

I would like to thank Associate Professor Dr. Somskaow Bejranonda, Assistant Professor Dr. Supanee Harnphattananusorn from Department of Economics and Associate Professor Dr. Suwanna Praneetvatakul from Department of Agricultural and Resource Economics, Kasetsart University for helpful comments and suggestions. Lastly, I would like to give my special thank to my wife, Mrs. Patra Attavanich, and my research assistant, Ms. Siwabhorn Pipitpukdee for data collection and management. I'm responsible for any errors.

Witsanu Attavanich, Ph.D.

Department of Economics,

Faculty of Economics,

Kasetsart University

Abstract

The objectives of this study are to analyze the effect of climate change on farmland values in Thailand and investigate implications for greenhouse warming under future climate change and socio-economic scenarios using the Ricardian approach allowing a variety of the adaptations that farmers make in response to changing economic and climate conditions. The main sources of data are obtained from 2011/2012 national agricultural household socio economics survey conducted by Office of Agricultural Economics, Thailand Meteorology Department, National Economic and Social Development Board, and Intergovernmental Panel on Climate Change.

This study finds that both mean and variation of temperature and precipitation significantly determine farmland values. Overall, the accumulative damage values from 2011/2012 crop year to 2041-2050 period range from $17.499 billion to $83.826 billion. Projected climate change impacts on the irrigated farms are equal to 6.666 billion to $20.406 billion, while the impacts on rainfed farms range from $10.833 billion to $63.420 billion. By downscaling the analysis to the province level, this study finds that irrigated farms in all provinces will be negatively affected by the climate change across all climate scenarios, while results are mixed for the rainfed farm subsample.

To mitigate the climate change impacts, Government should provide the support of the collection, development and building the database, knowledge and local wisdom with the cooperation from all sectors for managing the risks arising from climate change and at the same time establish and develop technology in response to climate change. It is also recommended to raise awareness of climate change impacts and convey information, knowledge and technology to development parties at all levels.

Effect of Climate Change on Thailand's Agriculture: New Results

ผลกระทบของการเปลี่ยนแปลงสภาพภูมิอากาศที่มีต่อภาคการเกษตรของประเทศไทย: ผลการศึกษาใหม่

1. Introduction

Recent studies, including those by the Intergovernmental Panel on Climate Change (IPCC)(2007a; 2007b; 2013; 2014), indicate that greenhouse gas (GHG) emissions and resultant atmospheric concentrations have led to changes in the world's climate conditions, such as increases in temperatures, extreme temperatures, droughts, and rainfall intensity. Such changes are expected to continue and agriculture is potentially the most sensitive economic sector to climate change, given that agricultural production is highly influenced by climatic conditions (e.g., Mendelsohn et al. 1994; Schlenker and Roberts 2009; Attavanich et al. 2013; Attavanich and McCarl 2014; IPCC 2014; Brown et al. 2015). Compared with developed countries, developing countries are more vulnerable to climate change since they are already in a hot climate zone, depend on labor-intensive technologies with fewer adaptation opportunities, and a majority of people in these countries rely heavily on the agricultural sector (Mendelsohn et al. 2001).

Thailand is one of developing countries that agriculture plays a crucial role. Not only was it a major source of food for the Thai people, but it also was a major source of employment and revenue from exporting agricultural products. From 1980s to 1990s, Thailand's economy was expanded at the high rate of growth leading to a reduction in poverty rate. During this period, the United Nations counted in Thailand to be one of the countries succeeding in the economic development. The expansion of Thai economy also helped improve the economic status of Thailand from the low income country to the middle income country and transformed the Thai economy from agricultural-dependent economy to more industrial-dependent economy. Such transformation have led to the economic disparity between agricultural and industrial sectors.

According to the Office of the National Economic and Social Development Board (NESDB), agricultural activities contributed about 10 percent of the gross domestic production (GDP) in 2016 (NESDB 2017) and has played a dominant role in the labor market. It employed about 11.7 million people, accounting for 30.7 percent of labor force in 2016 (NSO 2017) and about 5.9 million households were in agriculture in 2015 (Office of Agricultural Economics 2016). The above statistics imply that a majority of people in agricultural sector are poorer than those in other economic sectors. Therefore, climate change impacts on agriculture are expected to significantly affect the economy and the livelihood of the people in this country.

While there are many studies analyzing the effect of climate change on agriculture in Thailand, most studies (except for Khamwong and Praneetvatakul 2011 and Attavanich 2013) use the traditional production function approach, which may overestimate the damage from climate change since the model allows little adaptation of farmers. Khamwong and Praneetvatakul (2011) is the first who utilize the Ricardian approach to examine the climate change impacts on agriculture in Thailand. Although their study provides several aspects of climate change impacts of Thai agriculture, it focuses only on the northeast region of Thailand and employs a broad scale level of dataset, province-level data, which may not correctly predict the decision making of a farmer and adequately identify areas potentially affected by climate change. Lastly, their study use the net farm revenue per rai as a dependent variable, which may generate a potential problem since the original Ricardian analysis uses the land value as the dependent variable and the land value is the present value of a future stream of annual net farm revenue (See the theoretical framework of Ricardian approach in the next section).

While Attavanich (2013) attempted to address possible problem faced in Khamwong and Praneetvatakul (2011), the study utilized an out of date climate projections from IPCC AR4 (IPCC 2007) and did not take into account the role of changes in future socio-economic conditions, which play a crucial role in explaining the adaptive capability of farmers to climate change and hence damages caused by climate change. Also Attavanich (2013) did not control for factors reflecting the climate variability and extreme events, which could potentially affect agricultural sector in Thailand. Last but not least, Attavanich (2013) utilizes the simple approach by assigning climate data of the climate station that is nearest to each province. The current study will address all issues to improve the better estimates of climate change impacts on Thailand's agriculture and reveal interviewed results from policy makers in several aspects including the impacts of climate change related policies on working operation, driving the policies related to climate change, and obstacles of driving the policies related to climate change

2. Objectives of the Study

1) To analyze the effect of climate change on Thailand's agriculture.
2) To project climate change impacts on Thailand's agriculture under future changes in climate and socio-economic conditions.

3. Benefits from the Study

1) Policy makers could use the results from this study for their mid to long term planning related to agricultural risk management.
2) Agricultural producers could use the results from this study to adjust their adaptation strategies especially those in the projected vulnerable regions.

4. Scope of the Study

For the second objective of this study, the future climate change impacts and changes in socio-economic conditions will be predicted during 2041-2050. Also to evaluate the current climate change related risk management strategies of the Thai public sector in predicted vulnerable areas whether they are capable of minimizing the future damage, the study will interview public officers who are responsible for agricultural risk planning.

5. Literature Review and Theoretical Framework

5.1 Literature Review

The Effect of Climate Change on Agriculture

In view of its importance to economic well-being, effects of climate change on agriculture have been well research and documented, dating back at least 25 years (e.g. Smith and Tirpak 1989; Mendelsohn et al. 1994;Adams et al. 1990;Reilly et al. 2003; McCarl et al. 2008; Attavanich et al. 2013; Attavanich and McCarl 2014; Attavanich 2013, 2016 and various IPCC reports).Overall, the effect of climate change on agriculture is mixed in developed countries, but negative impacts are found in developing countries. Moreover, in a country, the damage is heterogeneous across regions.

Using the agricultural sector model, Adams et al. (1990) find that agricultural welfare strictly increases in the U.S. with a 1.5°C warming and further warming could decrease this benefit at an increasing rate. The welfare gain from a 1.5°C warming with 7 percent precipitation is $55 billion in 2060. Further warming by 2.5°C could reduce these benefits to $47 billion. With similar approach, Reilly et al. (2003) estimated the net effect in terms of economic welfare of the combined changes in crop yields including adaptation and CO_2 fertilization effects, water supply, irrigation demand, pesticide expenditures, and livestock effects was generally positive. The increase in economic welfare was ranged from $0.8-$7.8 billion in 2030 and $3.2-$12.2 billion in 2090. U.S. producers generally suffered income losses due to lower commodity prices while consumers gained from these lower prices.

Using a large panel dataset for the 1977–2007 period with the instrumental variables approach, Miao, Khanna, and Huang (2016) investigated the effect of crop price and climate variables on rain-fed corn and soybean yields and acreage in the U.S.. Their study revealed that the impact of climate change on corn production ranged from −7 to −41 percent and on soybean ranges from −8 to −45 percent, depending on the climate change scenarios, time horizon, and global climate models used to predict climate change.

Using the Ricardian analysis, Mendelsohn, Nordhaus, and Shaw (1994) find that higher temperatures in all seasons except autumn reduce average U.S. farm values, while more precipitation outside of autumn increases farm values. They estimate that a climate change induced loss in U.S. farmland value ranging from -$141 to $34.8 billion. Schlenker, Hanemann, and Fisher (2005) do a similar study and find an annual loss in U.S. farmland value in the range of $5-$5.3 billion for dryland non-urban counties. Mendelsohn and Reinsborogh (2007) find that U.S. farms are much more sensitive to higher temperature than Canadian farms and but are less sensitive to precipitation increases. Deschenes and Greenstone (2007) find that climate change will lead to a long run increase of $1.3 billion (2002$) in agricultural land values. They indicate that agricultural land values in California, Nebraska, and North Carolina will be lowered substantially by climate change, while South Dakota and Georgia will have the biggest increases.

For developing countries, Seo and Mendelsohn (2008) find that in South America climate change will decrease farmland values except for irrigated farms. Moreover, they find small farms are more vulnerable to the increase in temperature, while large farms are more vulnerable to increases in precipitation. Mendelsohn, Arellano-Gonzalez, and Christensen (2010) project that, on average, higher temperatures decrease Mexican land values by 4 to 6 thousand pesos per degree Celsius amounting to cropland value reductions of 42-54% by 2100. Wang et al. (2009) find that in China an increase in temperature is likely to harm rain-fed farms but benefit irrigated farms. A small value loss is found in the Southeast China farms, while the largest damage is discovered in the Northeast and Northwest farms (Wang et al. 2009).

Overall, Brown et al. (2015) reviewed several studies and concluded that globally climate change risks extend beyond agricultural production to other elements of global food systems that are critical for food security, including the processing, storage, transportation, and consumption of food. Moreover, climate risks to food security increase as the magnitude and rate of climate change increase. Higher emissions and concentrations of greenhouse gases are much more likely to have damaging effects than lower emissions and concentrations. Also by applying the AgMIP global integrated model, Wiebe et al. (2015) project that yields of five commodities (coarse grains, rice, wheat, oilseeds, and sugar) would decline by a median of 7.2 percent in the high-concentration scenario, while area would increase by 3.8 percent, production and consumption would decline by 0.9 percent, exports and imports would increase by 4.0 percent and 5.3 percent (respectively), and prices would increase by 15.5 percent, all relative to a baseline projection for 2050 that does not include additional climate change between now and then. They also show that in the case of low international cooperation and high concentrations (SSP3/RCP 8.5), restricting trade results in higher prices, and thus more-adverse consequences of climate change, and a larger spread across models.

In Thailand, several studies have investigated the effect of climate change on agriculture. As early as 1987, UNEP (1989) finds that a doubling of CO_2 could increase the risk of yield variation and the loss of income to the farmers. Using the CERES crop models and climate input data derived from different GCMs, Center for Applied Economics Research (2000) finds that rice grown under rain-fed conditions in Thailand was found to be highly vulnerable to climate change due to an increase in greenhouse gases. Based on climate data from four general circulation models (GCMs), the study found similar declining trends in rice and maize yields overtime. Their magnitudes, however, vary depending on climate conditions, soil types and crop practice. Maize yields, for example, could drop from 5 percent in Nakhon Sawan province to 44 percent in Nakhon Ratchasima province. The impacts on rice yields could be even more extensive and diverse. Rice yields could drop by 57 percent in Roi-et province, but increase by 25 percent in Surin province. The four climate models also demonstrated that climate change could increase temperature in areas during the flowering period of crops by 1 to 7ºC. This will reduce flowering and harvesting periods as well as crop yields in general. The accumulation of CO_2 in the atmosphere also increases crop yields through the feedback effect, but only to a limited extent.

By using the CERES crop model, Office of Environmental Policy and Planning (2000) reveals that rice grown under rain-fed conditions was found to be highly vulnerable to climate change. Moreover, yields of rice and maize are projected to decline as much as 57 and 44 percent as compared to the baseline, respectively, although their magnitudes vary depending on climate conditions, soil types, and crop practices.

Buddhaboon, Kongton, and Jintrawet (2005) simulate the effect of climate change on KDML 105 rice yield in Tung Kula paddy field by direct seeding method and set CO_2

concentration at 1.5 and 2.0 times of year 1980-1989 (normal year) in the period of 2040-2049 and 2066-2075, respectively. They reveal that climate change likely enhances overall rice yield.

Pannangpetch et al. (2009) employ a crop simulation model, the Decision Support System for Agro Technology Transfer (DSSAT), to analyze the impacts of global warming on rice, sugarcane, cassava, and maize production in Thailand. They find a little impact of rising atmospheric CO_2 concentration and temperature on the rice, sugarcane and maize production. However, cassava production may drop as much as 43 percent as compared to the baseline. Northeast region is highly vulnerable to the global warming since the production of all studied crops is project to drop significantly.

By using Crop DSS simulation model, Isvilanonda et al. (2009) conclude that climate change enhances KDML 105 rice yield in the northeast and the north, but adversely affects Suphan Buri 1 rice yield in central plain. Using changes in yields data, they find that the total production of KDML 105 is project to increase approximately 1.4 million ton, which is equivalent about 14,195 million baht. On the other hand, farmers in central plain, who grow Suphan Buri1, will face a reduction in their production about 0.249 million ton, creating a loss in value approximately 2,029 million baht. Khamwong and Praneetvatakul (2011) employ the Ricardian model with province-level data to analyze the impacts of climate change on agricultural revenue in northeast region. They find that rising temperature in summer and early rainy season and increased rainfall at the end of the rainy season decrease net farm revenue. On the other hand, increased rainfall in summer and early rainy season increases net farm revenue.

By extending the scope of study to the country level and constructing a finer scale dataset of Khamwong and Praneetvatakul (2011), Attavanich (2013) revealed that both temperature and precipitation significantly determine farmland values. Summer temperature, precipitation in the early rainy and summer season negatively affect the farmland values, while winter temperature, precipitation in the late rainy and winter season enhance the farmland values. Overall, the projected negative impacts of climate change on Thailand's agriculture ranged from $24 to $94 billion in accumulative term from 2005 to 2049. By downscaling the analysis to the province level, this article found that western, upper part of central, and the left part of northern regions are projected to be better off, while southern, eastern regions, lower part of central, and the right part of northern regions is projected to be worse off. For the rice production, Attavanich (2016), using climate projections and shared socioeconomic pathways, projected that rice yield, rice acreage, and rice supply in Thailand generally tended to be decreased under future changes in climate and socio-economic conditions.

Adaptation Strategies

Climate change is expected to affect agriculture productivity and ecosystems over space (Zilberman et al. 2004; Mendelsohn and Dinar 2009). Adaptation is the least explored economic area to date (McCarl et al. 2014). Adaptation involves the purposeful manipulation of land productivity, land use, and land management to increase productivity in the face of such shifts. There are two types of adaptation: actions undertaken by private decision makers in their own best interests (autonomous adaptation) and actions undertaken by the public sector (planned adaptation) in the name of society (IPCC 2014).

A number of potential adaptation options are available. These are often variations of existing climate risk management strategies (Howden et al. 2007) and include changes in enterprise choice, crop, or livestock mix; moisture management; irrigation, soil, and water conservation; and management of natural areas, among others (McCarl 2007). A number of authors have examined observed or potential adaptations in the agricultural sector.

In the US, Reilly et al. (2003) and Attavanich et al. (2013) examined changes in crop acreage and found northward shifts in crop mixes. Mu et al. (2013) examined the ways climate change induced land use adaptation between crop and pasture in the United States and investigated that climate change causes shifts in land from crop to pasture and a lowering of stocking rates. They estimated that projected climate change will decrease cropland by 6% and increase pasture land. Seo (2010) revealed that, in Africa, a hotter and wetter climate causes a shift from crops toward animals.

Studies also have shown that cropping system management adjustments can be used to adapt (Butt et al. 2005; Travasso et al. 2006; Challinor et al. 2007). Reilly et al. (2003) showed considerable potential to varietal adaptation, but Schlenker and Roberts (2009) suggested limited historical adaptation of seed varieties or management practices to warmer temperatures. Jin et al. (1994) revealed that using new rice cultivars and changing planting dates in southern China could substantially adapt to climate change and increase rice yields. Kurukulasuriya and Mendelsohn (2008*a*, 2008*b*) found that, in Africa, farmers adapted by shifting toward more heat-tolerant crops as temperatures rises and that farmers will also shift toward more heat-tolerant and water-loving crops. In Greece, Kapetanaki and Rosenzweig (1997) found that changing planting dates and varieties of corn could increase yields by 10%. In Spain, Iglesias et al. (2000) found that hybrid seeds and altered sowing dates could allow for double cropping of wheat and corn, thus increasing yields and reducing water use.

Wang et al. (2010) concluded that in recent years, China has made tangible progress on the implementation of adaptation strategies in the agricultural sector. Efforts have been made to increase public investment in climate change research, and special funding has been allocated to adaptation issues. An experiment with insurance policies and increased public investment in research are just two examples of climate adaptation measures. Beyond government initiatives, farmers have implemented their own adaptation strategies, such as changing cropping patterns, increasing investment in irrigation infrastructure, using water saving technologies and planting new crop varieties to increase resistance to climatic shocks.

In India, Deb et al. (2015) used the crop simulation model CERES-Maize to simulate maize yield under future climate change for the future time windows. Simulation results show that climate change could reduce maize productivity by 10.7−18.2%, compared to baseline yield. They also indicated that the projected decline in maize yield could be offset by early planting of seeds, lowering the farm yard manure application rate, introducing supplementary irrigation and shifting to heat tolerant varieties of maize.

