Chapter 7

Summary, Conclusion and Implications for Policy and Research

7.1 Summary

The research attempts to estimate the economic implications of climate change on Nepalese agriculture since 1980. The study also estimates the impact of climate change on three ecological regions of Nepal to see whether the effect of climate change differs in different regions. This study had three main objectives. The first main objective was to measure the economic impact of climate change on land value and net revenue from agriculture (crop farming only) in Nepal, and to predict the impact of climate change under SRES A2, A1B and B1 scenario for year 2030, 2060 and 2090. In addition to measuring climate change impact, the second major objective of the study was to examine the choice of crop made by the Nepalese farmers to cultivate at the climate conditions they face and to predict how their crop choice changes to respond to the different climatic circumstances as climate changes. For these both purposes, the study used cross-sectional household survey data of NLSS-III carried out by Central Bureau of Statistics in 2010/11. The third major objective was to develop yield response functions for major Nepalese crops. To fulfill this objective, the study relied upon the district level data on yield of six major Nepalese crops from year 1980 through 2009. These yield functions are then used to predict the crop specific consequences on yields of climate change.

There is limited literature on climate change impact on Nepalese agriculture. The climate change impact studies based on cross-sectional data are very rare in Nepalese context. The previous such studies were based upon small sample limited to only a few districts. The important distinction of this study is that it is based upon the observations from almost entire country. An important contribution of this study is that it explores how Nepalese farmers adapt to climate by changing crops.

For the first objective, the study applied cross-sectional Ricardian approach to measure the economic impact of change of climate attributes (temperatures and rainfall) on land value as well as net income from agriculture, controlling the impact of other factors. By regressing farmland value or net income per hectare on
temperature, rainfall and other variables, the marginal contribution of these factors to farm value or income can be estimated. The analysis controlled for effects of other key soil, socio-economic, household characteristics influencing land value or income.

The results of the cross-sectional farm value regressions show that most of the control variables in the regressions are significant. The findings reveal that lands in urban areas have higher values compared to rural areas. Further, the areas with higher population density, higher per capita income and higher road density imply higher land value. The findings also reveal that compared to rain-fed land seasonally irrigated land has higher value and year round irrigated land is furthermore valuable and findings demonstrate the importance of irrigation facility in agriculture. In addition, the results reveal that lowland farms possess higher values than the upland farms. The estimated results show the proportion of different soils in the land also influence farm price. In comparison to base soil type loam, the increase in the proportion of sand in the soil increases land value whereas more silt and clayloam decreases land value. The increase in proportion of clay on soil negatively effects land value but it is not significantly different from zero.

Results from the empirical model confirm that climate variables are important determinants of land value and their impact on farm values are nonlinear. Increases in winter and spring season rainfall reduce land value but more rainfall in the fall season has beneficial impact on farm land values. The land values demonstrate hill shaped response on rainfall variables of all seasons. The