Mainuddin et al. (2013) assessed the potential impact of climate change on the yield of rainfed rice in the lower Mekong Basin and evaluated some adaptation options, using a crop growth simulation model. They found that widely used adaptation options such as changing planting date, supplementary irrigation, and reduction in fertility stress and found that negative impact on yield can be offset and net increase in yield can be achieved.

Within livestock systems, many adaptation options were connected with maintaining the availability of fodder and feed and reducing heat stress from animal housing (McCarl 2007; Parry et al. 2009). McCarl and Reilly (2008) estimated changes in the size of the US livestock herd under 2030 climate scenarios and predicted increased sheep, cow calf, dairy, turkey, hog, and broiler numbers with less feedlot beef animals. In South America, Seo et al. discovered that livestock increased with warming, but decreased when it became too wet. In Africa, Seo and

Mendelsohn (2008*a*) revealed that a warming climate is harmful to commercial livestock but beneficial to small landowners. Seo et al. (2009) found climate change will likely decrease African dairy cattle but increase sheep and chickens, although adaptation measures vary across agro-ecological zones.

Farmers could adapt to climate change by adjusting livestock numbers and species. Mu et al. (2013) found that adaptation involves reductions in cattle stocking rates under projected climate change. Alternatively, farmers could switch breeds so that livestock can adapt to a warmer temperature and changes in precipitation. Zhang (2013) examined breed choices among cattle in Texas and explored that heat-tolerant breeds like Brangus cattle are used as an adaptation strategy in a hot and humid environment.

Adaptation has been found to improve welfare, so it is therefore very likely that people will autonomously adapt (Butt et al. 2005; Mendelsohn and Dinar 2009). However, most impacts due to climate change are projected to continue to increase for some time (IPCC 2007*b*). This implies a need for continuing adaptation. Furthermore, some adaptation actions may not be practical due to costs or barriers. Therefore, it is likely that some climate change impacts are unavoidable (Parry et al. 2009). The resolution of who is going to pay for adaptation is also a major issue.

Social-economic development and adaptation are intimately linked (Parry et al. 2009). Technological sophistication and progress are important determinants of farm productivity and adaptation potential and also influence adaptation demand. In particular, if technological progress lags behind population growth, there will be increased competition among land uses, including those for adaptation and mitigation (Mendelsohn and Dinar 2009; McCarl et al. 2012). Lobell et al. (2008) indicated that South Asia and Southern Africa are regions that, without sufficient adaptation measures, will likely suffer negative impacts on several crops important to large, food-insecure human populations. The United Nations Framework Convention on Climate Change (UNFCCC) estimated that the annual cost of agricultural and forest adaptation ranged between \$11.3 and \$ 12.6 billion for 2030, with developing counties needing \$7 billion dollars (McCarl 2007). With such levels of adaptation, about 80% of the costs of potential impacts might be avoided, but about 20% might not (Parry et al. 2009), and cost of adaptation may rise steeply after 2030 (IPCC 2007*b*).

According to the above studies, we can classify the model used to analyze the impacts of climate change on agriculture into three categories (e.g., Mendelsohn, Nordhaus, and Shaw 1994; Seo, Mendelsohn, and Munasinghe 2005; Wang et al. 2009), which consist of: 1) the traditional production function approach (e.g., Smith and Tirpak 1989; Attavanich and McCarl 2014); 2) Ricardian approach (e.g., Mendelsohn, Nordhaus, and Shaw 1994; Attavanich 2013); and 3) the agro-economic approach (e.g., Adams et al. 1999). Mendelsohn, Nordhaus, and Shaw (1994) is the first who criticize that the traditional production function approach has a serious drawback since the model tends to overestimate the damage from climate change by omitting a variety of adaptations that farmers can make in response to changing economic and environmental conditions. While the agro-economic approach incorporates the climate change adaptation of farmers, they are difficult to build especially in the developing countries due to data availability and complexity of the model.

Mendelsohn, Nordhaus, and Shaw (1994) are the first who introduce the Ricardian approach to bridge the gap between the traditional production function approach and the agro-economic approach. Recently the Ricardian approach is gaining popularity. This approach is applied to both developed countries such as U.S. and Canada (e.g., Mendelsohn, Nordhaus, and

Shaw 1994, 2001; Reinsborough 2003) and developing countries such as Brazil, India, Sri Lanka, and China (Dinar et al. 1998; Kumar and Parikn 2001; Mendelsohn et al. 2001; Seo, Mendelsohn, and Munasinghe 2005; Wang et al. 2009).

In Thailand, there are many studies analyzing the effect of climate change on agriculture. However, most studies (except for Khamwong and Praneetvatakul 2011 and Attavanich 2013) use the traditional production function approach, which may overestimate the damage from climate change since the model allows little adaptation of farmers. Khamwong and Praneetvatakul (2011) is the first who utilize the Ricardian approach to examine the climate change impacts on agriculture in Thailand. Although their study provides several aspects of climate change impacts of Thai agriculture, it focuses only on the northeast region of Thailand. Moreover, their study employs a broad scale level of dataset, province-level data, which may not correctly predict the decision making of a farmer and adequately identify areas potentially affected by climate change. Lastly, they use the net farm revenue per rai as a dependent variable. Although the net farm revenue per rai is employed by several studies, it may generate a potential problem since the original Ricardian analysis uses the land value as the dependent variable and the land value is the present value of a future stream of annual net farm revenue (See the theoretical framework of Ricardian approach in the next section).

While Attavanich (2013) attempted to address possible problem faced in Khamwong and Praneetvatakul (2011), the study utilized a bit out of date climate projections from IPCC AR4 (IPCC 2007) and did not take into account the role of changes in future socio-economic conditions, which play a crucial role in explaining the adaptive capability of farmers to climate change and hence damages caused by climate change. Also Attavanich (2013) did not control for factors reflecting the climate variability and extreme events, which could potentially affect agricultural sector in Thailand.

The current research contributes to the literature of climate change and agriculture in Thailand by updating the results found in Attavanich (2013) by: using the recent climate projections from IPCC AR5 (IPCC 2014); controlling for changes in socio-economic conditions using future socioeconomic scenarios as reported by NESDB (2010); and adding variables capturing climate variability and extreme events. In addition, we also constructed the weighted average of climate data for each province from all climate stations within the radius of 250 kilometres from the centroid of the province.

5.2 Theoretical Framework

The Ricardian approach developed by Mendelsohn, Nordhaus, and Shaw (1994) is the primary method that we use in this paper. In contrast to the traditional production function approach, the Ricardian approach allows a variety of the adaptations that farmers make in response to changing economic and climate conditions. By not permitting a complete range of adjustments, previous studies have overestimated damages from climate change. Following Mendelsohn, Nordhaus, and Shaw (1994), figure 1 shows the hypothetical values of output in four different sectors as a function of a single climate variable, say temperature.

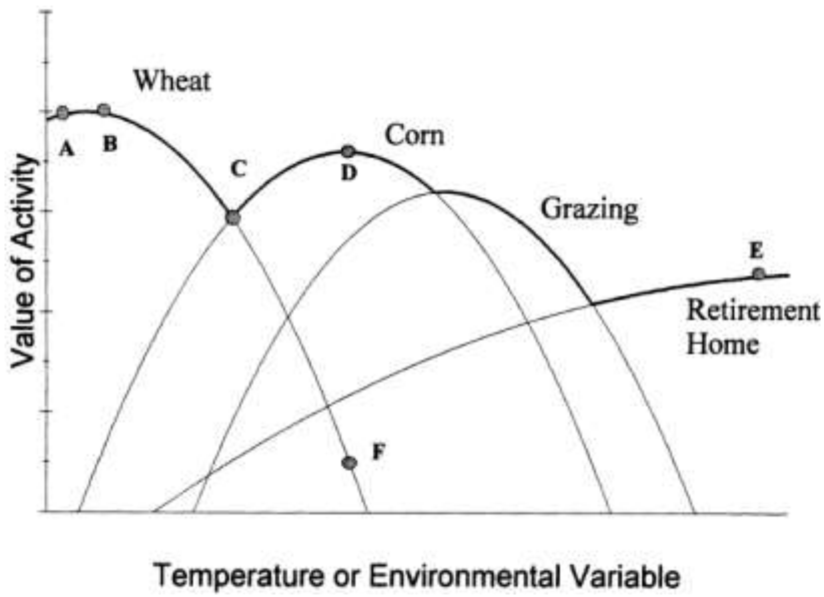

Figure 1. Ricardian function and bias in traditional production function studies
Source: Mendelsohn, Nordhaus, and Shaw (1994)

In each case, we assume that the traditional production function approach provides a correct assessment of the economic value of the activity as a function of temperature. The four function give a simplified example of how the value of wheat, corn, grazing, and retirement homes might look as a function of temperature. For instance, the wheat production function shows how the value of wheat vary as the temperature increases from cold temperatures such as point A, then peaking at point B, finally falling as temperatures rise too high. A production function approach would estimate the value of wheat production at different temperatures along this curve. The production-function approach could create bias since it fails to allow for economic substitution as conditions change. For example, when the temperature rises above point C, adaptive and profit-maximizing farmers will switch from wheat to corn. As temperature rises, the production-function approach might calculate that the yield has fallen to F in wheat, but wheat is in reality no longer produced; the realized value is actually much higher, at point D, where corn is now produced. At a slightly higher temperature, the land is no longer optimally used for corn but switches to grazing, and production-function estimates that do not allow for this conversion will again overestimate the losses from climate change. Finally, at point E, even the best agricultural model will predict that the land is unsuitable for farming or grazing and that the damage is severe. A more complete approach might find that the land has been converted to retirement villages.

Instead of studying yields of specific crops, the Ricardian approach examines how climate in different locations affects the net rent or value of farmland. By directly measuring farmland values, the approach account for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptations to different climates. The results of the Ricardian approach can be seen in figure 1. We assume that the "value" measured along the vertical axis is the net yield per acre of land; more precisely, it is the value of output less the value of all inputs (excluding land rents). Under competitive markets, the land rent will be equal to the net yield of the highest and best use of the land. This rent will in fact be equal to the heavy solid line in figure 1. The solid line in figure 1 is labeled as the “best-use value function”.

As mentioned in Mendelsohn, Nordhaus, and Shaw (1994), we do not generally observe market land rents because land rent is generally a small component of the total profits. However, with farms, land rents tend to be a large fraction of total costs and can be estimated with reasonable precision. Farm value is the present value of future rents, so if the interest rate, rate of capital gains, and capital per acre are equal for all parcels, then farm value will be proportional to the land rent. Therefore, by observing the relationship of farm values to climatic and other variables, we can infer the shape of the solid, best-use value function in figure 1.

The Ricardian approach assumes that each farmer maximizes income subject to the exogenous conditions of their farms. Specifically, the farmer chooses the inputs and the combination of crop and/or livestock, indexed by *j*, that maximizes net revenue for each unit of land:

$$Max\pi_i = \sum_{j\in J} P_{ij} Q_{ij} (X_{ij} | C_i, H_i, S_i) - \sum_{j\in J} P_{ij} X_{ij} \quad (1)$$

where π_i is the net revenue of farm *i*, P_{ij} is a vector of input and output prices, Q_{ij} is the production function for each crop or livestock *j*, X_{ij} is a vector of endogenous input choices such as seeds, fertilizer, pesticides, irrigation, hired labor and capital, C_i is a vector of climate variables, H_i is a vector of economic control variables and S_i is a vector of soil characteristics.

Differentiating equation (1) with respect to each input identifies the set of inputs that maximizes net farm revenue. The resulting locus of net revenues for each set of exogenous variables is the Ricardian function shown in equation (2). Details of mathematical derivation can be found in Mendelsohn, Nordhaus, and Shaw (1994). It describes how net revenue will change as exogenous variable change.

$$\pi^* = \pi(C_i, H_i, S_i | P_{ij}) \quad (2)$$

If land is traded in the perfectly competitive market, the land value(V) will be equal to the present value of the net revenue of each farm shown in equation (3).

$$V = \int_0^\infty \pi_i^* e^{-rt} dt \qquad (3)$$

where r is the interest rate.

The welfare impact (W) of climate change is calculated by computing the difference between the value of farmland under the new climate (B) and the value of farmland under the current climate (A) as illustrated in equation (4).

$$W_t = \sum_i \left[V_{it}(C_B) - V_{it}(C_A) \right] \cdot L_{it} \qquad (4)$$

where L_{it} is the amount of land at period t of farm *i*.

6. Methodology

6.1 Empirical Estimation

To answer the first objective and capture the expected non-linear relationship between the farmland value and climate, we specify the following model to examine the impacts of climate change on agriculture in Thailand:

$$V = \alpha_0 + \alpha_{1s} T_s + \alpha_{2s} T_s^2 + \alpha_{3s} P_s + \alpha_{4s} P_s^2 + \alpha_{5s} G_s + \alpha_{6s} G_s^2 + \sum_k d_k Z_k + e \qquad (5)$$

where the dependent variable, *V*, is the farmland value per hectare, *T* and *P* represent a vector of seasonal temperature and precipitation variables, s is season including: winter (November-January); summer(February-April); early rainy (May-July); and late rainy (August-October). G represents a vector of climate variability and extreme variables (i.e., extreme maximum temperature and maximum rainfall within 24 hours).

Z is a vector of relevant control variables capturing characteristics of household (e.g., education level of the principal operator), farm (e.g., size of farmland, irrigation status), locations (e.g., district or province-level population density, district or province-level median household income, altitude, soil characteristics, migration of people from other regions), and *e* is an error term.

Following Schlenker, Hanemann, and Fisher (2005), this article divides the sample between irrigated and rainfed farms and estimate equation (5) to obtain the best-value function across different farms using the ordinary least square (OLS) with robust standard errors for each subsample.

6.2 Climate Change Projection

To answer the second objective of the study, we investigate the implication of future climate change on Thailand's agriculture by employing our estimated coefficients in equation (5) discussed in the previous section together with future climate projections from the 2014 IPCC AR5 report under four representative concentration pathways (RCPs) including RCP2.6 RCP4.5 RCP6.0 and RCP8.5 to account for uncertainty in climate projections due to different assumptions used in each RCP. Table 1 provides description of each RCP.

Table 1. Description of Representative Concentration Pathways

	Description
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 in 2100.
RCP6	Stabilization without overshoot pathway to 6 W/m^2 at stabilization after 2100
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 at stabilization after 2100
RCP2.6	Peak in radiative forcing at ~ 3 W/m^2 before 2100 and decline

Source: IPCC (2014)

6.3 Projections of Socio-Economic Conditions

To account for future changes in socio-economic aspect, this study use the latest projected Thailand's population reported by NESDB (2013). NESDB (2013) projected the future population from 2010-2030. This study further extrapolate the future population to 2050 using quadratic trend analysis with the population data from 1990-2015 and projected data from NESDB (2010). The change in population and population density could affect the demand for land use, which can finally affect the agricultural land value.

6.4 Data Collection from Interview

After obtaining the projected climate change impacts, this study invited 42 government officers who are responsible for climate change projects in the agricultural sector and organized the focus group to obtain expert opinions regarding the problems of driving climate change policies to mitigate the climate change impacts in agricultural sector. The focus group was organized on September 2, 2016 and there were 30 government officers attending the focus group. A majority of government officers were from departments and offices under the authority of Ministry of Agriculture and Cooperatives. The remaining officers from other organizations such as officers from the Office of Natural Resources and Environmental Policy and Planning, Department of Meteorology, the Office of National Economic and Social Development Board, and Thailand Greenhouse Gas Management Organization (Public Organization). The opinion from these government officers could reveal the problems that Thailand is facing and lead us to find way out to reduce the impacts of climate change in agricultural sector.

6.5 Data

Data used in this study are collected from various sources. For the most part, the data are from the 2011/2012 national agricultural household socio economics survey at the farm level with 6,701 completed farms sampled across 77 provinces from Office of Agricultural Economics. 307 out of 6,701 farms, or about 4.5%, have been removed from calculation to address the outliner problem[1] and incomplete data on farmland values. In total, we have 6,394 farms. Among crop years, this study selects 2011/2012 crop year for the analysis instead of using the more updated crop-year data since it was the normal year, which is appropriate for long-term climate change study. In 2012/2013 crop year, Thailand encountered with the great flood which widely affects agricultural area. In crop years of 2013/2014, 2014/2015, and 2015/2016, the unusual rice-pledging program guaranteeing the purchased price of rice 50 percent above market price was launched. During these periods, Thailand also faced prolonged drought together with political turmoil. Events from 2012/2013 crop year to 2015/2016 crop year could provide unusual changes in land values in both agricultural and non-agricultural areas.

The collected data consist of: the estimated market value of farmland including building expressed in dollars per hectare at year 2012; education level of the principal operator; soil conditions; whether the farm has the problem of steep slope and flood problem; irrigation status;

---

[1] We have found that several farms located in the urban area, especially in large city such as Bangkok, Nonthaburi, and Chiang Mai provinces have very high land prices per rai with small income generated from agricultural activities. Including these farms in the estimation could bias the impacts of climate change on overall Thailand's agriculture.

debt status; whether the farm has main total sales from crop; whether the principal operator has farming occupation as the main career; and whether the farm is small, medium, or large farm.

Climate data are obtained from Thailand Meteorology Department, which gathers data from 76 meteorological stations throughout Thailand. The data include information on monthly temperature and precipitation from 1981 through 2015. Since the purpose of this study is to forecast the impacts of climate changes on agriculture, we focus on the long-run impacts of temperature and precipitation on agriculture, not year-to-year variation weather. We consequently analyze the 35-year average of each climate variable for every station during 1981-2015.

To capture seasonal effects of climate on agriculture, we construct the seasonal climate variables divided into four seasons including: winter (November-January); summer (February-April); early rainy (May-July); and late rainy (August-December) following Khamwong and Praneetvatakul (2011). In order to link the agricultural data which are organized in the farm-level and the climate data which are organized by station, this study puts additional efforts to calculate the weighted average of climate data for each province instead of using the climate data of the nearest climate station for each province. We first locate the centroid of each province and then draw a circle within the radius of 250 kilometers suggested by Perry and Hollis (2005). All climate data from stations in the circle are weighted with the distance from the centroid to the station meaning that the information provided by the closet climate station from the centroid of that province provide better climate information than those far away from the centroid of that province.

To account for location characteristics and potential of land for non-agricultural development, we collect several variables including: district-level population density; whether the farm locates in the plain area; Euclidian distance of the farm to the city of the province in which farm is located; and percent of agricultural land to total land area for province in which farm is located from various sources mainly from the National Statistical Office, Ministry of Agriculture and Cooperatives, Ministry of Interior, and Google Earth. Lastly, data of climate projections mentioned in the methodology section are collected from KNMI website.

Table 2 summarizes variables used in the estimation and their definitions. Tables 3, 4, and 5 provide summary statistics across the full sample, the subsample of irrigated farms, and the subsample of rainfed farms, respectively. According to Tables 2-4, we find that on average the farmland value per hectare of irrigated farms ($19,050) is higher than that of rainfed farms ($17,129). Overall the farmland in Thailand has its value on average equal to $17,617 per hectare. The mean monthly temperatures averaged during 1981-2015 across the subsamples in the early rainy, late rainy, and summer seasons are around 27.43-28.68 degree Celsius, while in the winter the monthly temperatures are in the range of 24.66-24.85 degree Celsius. Farms located in the irrigated area tend to receive higher temperatures than those located in the rainfed area. Late rainy season has the highest level of monthly precipitation, while winter season has the lowest level of monthly precipitation. Farms located in the irrigated area tend to receive

Table 2. Description of variables

Variable	Definition of Variables
farm value	Estimate of the current market value of farmland including building (dollars per hectare)
early rainy temperature	Normal monthly mean temperature (°C) from 1981 to 2015 during the early rainy season (May-July)
late rainy temperature	Normal monthly mean temperature (°C) from 1981 to 2015 during the late rainy season (August-October)
summer temperature	Normal monthly mean temperature (°C) from 1981 to 2015 during the summer season (February-April)
winter temperature	Normal monthly mean temperature (°C) from 1981 to 2015 during the winter season (November-January)
early rainy precipitation	Normal monthly precipitation (mm) from 1981 to 2015 during the early rainy season (May-July)
late rainy precipitation	Normal monthly precipitation (mm) from 1981 to 2015 during the late rainy season (August-October)
summer precipitation	Normal monthly precipitation (mm) from 1981 to 2015 during the summer season (February-April)
winter precipitation	Normal monthly precipitation (mm) from 1981 to 2015 during the winter season (November-January)
extreme maximum temperature	Normal monthly extreme maximum temperature (°C) from 1981 to 2015
maximum rainfall within 24 hrs	Normal monthly maximum rainfall within 24 hours (mm) from 1981 to 2015
population density	Population density per square kilometer for district in which farm is located
debt status	Whether the farm has debt (equal to 1 if yes)
farm occupation	Whether the principal operator has farming occupation as the main career

Table 2. (continue)

Variable	Definition of Variables
education	Whether the principal operator graduated at least grade 9 (equal to 1 if yes)
salt soil	Whether the farm has the problem of soil salinity (equal to 1 if yes)
sandy soil	Whether the farm has the problem with sandy soil (equal to 1 if yes)
steep slope	Whether the farm has the problem of steep slope (equal to 1 if yes)
flood problem	Whether the farm has the flood problem (equal to 1 if yes)
irrigate	Whether the farm is the irrigated farm (equal to 1 if yes)
main sale from crop	Whether the farm has main total sales from crop (equal to 1 if yes)
small farm	Whether the hectare hold is less than or equal to 2 hectares
medium farm	Whether the hectare hold is greater than 2 hectares and less than or equal to 5 hectares
large farm	Whether the hectare hold is greater than 5 hectares
plain	Whether the farm locates in the plain area (equal to 1 if yes)
distance	Euclidian distance, in kilometers, of the farm to the city of the province in which farm is located
percent agricultural land	Percent of agricultural land to total land area for province in which farm is located

Note: Values in Baht are converted with the exchange rate of 34 Baht/US.

lower rainfalls than those located in the rainfed area in all seasons. Considering climate variation, we can observe that there are slightly different extreme maximum temperature between irrigated and rainfed areas, which farms located in the rainfed area face with higher maximum rainfall within 24 hours. Population density in the irrigated area is greater than that in the rainfed area.

Table 3. Summary statistics of selected variables in the full sample

Variable	Mean	Std. Dev.	Min	Max
farm value ($/Hectare)	17,616.91	17,955.70	0.00	99,711.13
early rainy temperature (°C)	28.60	1.34	20.78	29.31
late rainy temperature (°C)	27.46	1.31	19.84	28.29
summer temperature (°C)	28.12	1.41	20.28	29.13
winter temperature (°C)	24.71	1.68	17.30	26.81
early rainy precipitation (mm.)	177.14	24.76	132.97	246.08
late rainy precipitation (mm.)	207.85	23.85	155.07	305.78
summer precipitation (mm.)	51.27	14.86	35.23	96.76
winter precipitation (mm.)	42.97	74.26	6.90	285.61
extreme max temperature (°C)	37.47	2.00	27.85	38.88
max rainfall within 24 hrs (mm.)	54.21	4.24	41.66	65.10
population density (persons/km sq)	171.02	195.56	7.47	4,345.25
debt status	0.64	0.48	0.00	1.00
farm occupation	0.71	0.46	0.00	1.00
education	0.11	0.31	0.00	1.00
salt soil	0.01	0.10	0.00	1.00
sandy soil	0.02	0.13	0.00	1.00
steep slope	0.01	0.11	0.00	1.00
flood problem	0.12	0.32	0.00	1.00
irrigate	0.25	0.44	0.00	1.00
main sale from crop	0.79	0.41	0.00	1.00
small farm	0.34	0.47	0.00	1.00
medium farm	0.38	0.49	0.00	1.00
large farm	0.28	0.45	0.00	1.00
plain	0.71	0.45	0.00	1.00
distance	42.05	31.14	0.00	164.00
percent agricultural land (hectares)	54.25	18.08	3.83	95.47
central	0.19	0.39	0.00	1.00
east	0.07	0.25	0.00	1.00
north	0.19	0.39	0.00	1.00
northeast	0.43	0.50	0.00	1.00
lower south	0.06	0.25	0.00	1.00
upper south	0.06	0.24	0.00	1.00
number of observation	6,394			

Table 4. Summary statistics of selected variables in the subsample of irrigated farms

Variable	Obs	Mean	Std. Dev.	Min	Max
farm value ($/Hectare)	1,624	19,050.22	19,136.29	0.00	98,416.29
early rainy temperature (°C)	1,624	28.68	1.23	20.78	29.31
late rainy temperature (°C)	1,624	27.56	1.20	19.84	28.29
summer temperature (°C)	1,624	28.23	1.33	20.28	29.13
winter temperature (°C)	1,624	24.85	1.60	17.30	26.80
early rainy precipitation (mm.)	1,624	169.16	21.97	132.97	227.90
late rainy precipitation (mm.)	1,624	203.95	18.66	155.07	286.46
summer precipitation (mm.)	1,624	48.41	12.41	35.23	92.35
winter precipitation (mm.)	1,624	34.59	60.81	6.90	285.61
extreme max temperature (°C)	1,624	37.44	1.76	27.85	38.88
max rainfall within 24 hrs (mm.)	1,624	53.27	3.71	41.66	63.55
population density (persons/km sq)	1,624	252.54	319.10	11.67	4,345.25
debt status	1,624	0.66	0.47	0.00	1.00
farm occupation	1,624	0.71	0.46	0.00	1.00
education	1,624	0.12	0.33	0.00	1.00
salt soil	1,624	0.01	0.11	0.00	1.00
sandy soil	1,624	0.01	0.11	0.00	1.00
steep slope	1,624	0.01	0.09	0.00	1.00
flood problem	1,624	0.17	0.37	0.00	1.00
main sale from crop	1,624	0.86	0.34	0.00	1.00
small farm	1,624	0.34	0.47	0.00	1.00
medium farm	1,624	0.35	0.48	0.00	1.00
large farm	1,624	0.31	0.46	0.00	1.00
plain	1,624	0.78	0.41	0.00	1.00
distance	1,624	30.57	27.59	0.00	164.00
percent agricultural land	1,624	53.27	20.83	3.83	95.47
central	1,624	0.43	0.50	0.00	1.00
east	1,624	0.05	0.22	0.00	1.00
north	1,624	0.22	0.41	0.00	1.00
northeast	1,624	0.22	0.42	0.00	1.00
lower south	1,624	0.05	0.22	0.00	1.00
upper south	1,624	0.02	0.15	0.00	1.00
number of observation		1,624			

Table 5. Summary statistics of selected variables in the subsample of rainfed farms

Variable	Mean	Std. Dev.	Min	Max
farm value ($/Hectare)	17,128.92	17,510.97	0.00	
early rainy temperature (°C)	28.57	1.38	20.78	29.31
late rainy temperature (°C)	27.43	1.34	19.84	28.29
summer temperature (°C)	28.08	1.44	20.28	29.13
winter temperature (°C)	24.66	1.70	17.30	26.81
early rainy precipitation (mm.)	179.85	25.07	132.97	246.08
late rainy precipitation (mm.)	209.17	25.25	155.07	305.78
summer precipitation (mm.)	52.24	15.49	35.23	96.76
winter precipitation (mm.)	45.82	78.11	6.90	285.61
extreme max temperature (°C)	37.48	2.07	27.85	38.88
max rainfall within 24 hrs (mm.)	54.53	4.36	41.66	65.10
population density (persons/km sq)	143.27	116.55	7.47	2,796.19
debt status	0.64	0.48	0.00	1.00
farm occupation	0.71	0.46	0.00	1.00
education	0.11	0.31	0.00	1.00
salt soil	0.01	0.10	0.00	1.00
sandy soil	0.02	0.14	0.00	1.00
steep slope	0.02	0.12	0.00	1.00
flood problem	0.10	0.30	0.00	1.00
main sale from crop	0.76	0.43	0.00	1.00
small farm	0.34	0.47	0.00	1.00
medium farm	0.39	0.49	0.00	1.00
large farm	0.26	0.44	0.00	1.00
plain	0.69	0.46	0.00	1.00
distance	45.97	31.32	0.00	164.00
percent agricultural land	54.59	17.04	3.83	85.23
central	0.10	0.30	0.00	1.00
east	0.08	0.26	0.00	1.00
north	0.18	0.38	0.00	1.00
northeast	0.50	0.50	0.00	1.00
lower south	0.07	0.25	0.00	1.00
upper south	0.08	0.27	0.00	1.00
number of observation	4,770			

7. Empirical Results

This chapter provides empirical results from Ricardian model regarding the effect of climate on farmland value and Thailand's agriculture. The study also projects implications of climate change impacts under climate change scenarios. Lastly, results from interviewing key government officers who is responsible for climate change policies are provided.

7.1 Effect of Climate Change on Thailand's Agriculture

As the Ricardian approach estimates the importance of climate and other variables on farmland values, Tables 6, 7, and 8 provide the regression results of the full sample, the subsample of irrigated farms and the subsample of rainfed farms, respectively, by regressing farmland values on variables of climate, soil, operator characteristics, farm characteristics, and location characteristics to estimate the best-value function across different farms in Thailand. There are 6,394, 1,624, and 4,770 cross-sectional observations for the full sample, the subsample of irrigated farms and the subsample of rainfed farms, respectively.

In order to give a sense of the importance of non-climate variables in the model, we begin with a model that contains only climate variables in each table, which we call the "climate only" specification. The "climate only" specification in Tables 6-8 is a quadratic model that includes the 10 measures of climate capturing both mean and variability of climate conditions. For each variable, linear and quadratic terms are included to reflect the nonlinearities that are apparent from field studies. We then consider the model that includes both climate and non-climate variables in each table, which we call the "climate and non-climate" specification. In addition to the "climate only" specification, this specification includes variables capturing characteristics of operator, soil, farm, and location to control for other factors influencing farmland values.

Overall, we find that the adjusted R squared has been significantly improved after adding the non-climate variables in all cases. Climate variables statistically affect farmland values and their squared terms are significant for the full sample and subsamples, implying that the observed relationships are non-linear as found in the field studies. Temperature variables tend to play less important role in the subsample of irrigated farms than that in the full sample and the subsample of rainfed farms in explaining the farmland values. Some of the squared terms are positive (i.e., early rainy temperature, summer temperature, late rainy precipitation, and summer precipitation for the full sample; early rainy temperature, summer temperature, winter temperature, late rainy precipitation, summer precipitation, and winter precipitation for the irrigated farm subsample; and early rainy temperature, summer temperature, late rainy precipitation, summer precipitation for the subsample of irrigated farms) implying that there is a minimally productive level of temperature and precipitation in that season and that either more or less temperature and precipitation will raise farmland values. The negative coefficient of squared terms implies that there is an optimal level of a climate variable from which the value function decreases in both directions.

Table 6. Regression models explaining farm values in the full sample

Farm value	Climate Only	Climate and Non-Climate
early rainy temperature	-990,861**	-1.931e+06***
	(466,609)	(579,496)
early rainy temperature^2	16,532**	32,838***
	(8,047)	(9,930)
late rainy temperature	1.569e+06***	2.163e+06***
	(440,709)	(549,775)
late rainy temperature^2	-28,021***	-38,436***
	(7,884)	(9,810)
summer temperature	-395,126***	-152,247
	(149,879)	(156,739)
summer temperature^2	7,099***	2,666
	(2,714)	(2,810)
winter temperature	56,929	47,892
	(52,033)	(54,980)
winter temperature^2	-1,219	-1,010
	(1,073)	(1,124)
early rainy precipitation	1,562***	1,478***
	(369.4)	(399.9)
early rainy precipitation^2	-3.880***	-3.591***
	(0.801)	(0.902)
late rainy precipitation	-2,119***	-2,865***
	(716.7)	(726.9)
late rainy precipitation^2	2.907**	4.136***
	(1.293)	(1.349)
summer precipitation	-2,181***	-1,835***
	(580.4)	(541.9)
summer precipitation^2	16.00***	13.71***
	(5.276)	(4.993)
winter precipitation	135.5	353.5**
	(96.24)	(142.3)
winter precipitation^2	-0.687**	-0.923***
	(0.287)	(0.333)
extreme max temperature	-13,128***	-6,814*
	(3,643)	(3,819)
max rainfall within 24 hrs	15,779***	15,178***
	(4,006)	(4,272)
max rainfall within 24 hrs^2	-109.1***	-92.41**
	(33.90)	(39.42)
population density	-	4.330*
	-	(2.380)
debt status	-	-3,266***
	-	(463.5)

Table 6. (Continue)

Farm value	Climate Only	Climate and Non-Climate
farm occupation	-	-2,385***
	-	(470.8)
education	-	3,453***
	-	(686.6)
soil salt	-	-2,644*
	-	(1,405)
sandy soil	-	14.92
	-	(1,368)
steep slope	-	-3,428**
	-	(1,512)
flood problem	-	-122.7
	-	(583.5)
irrigate	-	320.9
	-	(519.4)
main sale crop	-	-2,931***
	-	(554.6)
medium farm	-	-8,135***
	-	(518.8)
large farm	-	-11,324***
	-	(547.1)
plain	-	-1,652***
	-	(607.5)
distance	-	-32.01***
	-	(6.737)
percent agricultural land	-	78.26***
	-	(18.15)
east	-	-4,157**
	-	(1,890)
north	--	-2,322**
	-	(1,148)
northeast	-	-8,090***
	-	(1,310)
lower south	-	-38,469**
	-	(15,897)
upper south	-	-29,455**
	-	(14,684)
constant	-2.098e+06***	-363,073
	(346,942)	(364,900)
Observations	6,394	6,394
R-squared	0.149	0.270

Note: Standard Errors are in the parentheses and calculated using the Huber/White/sandwich estimator. ***,**,* are significant at 1, 5 and 10 percent, respectively.

Table 7. Regression models explaining farm values in the subsample of irrigated farms

Farm value	Climate Only	Climate and Non-Climate
early rainy temperature	-2.862e+06**	-2.162e+06
	(1.383e+06)	(1.397e+06)
early rainy temperature^2	48,292**	36,180
	(23,839)	(24,017)
late rainy temperature	3.608e+06***	2.738e+06**
	(1.188e+06)	(1.234e+06)
late rainy temperature^2	-64,625***	-48,709**
	(21,330)	(22,086)
summer temperature	-288,148	-179,297
	(387,831)	(362,681)
summer temperature^2	5,491	3,888
	(6,993)	(6,505)
winter temperature	-124,220	-92,191
	(154,917)	(141,255)
winter temperature^2	2,597	1,557
	(3,279)	(2,960)
early rainy precipitation	1,381*	2,160***
	(735.9)	(803.1)
early rainy precipitation^2	-2.213	-4.437**
	(1.680)	(1.893)
late rainy precipitation	-3,929***	-6,789***
	(1,457)	(1,646)
late rainy precipitation^2	4.613	11.49***
	(2.917)	(3.428)
summer precipitation	-2,644**	-4,061***
	(1,272)	(1,242)
summer precipitation^2	18.47	33.16***
	(12.19)	(11.86)
winter precipitation	-83.73	-201.8
	(236.9)	(253.5)
winter precipitation^2	-0.276	0.210
	(0.639)	(0.619)
extreme max temperature	-13,762	-19,883**
	(8,747)	(8,474)
max rainfall within 24 hrs	10,150	20,737*
	(9,832)	(11,581)
max rainfall within 24 hrs^2	-36.78	-135.6
	(85.79)	(107.2)
population density	-	0.676
	-	(2.387)
debt status	-	-5,643***
	-	(1,063)

Table 7. (Continue)

Farm value	Climate Only	Climate and Non-Climate
farm occupation	-	-2,441**
	-	(1,042)
education	-	4,397***
	-	(1,436)
soil salt	-	-2,708
	-	(2,152)
sandy soil	-	-269.9
	-	(4,562)
steep slope	-	583.2
	-	(3,059)
flood problem	-	1,200
	-	(1,181)
main sale crop	-	-5,128***
	-	(1,479)
medium farm	-	-9,237***
	-	(1,160)
large farm	-	-13,570***
	-	(1,201)
plain	-	-5,402***
	-	(1,556)
distance	-	-32.46**
	-	(16.27)
percent agricultural land	-	117.9***
	-	(35.35)
east	-	-3,929
	-	(3,078)
north	-	-10,268***
	-	(2,824)
northeast	-	-10,979***
	-	(2,179)
lower south	-	-16,934
	-	(33,716)
upper south	-	-15,040
	-	(30,969)
constant	-2.102e+06**	-2.046e+06**
	(956,711)	(915,507)
Observations	1,624	1,624
R-squared	0.074	0.236

Note: Standard Errors are in the parentheses and calculated using the Huber/White/sandwich estimator. ***,**,* are significant at 1, 5 and 10 percent, respectively.

Table 8. Regression models explaining farm values in the subsample of rainfed farms

Farm value	Climate Only	Climate and Non-Climate
early rainy temperature	-1.186e+06**	-1.241e+06*
	(528,367)	(660,228)
early rainy temperature^2	20,161**	21,165*
	(9,097)	(11,314)
late rainy temperature	1.484e+06***	1.327e+06**
	(521,113)	(645,513)
late rainy temperature^2	-26,530***	-23,509**
	(9,305)	(11,525)
summer temperature	-102,938	-90,673
	(172,308)	(186,435)
summer temperature^2	1,819	1,403
	(3,137)	(3,345)
winter temperature	-21,371	61,337
	(59,272)	(66,078)
winter temperature^2	297.9	-1,216
	(1,223)	(1,342)
early rainy precipitation	1,006**	893.1*
	(436.6)	(518.2)
early rainy precipitation^2	-3.022***	-2.338**
	(0.957)	(1.153)
late rainy precipitation	-646.4	-1,908**
	(836.2)	(920.2)
late rainy precipitation^2	0.811	3.139*
	(1.487)	(1.618)
summer precipitation	-1,945***	-1,659***
	(649.2)	(616.8)
summer precipitation^2	14.76**	12.08**
	(5.944)	(5.679)
winter precipitation	67.66	536.9***
	(110.1)	(185.3)
winter precipitation^2	-0.454	-1.252***
	(0.327)	(0.417)
extreme max temperature	-9,913**	-2,359
	(4,351)	(4,483)
max rainfall within 24 hrs	14,343***	17,695***
	(4,469)	(4,689)
max rainfall within 24 hrs^2	-105.3***	-128.8***
	(37.61)	(43.09)
population density	-	13.94***
	-	(4.365)
debt status	-	-2,368***
	-	(504.9)

Table 8. (Continue)

Farm value	Climate Only	Climate and Non-Climate
farm occupation	-	-2,255***
	-	(521.9)
education	-	2,856***
	-	(759.6)
soil salt	-	-2,908
	-	(1,832)
sandy soil	-	-75.01
	-	(1,383)
steep slope	-	-3,694**
	-	(1,628)
flood problem	-	-1,113*
	-	(640.9)
main sale crop	-	-2,565***
	-	(590.1)
medium farm	-	-7,607***
	-	(566.9)
large farm	-	-10,167***
	-	(609.6)
plain	-	-934.5
	-	(675.5)
distance	-	-27.61***
	-	(7.774)
percent agricultural land	-	45.62**
	-	(21.95)
east	-	-1,374
	-	(2,581)
north	-	1,393
	-	(1,281)
northeast	-	-3,436*
	-	(1,755)
lower south	-	-50,162**
	-	(19,825)
upper south	-	-45,862**
	-	(18,626)
constant	-1.529e+06***	-102,791
	(367,246)	(404,757)
Observations	4,770	4,770
R-squared	0.194	0.305

Note: Standard Errors are in the parentheses and calculated using the Huber/White/sandwich estimator. ***,**,* are significant at 1, 5 and 10 percent, respectively.

For the non-climate variables in the full sample, this study reveals that the farmland price per hectare of irrigated farms is not statistically higher than those of rainfed farms. In all cases, higher educational level of the principal operator and higher population density per square kilometer for district in which farm is located enhances the farmland values. Considering farm size, small farms tend to have higher farmland value per hectare than medium and large farms. On the other hand, farms having debt, soil problems, steep slope, main total sales from crop, and the principle operator's main career with farming tend to have lower farmland values. Similarly, farmland values could be decreased if the farm locates in the plain area and has the further Euclidian distance (kilometers) to the city of the province. Farms located in the central region have higher farmland values per hectare than those from other regions.

Using estimated results from Tables 6-8, the overall impact of climate as measured by the marginal impacts evaluated at the mean level of each variable is provided in Table 9. For temperature, we discover that higher early rainy temperatures are harmful for crops, while higher late rainy temperatures are beneficial for crops with statistical significance in the all samples. The higher early rainy temperatures by 1°C deviating from the mean value decrease the overall farmland values equal to $50,430.83, $89,802.55, and $28,378.54 per hectare for the full sample, irrigated and rainfed subsamples, respectively, while higher late rainy temperatures by 1°C deviating from the mean value increase the farmland values equal to $49,677.3 and $34,125.74 per hectare for the full sample and the subsample of rainfed farms, respectively. For the irrigated farms, a higher summer temperatures by 1°C deviating from the mean value increase the farmland values equal to $39,436.17. The marginal impacts of winter temperature in all subsamples are not statistically significant at 10 percent level.

For precipitation, we find that in all cases (full sample and subsamples) higher late rainy and summer precipitation adversely affects farmland value. Higher late rainy precipitation by 1 millimeter deviating from the mean value decreases the farmland values of irrigated and rainfed farms equal to $2,040.45 and $611.33 per hectare, respectively. On the other hand, higher early rainy precipitation is positively correlated to farmland value in irrigated farms, while higher winter precipitation enhances the farmland value in the rainfed farms. Farmland values will be increased about $585.53 and $445.22 per hectare as early rainy precipitation and winter precipitation increase by 1 millimeter deviating from the mean value, respectively.[2]

For climate variability, this study reveals that extreme maximum temperature negatively affects irrigated farms. The higher extreme maximum temperature by 1°C deviating from the mean value decrease the farmland values of irrigated farms equal to $-19,882.79 per hectare. On the other hand, increase in maximum rainfall within 24 hours by 1 millimeter deviating from the mean value enhance the farmland values of both irrigated and rainfed farms approximately 6,128.03 and 3,814.99, respectively.

[2] It is worth noting that the Ricardian approach assumes that real prices of all agricultural products are unchanged in the long run. Therefore, changes in farmland values per hectare due to changes in temperature and precipitation could positively correlated with the agricultural production including crop yields, anything being equal.

Table 9. Marginal effect of climate variables in the full sample and subsamples

	Full	Irrigated	Rainfed
farmvalue2	Coef.	Coef.	Coef.
early rainy temperature	-50,430.83**	-89,802.55**	-28,378.54*
	(21,211.64)	(45,064.48)	(16,825.19)
late rainy temperature	49,677.35**	59,664.73	34,125.74*
	(20,811.13)	(45,455.62)	(20,055.49)
summer temperature	-2,257.63	39,436.17**	-11,743.32
	(10,101.37)	(19,040.52)	(12,271.54)
winter temperature	-1,830.38	-15,556.34)	1,474.65)
	(8,558.63)	(16,806.94)	(10,317.50)
early rainy precipitation	203.77**	585.53***	63.58
	(102.09)	(195.81)	(132.16)
late rainy precipitation	-1,155.98***	-2,040.45***	-611.33*
	(272.95)	(458.42)	(357.44)
summer precipitation	-478.12**	-778.98**	-463.41**
	(173.32)	(374.15)	(196.19)
winter precipitation	285.88**	-186.41	445.22**
	(120.64)	(214.21)	(157.57)
extreme maximum temperature	-6,814.43*	-19,882.79**	-2,358.57
	(3,818.75)	(8,473.81)	(4,482.88)
maximum rainfall within 24 hrs	5,220.02***	6,128.03***	3,814.99***
	(1,070.18)	(2,138.46)	(1,298.76)

Note: ***,**,* are significant at 1, 5 and 10 percent, respectively.

Standard errors are reported in parentheses.

7.2 Implications for Greenhouse Warming

This section investigates the implications for greenhouse warming during 2041-2050 on Thailand's agriculture. To project the climate change impacts, the estimated coefficients from specification of "climate and non-climate" variables in Tables 6-8 are used together with the climate projections mentioned in the previous sections. Future climate projections are illustrated in figures 2-4.

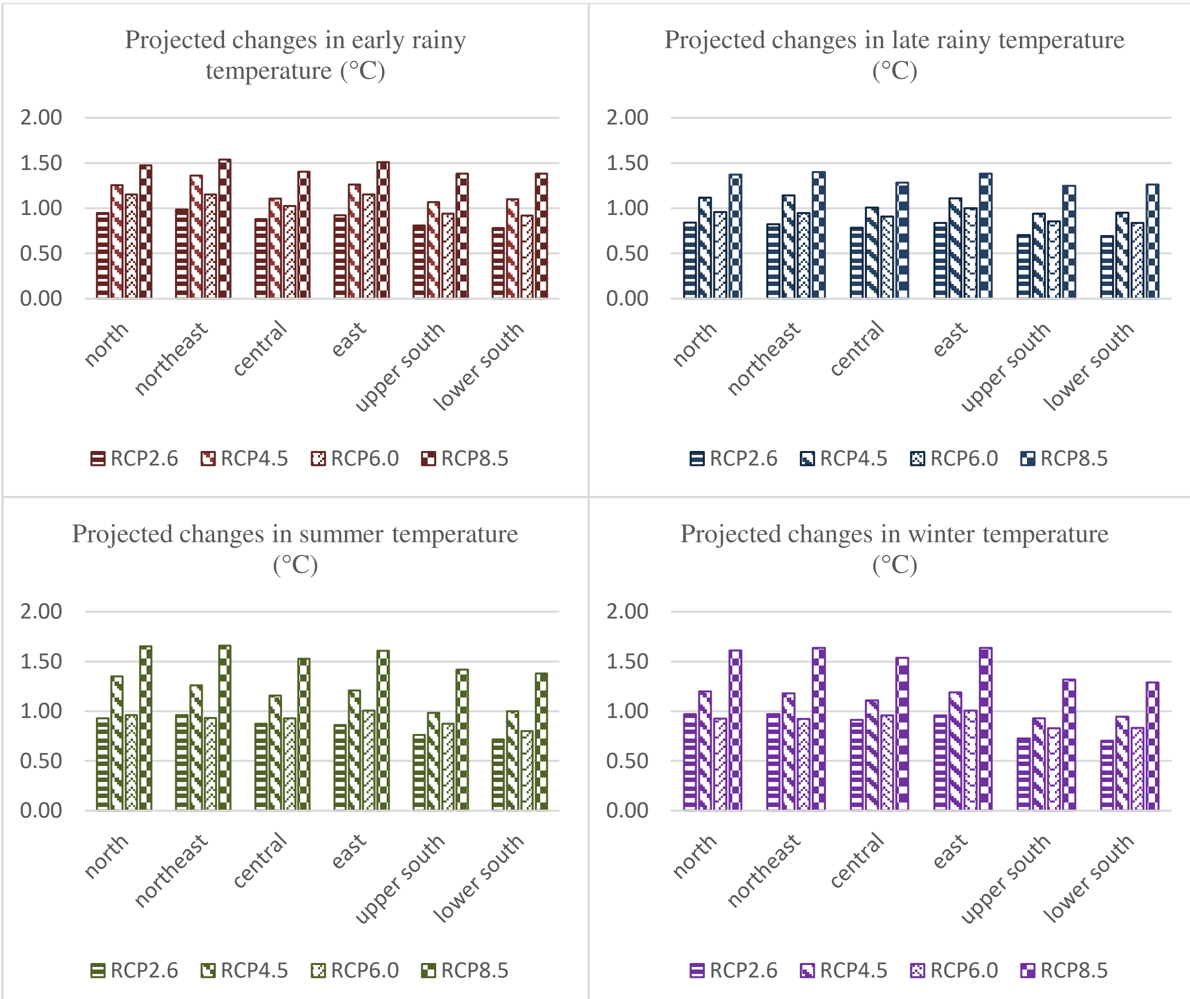

Figure 2. Projected changes in seasonal mean temperature in 2041-2050 from the baseline

In brief, future seasonal temperature projections in all scenarios and all regions shows trend of increasing temperature throughout Thailand (Figure 2). Increased temperatures in the summer and winter seasons are projected to have the value higher than other seasons.

For seasonal precipitation (Figure 3), total monthly precipitation likely fluctuates in the early rainy season and summer season, while future precipitation levels in late rainy precipitation and winter are projected to increase in almost all of scenarios and regions.

Figure 3. Projected percent changes in seasonal precipitation in 2041-2050 from the baseline

7.2.1 Climate Change Impacts at the National Level

By substituting climate projections, this study finds that overall (full sample) during 2041-2050 and without considering the changes in socio-economic conditions, farmland values per hectare are projected to decrease from $15,610 per hectare to $14,877, $14,156 , $13,361, and $12,144 per hectare in climate scenarios RCP2.6, RCP4.5, RCP6.0, and RCP8.5, respectively. By incorporating changes in socio-economic conditions, farmland values per hectare are projected to slightly decrease from scenarios without changes in socio-economic conditions.

By multiply the estimated farmland values per rai to the total farmland area in Thailand (about 23.88 million hectares), climate change are projected to adversely affect Thailand's agriculture ranging from $17.499 billion to $83.826 billion as shown in Table 10. We note that the calculated damage values can be seen as the accumulative damage values from 2011 to 2045 or 34 years. With the exchange rate of 34 THB/US dollar, the average annual damage value will be equal to THB17.499 billion to THB 83.826 billion.

As pointed out by Schlenker, Hanemann, and Fisher (2005), mixing both irrigated and rainfed farms could mislead the impacts of climate change since climate change affects irrigated and rainfed farms differently. Adding the variable capturing the irrigation status may not be enough to observe these differential impacts. They suggest to split the full sample into subsample of irrigated and rainfed farms.

Following the recommendation of Schlenker, Hanemann, and Fisher (2005), this study finds that rainfed farms are more sensitive to climate change than irrigated farms as expected. There is the consensus from all climate scenarios (RCP2.6-RCP8.5) that climate change will adversely affect rainfed farms ranging from $10.833 billion to $63.420 billion, while for the irrigated farms climate change will generate the loss ranging from $6.666 billion to $20.406 billion. With the exchange rate of 34 THB/US dollar, the average annual damage value will be equal to THB6.666 billion to THB20.406 billion. Adding changes in socio-economic conditions slightly affect the results.

Table 10. Implications for greenhouse warming at the national level

Farm type	Scenarios	Farmland value ($/Hectare)	Total land values ($1,000)	Total change ($1,000)
Irrigated	Baseline	16,964	82,029	-
	RCP2.6	15,586	75,364	(6,666)
	RCP2.6 & Socio	15,586	75,363	(6,667)
	RCP4.5	14,512	70,170	(11,859)
	RCP4.5 & Socio	14,512	70,170	(11,859)
	RCP6.0	13,637	65,939	(16,090)
	RCP6.0 & Socio	13,637	65,939	(16,090)
	RCP8.5	12,744	61,623	(20,406)
	RCP8.5 & Socio	12,744	61,624	(20,405)
Rainfed	Baseline	15,266	290,695	-
	RCP2.6	14,697	279,862	(10,833)
	RCP2.6 & Socio	14,675	279,450	(11,245)
	RCP4.5	14,066	267,844	(22,852)
	RCP4.5 & Socio	14,051	267,566	(23,129)
	RCP6.0	13,290	253,083	(37,612)
	RCP6.0 & Socio	13,273	252,758	(37,937)
	RCP8.5	11,992	228,350	(62,345)
	RCP8.5 & Socio	11,935	227,275	(63,420)
Full	Baseline	15,610	372,725	-
	RCP2.6	14,877	355,226	(17,499)
	RCP2.6 & Socio	14,860	354,813	(17,912)
	RCP4.5	14,156	338,014	(34,711)
	RCP4.5 & Socio	14,144	337,736	(34,988)
	RCP6.0	13,361	319,022	(53,702)
	RCP6.0 & Socio	13,347	318,697	(54,027)
	RCP8.5	12,144	289,974	(82,751)
	RCP8.5 & Socio	12,099	288,899	(83,826)

Note: Total farmland, irrigated farmland, and rainfed farmland are equal to 23,877,797 hectares, 19,042,449 hectares, and 4,835,348 hectares, respectively in 2014.

7.2.2 Climate Change Impacts at the Provincial Level

To identify the affected areas regarding the climate change impacts for adaptation planning, this study downscales the analysis to the provincial level. Results are separately provided for irrigated and rainfed farm subsamples as follow.

Climate change impacts on irrigated farms at the provincial level

Tables 11-14 provide climate change impacts on irrigated farms at the provincial level under climate change scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5 with and without changes in socio-economic conditions, respectively.

Here we find that all provinces will be negatively affected by the climate change across all climate scenarios. Southern, north, and northeastern regions are projected to receive higher negative impacts as compared to east and central regions. As expected, scenario RCP8.5 projects the highest negative impacts of climate change on Thailand’s agriculture following by projections from RCP6.0, scenario RCP4.5, scenario RCP2.6, respectively.

There is the consensus across all climate change scenarios that Surat Thani’s agricultural sector will receive the highest negative impacts from climate change ($537-1,428 million) followed by Nakhon Ratchasima ($365-$971 million), Chumphon ($290-$772), Nakhon Si Thammarat ($263-$772 million), Nong Khai ($257-$684 million), Chiang Rai ($198-$593 million), Ubon Ratchathani ($190-$507 million), and Songkhla ($184-$490 million), respectively.

Table 11. Implications for greenhouse warming on irrigated farms at provincial level under RCP2.6

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP2.6	RCP2.6 & Socio	RCP2.6	RCP2.6 & Socio
North					
Chiang Rai	2,178.09	2,178.13	2,178.09	(197.65)	(197.70)
Phayao	838.77	838.92	838.77	(73.97)	(74.11)
Lampang	471.11	471.12	471.11	(39.96)	(39.97)
Lamphun	502.65	502.66	502.65	(48.67)	(48.68)
Chiang Mai	1,556.68	1,556.74	1,556.68	(130.91)	(130.95)
Mae Hong Son	167.21	167.21	167.21	(8.55)	(8.55)
Tak	726.33	726.34	726.33	(75.26)	(75.28)
Kamphaeng Phet	644.32	644.54	644.32	(35.62)	(35.82)
Sukhothai	533.68	533.71	533.68	(21.22)	(21.24)
Phrae	383.44	383.48	383.44	(25.21)	(25.25)
Phetchabun	1,287.01	1,287.03	1,287.01	(22.62)	(22.62)
Nan	537.68	537.70	537.68	(14.09)	(14.10)
Uttaradit	1,035.20	1,035.24	1,035.20	(80.67)	(80.71)
Phitsanulok	960.66	960.73	960.66	(51.55)	(51.61)
Phichit	498.42	498.43	498.42	(51.65)	(51.66)
Northeast					
Loei	911.76	911.77	911.76	(94.48)	(94.50)
Nongbua Lamphu	499.65	499.66	499.65	(51.78)	(51.79)
Udon Thani	891.06	891.07	891.06	(92.33)	(92.35)
Nong Khai	2,481.45	2,481.50	2,481.45	(257.13)	(257.19)
Bueng Kan	604.53	604.54	604.53	(62.64)	(62.66)
Sakon Nakhon	1,298.29	1,298.31	1,298.29	(134.53)	(134.56)
Nakhon Phanom	745.68	745.70	745.68	(77.27)	(77.29)
Mukdahan	1,131.09	1,131.11	1,131.09	(117.21)	(117.23)
Yasothon	770.15	770.16	770.15	(79.80)	(79.82)
Ubon Ratchathani	1,837.82	1,837.86	1,837.82	(190.44)	(190.48)
Si Sa Ket	2,180.39	2,180.68	2,180.39	(152.53)	(152.80)
Surin	1,745.33	1,745.73	1,745.33	(146.11)	(146.48)
Buri Ram	1,124.72	1,124.74	1,124.72	(116.55)	(116.57)
Maha Sarakham	1,086.03	1,086.05	1,086.03	(107.18)	(107.20)
Roi Et	1,335.96	1,335.98	1,335.96	(138.44)	(138.46)
Kalasin	1,143.48	1,143.50	1,143.48	(118.49)	(118.51)
Khon Kaen	1,705.59	1,705.82	1,705.59	(153.85)	(154.06)
Chaiyaphum	1,333.85	1,333.88	1,333.85	(138.22)	(138.25)
Nakhon Ratchasima	3,523.65	3,523.72	3,523.65	(365.13)	(365.21)
Central					
Uthai Thani	397.32	397.35	397.32	(10.37)	(10.39)
Nakhon Sawan	1,675.45	1,675.55	1,675.45	(115.46)	(115.55)
Saraburi	975.09	975.32	975.09	(45.27)	(45.47)
Lop Buri	1,095.25	1,095.46	1,095.25	(76.37)	(76.56)
Sing Buri	254.30	254.31	254.30	(14.08)	(14.09)
Chai Nat	662.49	662.55	662.49	(26.66)	(26.70)
Suphanburi	1,142.50	1,142.57	1,142.50	(63.31)	(63.37)
Ang Thong	270.12	270.15	270.12	(9.10)	(9.13)
Ayutthaya	752.92	753.02	752.92	(36.29)	(36.37)
Nonthaburi	113.47	112.14	113.47	(4.55)	(3.30)
Bangkok	68.90	68.89	68.90	(4.57)	(4.55)

Table 11. (Continue)

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP2.6	RCP2.6 & Socio	RCP2.6	RCP2.6 & Socio
Pathum Thani	264.67	264.49	264.67	(9.99)	(9.82)
Samut Prakan	145.06	145.06	145.06	(8.78)	(8.78)
Samut Sakhon	202.28	202.28	202.28	(18.25)	(18.25)
Nakhon Pathom	927.93	927.40	927.93	(47.76)	(47.26)
Kanchanaburi	1,774.61	1,774.82	1,774.61	(119.75)	(119.95)
Ratchaburi	1,087.35	1,087.45	1,087.35	(92.16)	(92.26)
Samut Songkhram	167.60	167.63	167.60	12.87	12.85
Phetchaburi	211.91	211.96	211.91	(16.89)	(16.94)
Prachuap Khiri Khan	1,125.95	1,125.97	1,125.95	(116.67)	(116.70)
East					
Nakhon Nayok	305.18	305.12	305.18	(29.89)	(29.84)
Prachin Buri	410.79	410.68	410.79	(25.93)	(25.83)
Chachoengsao	1,115.55	1,115.07	1,115.55	(88.06)	(87.60)
Sa Kaeo	434.07	434.08	434.07	(39.15)	(39.16)
Chanthaburi	-	-	-	-	-
Trat	940.16	940.17	940.16	(97.42)	(97.44)
Rayong	699.20	699.21	699.20	(72.45)	(72.47)
Chon Buri	806.42	806.44	806.42	(83.56)	(83.58)
Upper South					
Chumphon	2,801.71	2,801.77	2,801.71	(290.32)	(290.38)
Ranong	331.76	331.77	331.76	(34.38)	(34.39)
Surat Thani	5,182.18	5,182.27	5,182.18	(536.99)	(537.10)
Phangnga	1,467.10	1,467.12	1,467.10	(152.02)	(152.06)
Phuket	-	-	-	-	-
Krabi	858.23	858.24	858.23	(88.93)	(88.95)
Nakhon Si Thammarat	2,539.10	2,539.15	2,539.10	(263.11)	(263.16)
Lower South					
Trang	483.33	483.34	483.33	(50.08)	(50.09)
Phatthalung	1,215.24	1,215.27	1,215.24	(125.93)	(125.95)
Songkhla	1,778.44	1,778.47	1,778.44	(184.29)	(184.33)
Satun	-	-	-	-	-
Pattani	643.51	643.52	643.51	(66.68)	(66.70)
Yala	229.59	229.60	229.59	(23.79)	(23.80)
Narathiwat	1,134.17	1,134.20	1,134.17	(117.53)	(117.55)
Total	**75,362.61**	**75,363.59**	**75,362.61**	**(6,665.64)**	**(6,666.62)**

Table 12. Implications for greenhouse warming on irrigated farms at provincial level under RCP4.5

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP4.5	RCP4.5 & Socio	RCP4.5	RCP4.5 & Socio
North					
Chiang Rai	2,178.09	2,020.53	2,020.55	(355.55)	(355.53)
Phayao	838.77	776.26	776.27	(136.60)	(136.59)
Lampang	471.11	434.50	434.51	(76.46)	(76.46)
Lamphun	502.65	469.06	469.07	(82.54)	(82.54)
Chiang Mai	1,556.68	1,434.70	1,434.72	(252.47)	(252.45)
Mae Hong Son	167.21	149.11	149.11	(26.24)	(26.24)
Tak	726.33	682.26	682.27	(120.06)	(120.05)
Kamphaeng Phet	644.32	577.17	577.18	(101.57)	(101.56)
Sukhothai	533.68	470.43	470.43	(82.78)	(82.78)
Phrae	383.44	347.05	347.05	(61.07)	(61.07)
Phetchabun	1,287.01	1,108.54	1,108.55	(195.07)	(195.06)
Nan	537.68	467.33	467.33	(82.24)	(82.23)
Uttaradit	1,035.20	948.30	948.31	(166.87)	(166.86)
Phitsanulok	960.66	858.91	858.92	(151.14)	(151.13)
Phichit	498.42	468.18	468.19	(82.39)	(82.38)
Northeast					
Loei	911.76	856.44	856.45	(150.71)	(150.70)
Nongbua Lamphu	499.65	469.34	469.34	(82.59)	(82.59)
Udon Thani	891.06	837.00	837.01	(147.29)	(147.28)
Nong Khai	2,481.45	2,330.91	2,330.93	(410.17)	(410.15)
Bueng Kan	604.53	567.86	567.86	(99.93)	(99.92)
Sakon Nakhon	1,298.29	1,219.52	1,219.54	(214.60)	(214.59)
Nakhon Phanom	745.68	700.44	700.45	(123.26)	(123.25)
Mukdahan	1,131.09	1,062.47	1,062.48	(186.96)	(186.95)
Yasothon	770.15	723.43	723.43	(127.30)	(127.29)
Ubon Ratchathani	1,837.82	1,726.33	1,726.34	(303.78)	(303.77)
Si Sa Ket	2,180.39	2,148.09	2,147.91	(182.90)	(183.09)
Surin	1,745.33	1,691.34	1,691.22	(200.16)	(200.28)
Buri Ram	1,124.72	1,077.49	1,077.31	(164.97)	(165.15)
Maha Sarakham	1,086.03	1,021.16	1,021.17	(172.80)	(172.79)
Roi Et	1,335.96	1,254.91	1,254.92	(220.83)	(220.81)
Kalasin	1,143.48	1,085.35	1,085.20	(177.80)	(177.95)
Khon Kaen	1,705.59	1,637.55	1,637.56	(222.45)	(222.43)
Chaiyaphum	1,333.85	1,252.93	1,252.94	(220.48)	(220.47)
Nakhon Ratchasima	3,523.65	3,309.88	3,309.91	(582.44)	(582.41)
Central					
Uthai Thani	397.32	348.16	348.16	(57.93)	(57.92)
Nakhon Sawan	1,675.45	1,521.14	1,521.16	(267.68)	(267.66)
Saraburi	975.09	875.92	875.80	(141.97)	(142.10)
Lop Buri	1,095.25	995.31	995.32	(175.15)	(175.14)
Sing Buri	254.30	227.94	227.94	(39.89)	(39.89)
Chai Nat	662.49	588.87	588.88	(98.23)	(98.22)
Suphanburi	1,142.50	1,027.42	1,027.41	(175.96)	(175.97)
Ang Thong	270.12	237.91	237.91	(40.36)	(40.37)
Ayutthaya	752.92	675.87	675.83	(111.44)	(111.48)
Nonthaburi	113.47	100.63	100.63	(15.70)	(15.70)
Bangkok	68.90	62.55	62.55	(10.80)	(10.80)

Table 12. (Continue)

Province	Total land value ($Million) Baseline	RCP4.5	RCP4.5 & Socio	Total change ($Million) RCP4.5	RCP4.5 & Socio
Pathum Thani	264.67	237.65	237.84	(35.96)	(35.77)
Samut Prakan	145.06	131.90	131.90	(21.68)	(21.68)
Samut Sakhon	202.28	187.54	187.55	(33.00)	(33.00)
Nakhon Pathom	927.93	851.53	851.86	(121.42)	(121.09)
Kanchanaburi	1,774.61	1,610.02	1,610.03	(282.07)	(282.05)
Ratchaburi	1,087.35	1,003.45	1,003.44	(175.89)	(175.90)
Samut Songkhram	167.60	130.04	130.05	(22.88)	(22.88)
Phetchaburi	211.91	194.50	194.50	(34.23)	(34.22)
Prachuap Khiri Khan	1,125.95	1,057.64	1,057.65	(186.11)	(186.10)
East					
Nakhon Nayok	305.18	285.04	285.04	(50.16)	(50.16)
Prachin Buri	410.79	379.90	379.90	(56.05)	(56.05)
Chachoengsao	1,115.55	1,022.48	1,022.49	(179.93)	(179.92)
Sa Kaeo	434.07	402.45	402.46	(70.82)	(70.82)
Chanthaburi	-	-	-	-	-
Trat	940.16	883.12	883.13	(155.40)	(155.39)
Rayong	699.20	656.78	656.78	(115.57)	(115.57)
Chon Buri	806.42	757.50	757.51	(133.30)	(133.29)
Upper South					
Chumphon	2,801.71	2,631.74	2,631.77	(463.11)	(463.08)
Ranong	331.76	311.64	311.64	(54.84)	(54.84)
Surat Thani	5,182.18	4,867.79	4,867.83	(856.59)	(856.54)
Phangnga	1,467.10	1,378.09	1,378.10	(242.50)	(242.49)
Phuket	-	-	-	-	-
Krabi	858.23	806.16	806.17	(141.86)	(141.85)
Nakhon Si Thammarat	2,539.10	2,385.06	2,385.08	(419.70)	(419.68)
Lower South					
Trang	483.33	454.00	454.01	(79.89)	(79.89)
Phatthalung	1,215.24	1,141.52	1,141.53	(200.87)	(200.86)
Songkhla	1,778.44	1,670.55	1,670.56	(293.97)	(293.95)
Satun	-	-	-	-	-
Pattani	643.51	604.47	604.47	(106.37)	(106.36)
Yala	229.59	215.67	215.67	(37.95)	(37.95)
Narathiwat	1,134.17	1,065.37	1,065.38	(187.47)	(187.46)
Total	**75,362.61**	**70,170.09**	**70,170.35**	**(11,859.15)**	**(11,858.89)**

Table 13. Implications for greenhouse warming on irrigated farms at provincial level under RCP6.0

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP6.0	RCP6.0 & Socio	RCP6.0	RCP6.0 & Socio
North					
Chiang Rai	2,178.09	1,907.02	1,907.01	(469.10)	(469.12)
Phayao	838.77	729.85	729.86	(183.04)	(183.03)
Lampang	471.11	408.52	408.53	(102.45)	(102.45)
Lamphun	502.65	441.02	441.02	(110.60)	(110.60)
Chiang Mai	1,556.68	1,348.92	1,348.94	(338.29)	(338.28)
Mae Hong Son	167.21	140.19	140.19	(35.16)	(35.16)
Tak	726.33	641.47	641.48	(160.87)	(160.87)
Kamphaeng Phet	644.32	542.66	542.67	(136.09)	(136.09)
Sukhothai	533.68	442.30	442.30	(110.92)	(110.92)
Phrae	383.44	326.30	326.30	(81.83)	(81.83)
Phetchabun	1,287.01	1,077.54	1,077.38	(226.00)	(226.16)
Nan	537.68	439.39	439.39	(110.19)	(110.19)
Uttaradit	1,035.20	891.60	891.61	(223.60)	(223.59)
Phitsanulok	960.66	807.56	807.57	(202.53)	(202.52)
Phichit	498.42	440.19	440.19	(110.39)	(110.39)
Northeast					
Loei	911.76	805.24	805.25	(201.94)	(201.93)
Nongbua Lamphu	499.65	441.28	441.28	(110.67)	(110.66)
Udon Thani	891.06	786.95	786.96	(197.36)	(197.35)
Nong Khai	2,481.45	2,191.54	2,191.57	(549.61)	(549.59)
Bueng Kan	604.53	533.90	533.91	(133.90)	(133.89)
Sakon Nakhon	1,298.29	1,146.61	1,146.62	(287.56)	(287.54)
Nakhon Phanom	745.68	658.56	658.57	(165.16)	(165.15)
Mukdahan	1,131.09	998.95	998.96	(250.52)	(250.51)
Yasothon	770.15	680.17	680.18	(170.58)	(170.57)
Ubon Ratchathani	1,837.82	1,623.11	1,623.13	(407.06)	(407.04)
Si Sa Ket	2,180.39	1,986.05	1,985.50	(344.14)	(344.71)
Surin	1,745.33	1,575.69	1,575.21	(315.42)	(315.90)
Buri Ram	1,124.72	993.32	993.33	(249.11)	(249.10)
Maha Sarakham	1,086.03	961.19	961.20	(232.77)	(232.76)
Roi Et	1,335.96	1,179.88	1,179.89	(295.90)	(295.89)
Kalasin	1,143.48	1,009.88	1,009.89	(253.27)	(253.26)
Khon Kaen	1,705.59	1,526.10	1,525.58	(333.67)	(334.19)
Chaiyaphum	1,333.85	1,178.02	1,178.03	(295.43)	(295.42)
Nakhon Ratchasima	3,523.65	3,111.98	3,112.02	(780.45)	(780.41)
Central					
Uthai Thani	397.32	324.67	324.67	(81.42)	(81.42)
Nakhon Sawan	1,675.45	1,430.19	1,430.21	(358.68)	(358.66)
Saraburi	975.09	813.80	813.81	(204.09)	(204.08)
Lop Buri	1,095.25	935.80	935.81	(234.69)	(234.68)
Sing Buri	254.30	214.14	214.14	(53.70)	(53.70)
Chai Nat	662.49	549.34	549.34	(137.77)	(137.76)
Suphanburi	1,142.50	962.12	962.13	(241.29)	(241.28)
Ang Thong	270.12	222.48	222.48	(55.80)	(55.79)
Ayutthaya	752.92	629.45	629.46	(157.86)	(157.85)
Nonthaburi	113.47	93.01	93.01	(23.32)	(23.32)
Bangkok	68.90	58.65	58.65	(14.71)	(14.71)

Table 13. (Continue)

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP6.0	RCP6.0 & Socio	RCP6.0	RCP6.0 & Socio
Pathum Thani	264.67	218.74	218.74	(54.86)	(54.85)
Samut Prakan	145.06	122.79	122.79	(30.79)	(30.79)
Samut Sakhon	202.28	176.33	176.33	(44.22)	(44.22)
Nakhon Pathom	927.93	785.71	785.79	(187.17)	(187.10)
Kanchanaburi	1,774.61	1,512.76	1,512.77	(379.38)	(379.36)
Ratchaburi	1,087.35	942.90	942.91	(236.47)	(236.46)
Samut Songkhram	167.60	122.27	122.27	(30.66)	(30.66)
Phetchaburi	211.91	182.87	182.87	(45.86)	(45.86)
Prachuap Khiri Khan	1,125.95	994.40	994.42	(249.38)	(249.37)
East					
Nakhon Nayok	305.18	270.62	270.63	(64.57)	(64.57)
Prachin Buri	410.79	370.54	370.55	(65.32)	(65.32)
Chachoengsao	1,115.55	1,002.77	1,003.46	(199.55)	(198.86)
Sa Kaeo	434.07	385.57	385.58	(87.69)	(87.69)
Trat	940.16	830.32	830.33	(208.23)	(208.22)
Rayong	699.20	617.51	617.52	(154.86)	(154.86)
Chon Buri	806.42	712.76	712.94	(178.06)	(177.88)
Upper South					
Chumphon	2,801.71	2,474.39	2,474.42	(620.55)	(620.52)
Ranong	331.76	293.00	293.01	(73.48)	(73.48)
Surat Thani	5,182.18	4,576.74	4,576.79	(1,147.79)	(1,147.74)
Phangnga	1,467.10	1,295.70	1,295.71	(324.94)	(324.93)
Phuket	-	-	-	-	-
Krabi	858.23	757.96	757.97	(190.09)	(190.08)
Nakhon Si Thammarat	2,539.10	2,242.46	2,242.48	(562.38)	(562.36)
Lower South					
Trang	483.33	426.86	426.86	(107.05)	(107.05)
Phatthalung	1,215.24	1,073.27	1,073.28	(269.16)	(269.15)
Songkhla	1,778.44	1,570.67	1,570.68	(393.90)	(393.89)
Pattani	643.51	568.33	568.33	(142.53)	(142.52)
Yala	229.59	202.77	202.77	(50.85)	(50.85)
Narathiwat	1,134.17	1,001.67	1,001.68	(251.21)	(251.20)
Total	**75,362.61**	**65,939.27**	**65,939.09**	**(16,089.96)**	**(16,090.14)**

Table 14. Implications for greenhouse warming on irrigated farms at provincial level under RCP8.5

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP8.5	RCP8.5 & Socio	RCP8.5	RCP8.5 & Socio
North					
Chiang Rai	2,178.09	1,783.28	1,783.27	(592.83)	(592.84)
Phayao	838.77	685.12	685.11	(227.76)	(227.76)
Lampang	471.11	383.49	383.48	(127.48)	(127.49)
Lamphun	502.65	413.99	413.98	(137.62)	(137.63)
Chiang Mai	1,556.68	1,266.25	1,266.23	(420.94)	(420.96)
Mae Hong Son	167.21	131.60	131.60	(43.75)	(43.75)
Tak	726.33	602.15	602.15	(200.18)	(200.18)
Kamphaeng Phet	644.32	509.40	509.40	(169.34)	(169.35)
Sukhothai	533.68	415.19	415.19	(138.02)	(138.03)
Phrae	383.44	306.30	306.29	(101.82)	(101.83)
Phetchabun	1,287.01	978.38	978.37	(325.25)	(325.26)
Nan	537.68	412.46	412.45	(137.12)	(137.12)
Uttaradit	1,035.20	836.95	836.95	(278.23)	(278.24)
Phitsanulok	960.66	758.06	758.05	(252.01)	(252.01)
Phichit	498.42	413.21	413.21	(137.37)	(137.37)
Northeast					
Loei	911.76	755.88	755.88	(251.28)	(251.29)
Nongbua Lamphu	499.65	414.23	414.23	(137.70)	(137.71)
Udon Thani	891.06	738.72	738.71	(245.58)	(245.58)
Nong Khai	2,481.45	2,057.22	2,057.20	(683.89)	(683.91)
Bueng Kan	604.53	501.18	501.17	(166.61)	(166.61)
Sakon Nakhon	1,298.29	1,076.33	1,076.32	(357.81)	(357.82)
Nakhon Phanom	745.68	618.20	618.19	(205.51)	(205.52)
Mukdahan	1,131.09	937.72	937.71	(311.73)	(311.74)
Yasothon	770.15	638.48	638.48	(212.25)	(212.26)
Ubon Ratchathani	1,837.82	1,523.63	1,523.61	(506.51)	(506.52)
Si Sa Ket	2,180.39	1,777.19	1,777.05	(553.43)	(553.58)
Surin	1,745.33	1,419.42	1,419.41	(471.87)	(471.88)
Buri Ram	1,124.72	932.44	932.43	(309.98)	(309.98)
Maha Sarakham	1,086.03	896.07	896.06	(297.89)	(297.89)
Roi Et	1,335.96	1,113.41	1,113.32	(362.36)	(362.45)
Kalasin	1,143.48	947.99	947.98	(315.14)	(315.15)
Khon Kaen	1,705.59	1,395.84	1,395.82	(464.03)	(464.04)
Chaiyaphum	1,333.85	1,105.82	1,105.81	(367.61)	(367.62)
Nakhon Ratchasima	3,523.65	2,921.24	2,921.22	(971.13)	(971.15)
Central					
Uthai Thani	397.32	304.77	304.76	(101.32)	(101.32)
Nakhon Sawan	1,675.45	1,342.53	1,342.52	(446.31)	(446.32)
Saraburi	975.09	765.56	765.45	(252.32)	(252.43)
Lop Buri	1,095.25	878.44	878.44	(292.03)	(292.03)
Sing Buri	254.30	201.01	201.01	(66.82)	(66.83)
Chai Nat	662.49	517.78	517.77	(169.32)	(169.33)
Suphanburi	1,142.50	903.15	903.14	(300.24)	(300.25)
Ang Thong	270.12	209.38	209.38	(68.89)	(68.89)
Ayutthaya	752.92	593.31	593.28	(193.99)	(194.03)
Nonthaburi	113.47	88.52	89.44	(27.82)	(26.89)
Bangkok	68.90	55.05	55.05	(18.30)	(18.30)

Table 14. (Continue)

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP8.5	RCP8.5 & Socio	RCP8.5	RCP8.5 & Socio
Pathum Thani	264.67	206.67	206.70	(66.92)	(66.90)
Samut Prakan	145.06	115.26	115.32	(38.32)	(38.26)
Samut Sakhon	202.28	165.52	165.52	(55.03)	(55.03)
Nakhon Pathom	927.93	747.15	747.47	(225.79)	(225.47)
Kanchanaburi	1,774.61	1,420.04	1,420.03	(472.07)	(472.08)
Ratchaburi	1,087.35	885.11	885.10	(294.24)	(294.25)
Samut Songkhram	167.60	114.77	114.77	(38.16)	(38.16)
Phetchaburi	211.91	171.66	171.66	(57.07)	(57.07)
Prachuap Khiri Khan	1,125.95	933.46	933.45	(310.31)	(310.32)
East					
Nakhon Nayok	305.18	251.57	251.57	(83.63)	(83.63)
Prachin Buri	410.79	327.16	327.16	(108.76)	(108.76)
Chachoengsao	1,115.55	902.43	902.42	(300.00)	(300.01)
Sa Kaeo	434.07	355.20	355.20	(118.08)	(118.08)
Trat	940.16	779.43	779.42	(259.11)	(259.12)
Rayong	699.20	579.66	579.66	(192.70)	(192.71)
Chon Buri	806.42	668.56	668.55	(222.25)	(222.26)
Upper South					
Chumphon	2,801.71	2,322.73	2,322.71	(772.16)	(772.18)
Ranong	331.76	275.05	275.04	(91.44)	(91.44)
Surat Thani	5,182.18	4,296.23	4,296.19	(1,428.22)	(1,428.26)
Phangnga	1,467.10	1,216.28	1,216.27	(404.33)	(404.35)
Phuket	-	-	-	-	-
Krabi	858.23	711.50	711.50	(236.53)	(236.54)
Nakhon Si Thammarat	2,539.10	2,105.01	2,104.99	(699.78)	(699.80)
Lower South					
Trang	483.33	400.70	400.69	(133.21)	(133.21)
Phatthalung	1,215.24	1,007.49	1,007.48	(334.92)	(334.93)
Songkhla	1,778.44	1,474.40	1,474.38	(490.14)	(490.16)
Pattani	643.51	533.49	533.49	(177.35)	(177.36)
Yala	229.59	190.34	190.34	(63.28)	(63.28)
Narathiwat	1,134.17	940.28	940.27	(312.58)	(312.59)
Total	**75,362.61**	**61,623.49**	**61,623.89**	**(20,405.75)**	**(20,405.34)**

Climate Change Impacts on Rainfed Farms at the Provincial Level

Tables 15-18 provide climate change impacts on rainfed farms at the provincial level under climate change scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5 with and without changes in socio-economic conditions, respectively.

Unlike the irrigated area, for the rainfed area, mixed findings are revealed. Southern regions are projected to be negatively affected the most followed by eastern region, and central, while, north and northeastern regions are projected to obtain the positive impacts from climate change. In the southern regions, all provinces will be adversely affected by the global warming. For the eastern region, only Prachin Buri province is projected to obtain the positive benefit from climate change. For the central region, almost all provinces are negatively affected by the climate change. While north and northeastern regions are beneficial to climate change, under climate change scenario RCP8.5 almost all provinces in these regions will be negatively affected by climate change. Similar to irrigated farm results, as expected, scenario RCP8.5 projects the highest negative impacts of climate change on Thailand's agriculture following by projections from RCP6.0, scenario RCP4.5, scenario RCP2.6, respectively.

There is the consensus across all climate change scenarios that Surat Thani's agricultural sector will receive the highest negative impacts from climate change ($1,723-$6,101 million) followed by Nakhon Si Thammarat ($1,075-$4,037 million), Songkhla ($1,064-$3,646 million), Chumphon ($980-$3,808), Trang ($957-$3,335 million), Chanthaburi ($725-$2,882 million), Rayong ($685-$2,674 million), Roi Et ($594.20-$1,940 million) and Krabi ($588-$2,394), respectively.

While a majority of provinces are projected to obtain the negative climate change impacts, there are only nine provinces that always are beneficial in all climate change scenarios including Maha Sarakham, Surin, Si Sa Ket, Phitsanulok, Bueng Kan, Prachin Buri, Nakhon Panom, Uthai Thani, and Yasothon.

Table 15. Implications for greenhouse warming on rainfed farms at provincial level under RCP2.6

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP2.6	RCP2.6 & Socio	RCP2.6	RCP2.6 & Socio
North					
Chiang Rai	5,130.74	5,651.84	5,631.52	196.64	199.95
Phayao	2,261.28	2,457.74	2,449.51	68.58	69.62
Lampang	1,646.66	1,850.52	1,845.63	83.05	85.96
Lamphun	1,792.28	1,823.27	1,818.22	(13.55)	(15.05)
Chiang Mai	6,510.13	6,277.22	6,253.74	(237.33)	(254.43)
Mae Hong Son	585.11	614.63	613.29	6.14	6.32
Tak	1,758.12	1,786.59	1,780.29	(14.34)	(16.63)
Kamphaeng Phet	2,946.36	2,984.78	2,979.08	(29.09)	(30.39)
Sukhothai	1,769.55	1,909.07	1,904.46	45.93	47.42
Phrae	2,139.31	2,119.89	2,109.51	(46.89)	(52.58)
Phetchabun	3,575.01	3,899.23	3,887.27	115.85	118.43
Nan	2,721.56	2,845.68	2,837.56	21.38	20.80
Uttaradit	2,170.79	2,456.06	2,450.11	118.48	123.03
Phitsanulok	2,660.67	3,047.21	3,037.39	165.30	170.37
Phichit	4,551.79	4,376.72	4,357.94	(172.59)	(186.20)
Northeast					
Loei	2,692.35	2,912.56	2,901.57	74.20	74.41
Nongbua Lamphu	2,075.54	2,210.52	2,201.81	38.26	37.40
Udon Thani	4,551.99	4,956.61	4,920.89	143.04	134.44
Nong Khai	6,547.76	6,374.28	6,339.60	(205.61)	(227.57)
Bueng Kan	2,072.31	2,263.37	2,253.17	68.85	68.57
Sakon Nakhon	5,071.39	5,307.03	5,274.63	42.21	31.40
Nakhon Phanom	2,389.58	2,441.33	2,429.07	(12.39)	(17.27)
Mukdahan	2,142.73	2,183.82	2,175.90	(14.00)	(16.76)
Yasothon	2,385.30	2,625.75	2,615.11	90.44	91.25
Amnat Charoen	1,856.35	1,984.17	1,971.92	38.08	34.95
Ubon Ratchathani	6,925.76	7,269.12	7,222.52	69.39	53.83
Si Sa Ket	7,162.64	7,874.69	7,846.01	266.12	270.18
Surin	7,412.23	8,121.53	8,076.01	260.38	254.86
Buri Ram	5,655.76	6,214.93	6,189.31	208.46	209.89
Maha Sarakham	3,954.37	4,501.37	4,469.85	230.71	227.91
Roi Et	5,066.28	4,179.38	4,171.40	(568.91)	(594.20)
Kalasin	4,434.53	4,660.35	4,628.38	47.68	36.65
Khon Kaen	7,288.76	7,760.58	7,721.95	133.18	125.53
Chaiyaphum	4,283.21	4,531.73	4,505.70	62.61	55.49
Nakhon Ratchasima	12,147.90	12,040.16	11,984.21	(264.88)	(295.43)
Central					
Uthai Thani	976.30	1,127.89	1,124.65	65.97	68.28
Nakhon Sawan	3,788.34	4,004.09	3,990.81	53.16	52.32
Saraburi	3,097.38	2,798.64	2,782.43	(215.24)	(231.00)
Lop Buri	2,571.22	2,724.49	2,717.06	39.80	40.31
Chai Nat	1,380.62	1,536.68	1,532.32	61.54	63.46
Suphanburi	3,530.05	3,568.83	3,559.18	(38.81)	(42.15)
Ang Thong	2,066.23	1,776.89	1,773.50	(192.62)	(201.18)

Table 15. (Continue)

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP2.6	RCP2.6 & Socio	RCP2.6	RCP2.6 & Socio
Pathum Thani	1,504.43	1,271.49	1,314.61	(152.37)	(133.19)
Samut Prakan	885.72	870.47	1,048.33	(23.34)	77.91
Samut Sakhon	1,426.94	1,177.15	1,174.90	(160.24)	(167.36)
Nakhon Pathom	2,598.59	2,974.22	3,075.66	160.41	228.58
Kanchanaburi	3,777.64	3,920.49	3,910.08	13.65	12.59
Ratchaburi	2,330.85	2,310.80	2,303.29	(50.48)	(54.49)
Samut Songkhram	940.80	838.36	836.35	(71.75)	(75.17)
Phetchaburi	1,641.62	1,520.02	1,515.52	(94.08)	(99.17)
Prachuap Khiri Khan	5,810.38	5,355.55	5,341.89	(346.28)	(363.63)
East					
Nakhon Nayok	1,548.74	1,418.80	1,430.84	(97.04)	(92.95)
Prachin Buri	1,229.37	1,401.67	1,403.80	72.94	78.93
Chachoengsao	4,460.91	4,116.16	4,132.37	(263.44)	(261.44)
Sa Kaeo	2,002.96	2,013.95	2,032.18	(28.01)	(16.68)
Chanthaburi	7,832.59	6,738.91	6,788.59	(728.45)	(725.20)
Trat	1,986.58	1,707.40	1,719.21	(185.74)	(185.41)
Rayong	7,708.35	6,735.97	6,730.90	(660.30)	(685.22)
Chon Buri	5,165.26	4,785.88	4,797.88	(294.25)	(295.29)
Upper South					
Chumphon	9,566.90	8,136.95	8,127.05	(940.99)	(979.62)
Ranong	2,042.43	1,689.23	1,686.12	(226.99)	(237.01)
Surat Thani	15,296.50	12,742.18	12,718.95	(1,650.46)	(1,723.21)
Phangnga	3,926.49	3,291.85	3,286.04	(412.21)	(430.26)
Phuket	534.06	455.08	454.34	(52.07)	(54.31)
Krabi	5,991.09	5,142.62	5,134.40	(563.69)	(587.84)
Nakhon Si Thammarat	10,101.76	8,503.63	8,509.29	(1,041.65)	(1,075.48)
Lower South					
Trang	8,345.20	6,922.91	6,909.96	(916.08)	(956.66)
Phatthalung	4,342.65	3,631.68	3,629.04	(460.83)	(478.88)
Songkhla	9,127.11	7,540.74	7,526.98	(1,018.70)	(1,063.63)
Satun	2,714.08	2,241.77	2,237.58	(303.24)	(316.67)
Pattani	3,075.33	2,536.97	2,532.65	(345.34)	(360.39)
Yala	4,009.91	3,323.54	3,317.46	(441.79)	(461.28)
Narathiwat	3,023.87	2,494.51	2,489.75	(339.56)	(354.66)
Total	**290,695.36**	**279,862.19**	**279,450.47**	**(10,833.17)**	**(11,244.89)**

Table 16. Implications for greenhouse warming on rainfed farms at provincial level under RCP4.5

	Total land value ($Million)			Total change ($Million)	
Province	Baseline	RCP4.5	RCP4.5 & Socio	RCP4.5	RCP4.5 & Socio
North					
Chiang Rai	5,130.74	5,055.52	5,007.12	(220.78)	(246.17)
Phayao	2,261.28	2,395.18	2,386.85	(4.36)	(5.97)
Lampang	1,646.66	1,757.73	1,748.63	4.37	1.65
Lamphun	1,792.28	1,680.21	1,670.41	(124.85)	(130.80)
Chiang Mai	6,510.13	5,312.80	5,284.32	(893.20)	(921.03)
Mae Hong Son	585.11	562.60	560.97	(32.93)	(33.79)
Tak	1,758.12	1,520.25	1,512.76	(193.66)	(199.95)
Kamphaeng Phet	2,946.36	2,624.32	2,598.83	(281.93)	(298.83)
Sukhothai	1,769.55	1,635.67	1,622.26	(136.20)	(144.50)
Phrae	2,139.31	1,887.62	1,873.33	(214.64)	(224.74)
Phetchabun	3,575.01	3,623.97	3,601.53	(97.43)	(107.38)
Nan	2,721.56	2,634.78	2,625.58	(143.19)	(147.89)
Uttaradit	2,170.79	2,105.49	2,092.96	(112.03)	(118.68)
Phitsanulok	2,660.67	2,880.89	2,865.47	29.74	25.46
Phichit	4,551.79	3,704.76	3,684.77	(630.01)	(649.64)
Northeast					
Loei	2,692.35	3,009.10	2,998.85	82.35	82.29
Nongbua Lamphu	2,075.54	2,298.84	2,287.20	51.86	49.41
Udon Thani	4,551.99	5,206.62	5,177.25	205.50	200.09
Nong Khai	6,547.76	6,357.40	6,326.65	(334.25)	(350.22)
Bueng Kan	2,072.31	2,429.65	2,419.79	126.55	126.86
Sakon Nakhon	5,071.39	5,679.68	5,649.23	161.60	155.29
Nakhon Phanom	2,389.58	2,464.71	2,450.78	(41.53)	(47.01)
Mukdahan	2,142.73	2,309.54	2,298.20	18.09	15.12
Yasothon	2,385.30	2,734.44	2,726.30	111.08	112.45
Amnat Charoen	1,856.35	2,138.79	2,130.02	92.41	92.23
Ubon Ratchathani	6,925.76	7,915.79	7,874.28	309.32	302.83
Si Sa Ket	7,162.64	8,124.30	8,093.44	285.28	284.63
Surin	7,412.23	8,503.28	8,476.28	348.57	351.95
Buri Ram	5,655.76	6,512.61	6,488.70	279.51	280.53
Maha Sarakham	3,954.37	4,758.44	4,737.42	309.48	310.41
Roi Et	5,066.28	3,768.67	3,759.77	(898.65)	(917.52)
Kalasin	4,434.53	5,056.61	5,024.05	191.48	183.76
Khon Kaen	7,288.76	7,968.94	7,943.57	124.27	123.15
Chaiyaphum	4,283.21	4,840.57	4,816.25	160.75	156.78
Nakhon Ratchasima	12,147.90	12,523.03	12,464.58	(214.91)	(235.86)
Central					
Uthai Thani	976.30	1,065.72	1,060.92	15.71	14.74
Nakhon Sawan	3,788.34	3,838.86	3,812.54	(104.00)	(116.01)
Saraburi	3,097.38	2,507.23	2,488.31	(436.37)	(452.93)
Lop Buri	2,571.22	2,570.26	2,554.69	(90.20)	(97.50)
Chai Nat	1,380.62	1,431.67	1,425.20	(19.74)	(21.91)
Suphanburi	3,530.05	3,377.04	3,366.43	(208.24)	(214.11)
Ang Thong	2,066.23	1,626.86	1,619.51	(316.52)	(325.16)

Table 16. (Continue)

Province	Total land value ($Million) Baseline	RCP4.5	RCP4.5 & Socio	Total change ($Million) RCP4.5	RCP4.5 & Socio
Pathum Thani	1,504.43	1,138.92	1,161.10	(255.83)	(247.04)
Samut Prakan	885.72	838.37	1,079.86	(57.23)	80.20
Samut Sakhon	1,426.94	1,061.47	1,058.96	(253.11)	(258.42)
Nakhon Pathom	2,598.59	2,917.71	3,168.17	86.94	235.31
Kanchanaburi	3,777.64	3,529.65	3,513.99	(269.72)	(279.55)
Ratchaburi	2,330.85	2,059.94	2,046.10	(232.01)	(241.99)
Samut Songkhram	940.80	741.91	739.74	(143.47)	(146.72)
Phetchaburi	1,641.62	1,309.79	1,305.74	(241.87)	(247.50)
Prachuap Khiri Khan	5,810.38	4,886.76	4,866.47	(716.52)	(736.54)
East					
Nakhon Nayok	1,548.74	1,349.71	1,361.98	(164.75)	(159.40)
Prachin Buri	1,229.37	1,424.69	1,428.20	65.80	71.10
Chachoengsao	4,460.91	3,908.45	3,935.16	(462.95)	(452.20)
Sa Kaeo	2,002.96	1,903.02	1,927.60	(125.45)	(111.53)
Chanthaburi	7,832.59	6,171.28	6,240.13	(1,197.48)	(1,175.12)
Trat	1,986.58	1,507.99	1,514.53	(335.56)	(336.86)
Rayong	7,708.35	6,226.91	6,227.83	(1,093.07)	(1,107.12)
Chon Buri	5,165.26	4,533.09	4,548.60	(531.86)	(528.10)
Upper South					
Chumphon	9,566.90	7,340.23	7,329.36	(1,572.52)	(1,601.85)
Ranong	2,042.43	1,524.98	1,521.38	(359.13)	(366.67)
Surat Thani	15,296.50	11,407.05	11,380.50	(2,697.48)	(2,753.89)
Phangnga	3,926.49	2,952.21	2,945.74	(679.01)	(692.98)
Phuket	534.06	397.27	396.33	(94.73)	(96.72)
Krabi	5,991.09	4,580.01	4,569.71	(994.04)	(1,014.61)
Nakhon Si Thammarat	10,101.76	7,625.66	7,627.16	(1,729.96)	(1,755.17)
Lower South					
Trang	8,345.20	6,262.24	6,247.45	(1,449.96)	(1,480.40)
Phatthalung	4,342.65	3,267.40	3,266.17	(749.70)	(761.74)
Songkhla	9,127.11	6,849.87	6,838.83	(1,585.33)	(1,615.68)
Satun	2,714.08	2,030.46	2,026.25	(475.01)	(484.65)
Pattani	3,075.33	2,372.02	2,374.29	(498.56)	(504.54)
Yala	4,009.91	3,057.04	3,050.67	(670.01)	(683.59)
Narathiwat	3,023.87	2,266.97	2,262.10	(526.58)	(537.36)
Total	**290,695.36**	**267,843.54**	**267,566.05**	**(22,851.82)**	**(23,129.31)**

Table 17. Implications for greenhouse warming on rainfed farms at provincial level under RCP6.0

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP6.0	RCP6.0 & Socio	RCP6.0	RCP6.0 & Socio
North					
Chiang Rai	5,130.74	5,719.26	5,683.81	96.22	89.75
Phayao	2,261.28	2,475.61	2,461.81	15.07	12.71
Lampang	1,646.66	1,866.95	1,857.93	49.94	49.77
Lamphun	1,792.28	1,733.76	1,720.46	(126.67)	(133.24)
Chiang Mai	6,510.13	5,780.20	5,730.99	(774.11)	(805.84)
Mae Hong Son	585.11	615.74	612.89	(11.17)	(11.68)
Tak	1,758.12	1,738.58	1,726.69	(101.28)	(106.47)
Kamphaeng Phet	2,946.36	2,790.13	2,774.06	(244.67)	(252.72)
Sukhothai	1,769.55	1,885.78	1,872.75	(19.46)	(23.42)
Phrae	2,139.31	2,055.24	2,032.99	(159.83)	(171.83)
Phetchabun	3,575.01	3,981.68	3,957.06	64.98	60.48
Nan	2,721.56	2,775.98	2,761.34	(105.39)	(109.89)
Uttaradit	2,170.79	2,508.95	2,492.87	94.83	92.68
Phitsanulok	2,660.67	3,149.21	3,131.82	161.17	161.03
Phichit	4,551.79	4,045.61	4,007.54	(538.71)	(563.11)
Northeast					
Loei	2,692.35	3,005.22	2,989.57	52.95	51.45
Nongbua Lamphu	2,075.54	2,277.08	2,261.14	16.75	12.62
Udon Thani	4,551.99	5,189.58	5,144.34	155.45	142.77
Nong Khai	6,547.76	5,976.78	5,918.46	(679.55)	(714.64)
Bueng Kan	2,072.31	2,413.13	2,395.57	101.44	98.28
Sakon Nakhon	5,071.39	5,596.31	5,550.24	60.64	46.60
Nakhon Phanom	2,389.58	2,428.26	2,410.32	(98.06)	(105.29)
Mukdahan	2,142.73	2,275.31	2,260.15	(28.52)	(33.04)
Yasothon	2,385.30	2,761.85	2,746.13	107.22	106.14
Amnat Charoen	1,856.35	2,115.41	2,098.73	62.81	58.72
Ubon Ratchathani	6,925.76	7,756.24	7,690.28	151.78	132.31
Si Sa Ket	7,162.64	8,133.30	8,087.81	224.81	220.36
Surin	7,412.23	8,518.23	8,471.29	294.25	291.17
Buri Ram	5,655.76	6,522.92	6,486.41	238.63	236.19
Maha Sarakham	3,954.37	4,813.30	4,780.08	320.16	317.25
Roi Et	5,066.28	3,019.97	3,008.33	(1,499.60)	(1,528.65)
Kalasin	4,434.53	5,023.42	4,977.62	131.86	117.98
Khon Kaen	7,288.76	7,828.83	7,776.55	(42.94)	(57.51)
Chaiyaphum	4,283.21	4,878.09	4,844.75	143.20	136.93
Nakhon Ratchasima	12,147.90	12,435.55	12,350.50	(443.27)	(474.93)
Central					
Uthai Thani	976.30	804.95	796.92	(153.65)	(159.68)
Nakhon Sawan	3,788.34	3,335.07	3,290.82	(467.77)	(496.33)
Saraburi	3,097.38	2,063.83	2,042.96	(784.81)	(808.03)
Lop Buri	2,571.22	2,200.32	2,178.39	(355.88)	(371.13)
Chai Nat	1,380.62	1,244.59	1,235.15	(152.77)	(158.62)
Suphanburi	3,530.05	3,023.02	3,006.34	(487.27)	(499.83)
Ang Thong	2,066.23	1,275.71	1,267.22	(584.87)	(598.41)

Table 17. (Continue)

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP6.0	RCP6.0 & Socio	RCP6.0	RCP6.0 & Socio
Pathum Thani	1,504.43	946.38	1,013.64	(415.20)	(379.21)
Samut Prakan	885.72	821.04	1,098.53	(84.30)	88.36
Samut Sakhon	1,426.94	850.59	847.31	(422.37)	(430.55)
Nakhon Pathom	2,598.59	2,807.34	3,211.46	(5.47)	252.12
Kanchanaburi	3,777.64	2,897.04	2,878.09	(726.58)	(745.50)
Ratchaburi	2,330.85	1,684.74	1,669.88	(510.68)	(525.77)
Samut Songkhram	940.80	613.13	610.34	(246.72)	(251.76)
Phetchaburi	1,641.62	1,069.23	1,063.92	(430.89)	(439.97)
Prachuap Khiri Khan	5,810.38	4,166.23	4,129.90	(1,293.37)	(1,331.02)
East					
Nakhon Nayok	1,548.74	1,325.90	1,340.92	(214.01)	(205.66)
Prachin Buri	1,229.37	1,475.00	1,471.62	86.55	89.65
Chachoengsao	4,460.91	3,722.24	3,774.41	(675.20)	(646.97)
Sa Kaeo	2,002.96	1,994.62	2,016.95	(106.93)	(90.37)
Chanthaburi	7,832.59	5,956.47	6,064.47	(1,537.01)	(1,485.45)
Trat	1,986.58	1,559.75	1,595.93	(360.09)	(340.86)
Rayong	7,708.35	5,549.49	5,558.09	(1,702.29)	(1,716.64)
Chon Buri	5,165.26	4,236.88	4,268.76	(826.16)	(812.22)
Upper South					
Chumphon	9,566.90	5,914.12	5,898.42	(2,703.49)	(2,751.46)
Ranong	2,042.43	1,217.48	1,212.79	(604.55)	(616.26)
Surat Thani	15,296.50	9,154.00	9,119.14	(4,505.93)	(4,592.96)
Phangnga	3,926.49	2,379.12	2,370.41	(1,138.82)	(1,160.59)
Phuket	534.06	318.35	317.12	(158.08)	(161.14)
Krabi	5,991.09	3,673.83	3,660.30	(1,711.08)	(1,743.84)
Nakhon Si Thammarat	10,101.76	6,151.47	6,148.29	(2,911.25)	(2,954.90)
Lower South					
Trang	8,345.20	5,146.99	5,130.57	(2,365.47)	(2,409.17)
Phatthalung	4,342.65	2,815.58	2,821.85	(1,147.66)	(1,159.27)
Songkhla	9,127.11	5,918.91	5,910.58	(2,411.30)	(2,449.02)
Satun	2,714.08	1,743.58	1,739.24	(727.05)	(739.65)
Pattani	3,075.33	2,203.47	2,206.92	(685.55)	(691.42)
Yala	4,009.91	2,752.28	2,743.59	(967.22)	(984.77)
Narathiwat	3,023.87	1,979.02	1,973.88	(787.93)	(801.64)
Total	**290,695.36**	**253,083.16**	**252,758.38**	**(37,612.20)**	**(37,936.98)**

Table 18. Implications for greenhouse warming on rainfed farms at provincial level under RCP8.5

Province	Total land value ($Million)			Total change ($Million)	
	Baseline	RCP8.5	RCP8.5 & Socio	RCP8.5	RCP8.5 & Socio
North					
Chiang Rai	5,130.74	5,359.53	5,305.39	(135.17)	(157.72)
Phayao	2,261.28	2,368.94	2,352.71	(54.62)	(58.77)
Lampang	1,646.66	1,779.41	1,767.33	(0.31)	(2.60)
Lamphun	1,792.28	1,580.13	1,567.23	(259.30)	(267.67)
Chiang Mai	6,510.13	4,902.83	4,847.28	(1,549.50)	(1,600.55)
Mae Hong Son	585.11	568.48	565.12	(46.44)	(47.64)
Tak	1,758.12	1,445.40	1,431.32	(330.34)	(341.38)
Kamphaeng Phet	2,946.36	2,514.67	2,483.83	(486.52)	(508.83)
Sukhothai	1,769.55	1,729.42	1,711.31	(133.06)	(142.45)
Phrae	2,139.31	1,802.62	1,774.96	(370.13)	(390.64)
Phetchabun	3,575.01	3,607.93	3,573.03	(186.04)	(201.80)
Nan	2,721.56	2,565.82	2,546.95	(272.92)	(282.27)
Uttaradit	2,170.79	2,245.71	2,224.32	(73.08)	(81.86)
Phitsanulok	2,660.67	3,026.12	3,001.18	109.13	103.95
Phichit	4,551.79	3,298.50	3,261.58	(1,177.42)	(1,213.88)
Northeast					
Loei	2,692.35	2,674.83	2,645.48	(170.83)	(185.70)
Nongbua Lamphu	2,075.54	2,118.62	2,097.67	(90.61)	(99.87)
Udon Thani	4,551.99	4,776.23	4,692.33	(104.48)	(150.78)
Nong Khai	6,547.76	5,442.26	5,356.21	(1,187.32)	(1,252.41)
Bueng Kan	2,072.31	2,290.90	2,271.09	37.04	31.60
Sakon Nakhon	5,071.39	5,225.44	5,164.01	(185.96)	(215.35)
Nakhon Phanom	2,389.58	1,795.18	1,758.86	(571.97)	(602.62)
Mukdahan	2,142.73	2,061.60	2,041.09	(184.75)	(195.60)
Yasothon	2,385.30	2,619.30	2,593.72	29.85	21.23
Amnat Charoen	1,856.35	1,926.46	1,899.76	(58.11)	(71.77)
Ubon Ratchathani	6,925.76	7,124.98	7,029.35	(262.06)	(311.11)
Si Sa Ket	7,162.64	7,911.49	7,847.99	123.17	107.95
Surin	7,412.23	8,203.46	8,128.22	139.28	116.73
Buri Ram	5,655.76	6,097.87	6,027.34	(11.09)	(40.79)
Maha Sarakham	3,954.37	4,570.77	4,506.03	215.39	188.37
Roi Et	5,066.28	2,873.44	2,837.67	(1,889.91)	(1,940.08)
Kalasin	4,434.53	4,652.24	4,587.61	(102.33)	(134.74)
Khon Kaen	7,288.76	7,465.82	7,390.17	(299.46)	(333.07)
Chaiyaphum	4,283.21	4,181.13	4,124.48	(325.66)	(357.97)
Nakhon Ratchasima	12,147.90	9,202.66	9,061.95	(2,852.17)	(2,974.05)
Central					
Uthai Thani	976.30	1,101.59	1,093.35	33.65	32.28
Nakhon Sawan	3,788.34	3,750.08	3,712.33	(250.25)	(268.77)
Saraburi	3,097.38	2,151.13	2,122.30	(869.05)	(898.20)
Lop Buri	2,571.22	2,470.71	2,452.48	(223.99)	(232.32)
Sing Buri					
Chai Nat	1,380.62	1,470.73	1,460.13	(15.64)	(18.27)
Suphanburi	3,530.05	3,148.64	3,126.39	(484.28)	(497.80)
Ang Thong	2,066.23	1,380.83	1,366.96	(619.06)	(635.45)

Table 18. (Continue)

Province	Total land value ($Million) Baseline	RCP8.5	RCP8.5 & Socio	Total change ($Million) RCP8.5	RCP8.5 & Socio
Pathum Thani	1,504.43	958.60	1,054.92	(484.71)	(418.36)
Samut Prakan	885.72	817.59	1,093.01	(101.48)	104.41
Samut Sakhon	1,426.94	771.17	767.27	(560.01)	(570.20)
Nakhon Pathom	2,598.59	2,855.48	3,213.71	33.94	311.51
Kanchanaburi	3,777.64	3,291.70	3,266.72	(574.73)	(591.38)
Ratchaburi	2,330.85	1,734.25	1,711.91	(570.12)	(590.58)
Samut Songkhram	940.80	604.45	600.84	(299.50)	(305.36)
Phetchaburi	1,641.62	1,010.27	1,003.64	(554.88)	(566.11)
Prachuap Khiri Khan	5,810.38	3,530.36	3,491.81	(1,996.92)	(2,048.63)
East					
Nakhon Nayok	1,548.74	1,122.53	1,143.84	(400.46)	(387.69)
Prachin Buri	1,229.37	1,376.64	1,378.69	34.75	42.08
Chachoengsao	4,460.91	3,315.63	3,371.61	(1,093.66)	(1,059.49)
Sa Kaeo	2,002.96	1,175.52	1,182.89	(718.49)	(721.67)
Chanthaburi	7,832.59	4,480.17	4,544.79	(2,894.43)	(2,882.23)
Trat	1,986.58	1,073.62	1,068.28	(779.64)	(793.76)
Rayong	7,708.35	4,686.03	4,692.02	(2,647.42)	(2,673.53)
Chon Buri	5,165.26	3,637.78	3,673.70	(1,412.56)	(1,397.90)
Upper South					
Chumphon	9,566.90	5,188.89	5,164.25	(3,741.05)	(3,807.92)
Ranong	2,042.43	1,103.80	1,098.22	(801.56)	(816.14)
Surat Thani	15,296.50	8,269.60	8,228.55	(6,001.09)	(6,109.70)
Phangnga	3,926.49	2,122.01	2,111.28	(1,540.96)	(1,569.00)
Phuket	534.06	288.62	287.16	(209.59)	(213.40)
Krabi	5,991.09	3,237.80	3,221.42	(2,351.22)	(2,394.00)
Nakhon Si Thammarat	10,101.76	5,459.34	5,431.74	(3,964.46)	(4,036.59)
Lower South					
Trang	8,345.20	4,510.04	4,487.23	(3,275.10)	(3,334.68)
Phatthalung	4,342.65	2,350.79	2,338.91	(1,701.47)	(1,732.43)
Songkhla	9,127.11	4,934.20	4,909.70	(3,580.80)	(3,645.62)
Satun	2,714.08	1,466.78	1,459.37	(1,065.15)	(1,084.53)
Pattani	3,075.33	1,671.42	1,666.32	(1,200.10)	(1,219.44)
Yala	4,009.91	2,187.29	2,176.96	(1,559.04)	(1,586.86)
Narathiwat	3,023.87	1,634.20	1,625.94	(1,186.72)	(1,208.32)
Total	**290,695.36**	**228,350.45**	**227,275.19**	**(62,344.91)**	**(63,420.18)**

7.3 Interviewed Results

This section provides results from interviewing 30 representatives from government officers attended the focus group seminar organized on September 2, 2016. A majority of government officers were from departments and offices under the authority of Ministry of Agriculture and Cooperatives. Officers from other organizations related to the climate change also attended such as officers from the Office of Natural Resources and Environmental Policy and Planning, Department of Meteorology, the Office of National Economic and Social Development Board, and Thailand Greenhouse Gas Management Organization (Public Organization). Details can be explained below.

7.3.1 Impacts of Climate Change Related Policies on Working Operation

The government officers were asked whether they were affected by any climate change related policies in their working operations including: the budget and work plan; policy implementation; coordinator with other organizations from both inside and outside of the Ministry of Agriculture and Cooperatives; and monitoring and evaluation. According to the focus group, the group of government officers revealed that almost all of them did not have the budget plan for projects related to climate change. They also revealed that climate change projects were usually the last priority for them since they were not included in the normal work plan. The group also provided the opinion that the climate change projects under the 2013-16 Strategy had the crossing cutting problem in term of communication among organizations and each organization worked on the projects of climate change separately. There was no integration of climate change planning in organizations. Lastly, for monitoring and evaluation, it is disclosed that the 2013-16 Strategy did not have well-designed and unclear indicators to facilitate the monitoring and evaluation process.

7.3.2 Driving the Policies Related to Climate Change

Almost all representatives from organizations reported that there was a slow progress of driving the policies related to climate change because their head/administrative of the organizations usually give the first priority to their normal work plan and will drive the projects related to climate change as the last priority. Moreover, they think that the climate change is the long-term problem and they need to give the first priority to the short-term problems.

7.3.3 Obstacles of Driving the Policies Related to Climate Change

There were several obstacles that obstruct the implementation of the climate change policies. The first obstacle is the budget shortage because almost all organizations did not have projects under the 2013-16 Strategy. Therefore, they had no budget to drive the policies. The second obstacle is indicators and objectives of the 2013-16 Strategy were not well-designed and unclear. The third obstacle is that head/administrative of the organizations usually give the last priority to the projects related to climate change since they were not included in the normal work plan. Fourthly, the obstacle came from the fact that there were a few meetings/seminars related to the climate change issues. Therefore, exchanging the idea and coordination among organizations were difficult. The fifth obstacle is that there was no integration of climate change policy and planning among all organizations and no joint KPIs related to climate change projects among organizations. Lastly, the lack of central database related to technological knowledge and innovation related to climate change and agriculture is the sixth obstacle.

7.3.4 How to Solve the Problems

To solve the problems, it is recommended that the climate change projects should be included in the normal work plan of the organization both TOR and agenda. Moreover, to obtain continue annual budget, the climate change projects should be included in the strategic plan of the Ministry of Agriculture and Cooperatives. New organization/unit should be set up to take care of all issues related to climate change and agriculture. Furthermore, well-designed and clear indicators on the climate change strategic plan may be needed. In addition, enhancing the recognition of the head or administrative of organizations regarding the climate change impacts may be needed. The action plan to drive the climate change strategic plan should be drafted and implemented. Collecting the knowledge from local wisdom related to adaptation strategies/ technology may be important.

7.3.5 Discussion

By comparing results from the current article with previous studies especially Attavanich (2013), we find that the damage values of the current study (both irrigated and rainfed areas) that incorporates climate variability in the model are larger than those found in Attavanich (2013). While Attavanich (2013) found that climate change is beneficial to some provinces in the irrigated area, the current study reveals that all provinces with irrigated farming will be adversely affected by climate change. Both studies found that all provinces in the southern regions and a majority of provinces in the central region will received negative impacts from climate change. Lastly, adding future projections of change in population provides slightly different outcomes. This may be explain by the fact that both studies remove farms having very value per hectare, which could reduce the pressure of farmland for non-agricultural development use.

8. Conclusions and Policy Implications

This section provides summary of this study, policy implications, and recommendations from this study and future research possibilities.

8.1 Conclusions

This research study employs the Ricardian approach to analyze the effect of climate change on Thailand's agriculture and investigate implications for greenhouse warming under future climate change scenarios and future changes in socio-economic conditions during 2041-2050. The study also provides interviewed results from government officers regarding climate change policies to mitigate climate change impacts on Thailand's agriculture.

A unique farm-level dataset is constructed using data from several sources mainly from the 2011/2012 national agricultural household socio economics survey. The weighted average normal climatological variables during 1981-2015 across climate stations within the radius of 250 kilometers in each province of Thailand are constructed using climate data from Thailand Meteorology Department. Future climate change projections are obtained from IPCC AR5 (IPCC, 2014). Also the latest projected Thailand's population from 2010-2030 reported by NESDB (2013) are employed to reflect changes in socio-economic conditions.

The study finds that both mean and variability of temperature and precipitation significantly determine farmland values, and non-climate factors (e.g., operator's characteristics, farm characteristics, and location characteristics where farms locates) also play a crucial role in explaining farmland values. Overall, the study predicts that greenhouse warming is projected to adversely affect Thailand's agriculture. The accumulative damage values from 2011/2012 crop year to 2041-2050 period range from \$17.499 billion to \$83.826 billion. With the exchange rate of 34 THB/US dollar, the average annual damage values will be ranged from THB17.499 billion to THB 83.826 billion.

By separating the full sample into subsamples of irrigated and rainfed farms, this study finds that climate change will adversely affect rainfed farms ranging from $10.833 billion to $63.420 billion, while climate change will generate the loss to irrigated farms ranging from $6.666 billion to $20.406 billion. With the exchange rate of 34 THB/US dollar, the average annual damage value will be equal to THB6.666 billion to THB20.406 billion. Adding changes in socio-economic conditions slightly affect the results.

For the analysis of irrigated farms at the provincial level, we reveal that all provinces will be negatively affected by the climate change across all climate scenarios. Southern, north, and northeastern regions are projected to receive higher negative impacts as compared to east and central regions. Surat Thani's agricultural sector will receive the highest negative impacts from climate change ($537-1,428 million) followed by Nakhon Ratchasima ($365-$971 million), Chumphon ($290-$772), Nakhon Si Thammarat ($263-$772 million), Nong Khai ($257-$684 million), Chiang Rai ($198-$593 million), Ubon Ratchathani ($190-$507 million), and Songkhla ($184-$490 million), respectively.

For the analysis of rainfed farms at the provincial level, we find that southern regions are projected to be negatively affected the most followed by eastern region, and central, while, north and northeastern regions are projected to obtain the positive impacts from climate change. While north and northeastern regions are beneficial to climate change, under climate change scenario RCP8.5 almost all provinces in these regions will be negatively affected by climate change. The study also discovers that Surat Thani's agricultural sector will receive the highest negative impacts from climate change ($1,723-$6,101 million) similar to the find from the irrigated farm subsample. Nakhon Si Thammarat ($1,075-$4,037 million) ranks second in term of total damage values followed by Songkhla ($1,064-$3,646 million), Chumphon ($980-$3,808), Trang ($957-$3,335 million), Chanthaburi ($725-$2,882 million), Rayong ($685-$2,674 million), Roi Et ($594.20-$1,940 million) and Krabi ($588-$2,394), respectively.

8.2 Policy Implications

Governmental organizations involving in the agricultural sectors should provide the following supports to mitigate the climate change impacts. 1) support the collection, development and building the database, knowledge and local wisdom with the cooperation from all sectors for managing the risks arising from climate change; 2) support the establishment and development technology in response to climate change; 3) support by enhancing the raise awareness of climate change impacts and convey information, knowledge and technology to development parties at all levels; 4) support by increasing the efficiency and fairness in access to water resources for agriculture and the use of soil resources and build the readiness to cope and reduce the damage from climate change; 5) support the development of proper mechanisms, measures, and infrastructure to support the adaptation of farmers, farmer institutions and related businesses

It is also recommended that the climate change projects should be included in the normal work plan of the organization. Moreover, the climate change projects should be included in the strategic plan of the Ministry of Agriculture and Cooperatives to obtain continue annual budget. Furthermore, well-designed and clear indicators on the climate change strategic plan may be needed. Instead of waiting for the assistance of the government organizations, farmers in the affected areas should also adapt their crops from season to season to ensure that the seeding material used and planting times are adjusted to the expected weather in a specific season, or prepare to change the land use from crops to pasture or trees, trees to grazing land. For livestock and fish species/breeds, farmers can similarly select breeds and species that are better adapted to warmer climates. Adaptation strategies regarding the moisture management, irrigation and soil and water conservation are also recommended to mitigate the farm's damage in the world of changing climate. Finally, it is worth noting that the accuracy of the results depends on whether the real situations are similar to assumptions used in future scenarios.

8.3 Future Research

Future research should apply finer-downscale climate projections to obtain better results for each province. Also the analysis in the finer scale that the provincial level may be needed since climate change problem and their impacts are location specific. Moreover, adaptation capacity of farmers in the sensitive areas is also a concerned issue and future research should alleviate this concern so that the policy makers can use the results to provide the assistance to those who have low ability to adapt in the world of changing climate.

9. References

Adams, R. M., B. A. McCarl, K. Segerson, C. Rosenzweig, K. J. Bryant, B. L. Dixon, J. R. Conner, R. E. Evenson, and D. S. Ojima. 1999. The economic effects of climate change on u.s. agriculture. In *The impact of climate change on U.S.agriculture.*,eds R. Mendelsohn and J. Newmann: Cambridge University Press, London: 180.0054.

Buddhaboon, C., S.Kongton, and A. Jintrawet. 2005. Climate scenario verification and impact on rain0.00fed rice production. In*The study of future climate change impact on water resource and rain0.00fed agricultural production*.,eds S. Chinvanna and A. Snidvongs. Proceedings of the APN CAPABLE CB0.0001 Synthesis Workshop, Vientaine, Lao PDR, 290.0030 July 2004. SEA START RC Technical Report No. 13.

Attavanich, W. 2013. "The effect of climate change on Thailand's agriculture." Selected Paper Presenting at the 7th International Academic Conference, Prague, Czech Republic. September 1–4.

Attavanich, W. 2016. The effect of climate change on global rice production under shared socioeconomic and representative concentration pathways. Department of Economics, Kasetsart University, Thailand.

Attavanich, W. and McCarl, B.A., 2014. How is CO_2 affecting yields and technological progress? A statistical analysis. *Climatic change*, *124*(4), pp.7470.00762.

Attavanich, W., McCarl, B.A., Ahmedov, Z., Fuller, S.W. and Vedenov, D.V., 2013. Effects of climate change on US grain transport. *Nature Climate Change*, *3*(7), pp.6380.00643.

Brown, M.E., Antle, J.M., Backlund, P., Carr, E.R., Easterling, W.E., Walsh, M.K. and Tebaldi, C., 2015. Climate change, global food security, and the US food system. *Washington, DC: United States Department of Agriculture. http://www. usda. gov/oce/climate_change/FoodSecurity. htm, accessed October*, *15*, p.2015.

Deschenes, O., and M. Greenstone. 2007. The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review* 97 (1): 354–85.

Dinar, A., R. Mendelsohn, R. Evenson, J. Parikh, A. Sanghi, K. Kumar, J. McKinsey, and S. Lonergan (eds) 1998. Measuring the impact of climate change on Indian agriculture. World Bank Technical Paper No. 402, Washington, DC.

IPCC, 2013. *Summary for Policymakers*. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.0.00K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

IPCC, 2014. *Summary for policymakers*. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 10.0032.

IPCC, ed. 2007a. *Climate change 2007: The physical science basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller. Cambridge, UK: Cambridge University Press.

———. 2007b. *Climate change 2007: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., eds. M. L. Parry, O. F. Canziani, P. J. Palutikof, P. J. van der Linden and C. E. Hanson. Cambridge, UK: Cambridge University Press.

Isvilanonda, S., S. Praneetvatakul, and C. Khamwong. 2009. Economic impact assessment of climate change on rice production in Thailand. Project Code: RDG5130015.The Thailand Research Fund, Thailand.

Khamwong, C., and S. Praneetvatakul. 2011. Impact of climate change on agricultural revenue and adaptation strategies of farmers in Northeasterm Thailand. Kasetsart Journal (Social Science) 32: 2140.00228.

Kumar, K. and J. Parikh. 2001. Indian agriculture and climate sensitivity. *Global Environmental Change* 11: 147–54.

McCarl, B. A., W. Attavanich, M. Musumba, J. Mu, and R. Aisabokhae. 2013. Land use and climate change. In *The Oxford Handbook of Land Economics.*, eds. M. Joshua Duke, JunJie Wu. Oxford University Press.

McCarl, B. A., X. Villavicencio, and X. Wu. 2008. Climate change and future analysis: Is stationarity dying? *American Journal of Agricultural Economics* 90 (5): 1241–47.

Mendelsohn, R (eds.). 2001. Global Warming and the American Economy: A Regional Assessment of Climate Change. Cheltenham: Edward Elgar Publishing.

Mendelsohn, R., J. Arellano0.00Gonzalez, and P. Christensen. 2010. A Ricardian analysis of Mexican farms. *Environment and Development Economics* 15 (2): 153–71.

Mendelsohn, R., W. D. Nordhaus, and D. Shaw. 1994. The impact of global warming on agriculture: a Ricardian analysis. *American Economic Review* 84: 753–71.

Mendelsohn, R., and M. Reinsborough. 2007. A Ricardian analysis of U.S. and Canadian farmland. *Climatic Change* 81 (1): 9–17. \

Office of Environmental Policy and Planning. 2000. Thailand's Initial National Communication under the United Nations Framework Convention on Climate Change. Ministry of Science, Technology, and Environment. Bangkok, Thailand. 100 p.

Pannangpetch K., V. Sarawat, S. Boonpradub, S. Ratanasriwong, S. Kongton, S. Nilpunt, C. Buddhaboon, K. Kunket, I. Buddhasimma, P. Kapetch, K. Ek0.00un, W. Damrhikhemtrakul. 2009. Impacts of global warming on rice, sugarcane, cassava, and maize production in Thailand. Project Code: RDG5130007. The Thailand Research Fund, Thailand.

Perry, M. and Hollis, D., 2005. The generation of monthly gridded datasets for a range of climatic variables over the UK. *International Journal of Climatology*, *25*(8), pp.10410.001054.

Reilly, J., F. Tubiello, B. A. McCarl, D. Abler, R. Darwin, K. Fuglie, S. Hollinger, C. Izaurralde, S. Jagtap, and J. Jones. 2003. U.S. agriculture and climate change: new results. *Climatic Change* 57: 43–67.

Reinsborough, M. J. 2003. A Ricardian model of climate change in Canada. *Canadian Journal of Economics* 36: 210.0040.

Schlenker, W., W. M. Hanemann, and A. C. Fisher. 2005. Will U.S. agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. *American Economic Review* 95 (1): 395–406.

Schlenker, W., and M. J. Roberts. 2009. Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences* 106 (37): 15594.

Seo, S. N., and R. Mendelsohn. 2008. An analysis of crop choice: Adapting to climate change in Latin American farms. *Ecological Economics* 67: 109–16.

Seo, S., R. Mendelsohn, and M. Munasinghe. 2005. Climate change and agriculture in Sri Lanka: A Ricardian valuation. *Environmental and Development Economics* 10: 581–96.

Smith, J. B., and D. A. Tirpak (eds.). 1989. The Potential effects of global climate change on the United States: Report to Congress, United States, Environmental Protection Agency. Office of Policy, Planning, and Evaluation.

Wang, J., R. Mendelsohn, A. Dinar, J. Huang, S. Rozelle, and L. Zhang. 2009. The impact of climate change on China's agriculture. *Agricultural Economics* 40 (3): 323–37.

Wiebe, K., Lotze0.00Campen, H., Sands, R., Tabeau, A., van der Mensbrugghe, D., Biewald, A., Bodirsky, B., Islam, S., Kavallari, A., Mason0.00D'Croz, D. and Müller, C., 2015. Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. *Environmental Research Letters*, *10*(8), p.085010.

Van Vuuren, D and K. Riahi. 2008. Do recent emissions trends imply higher emissions forever? *Climatic Change* 91: 2370.00248.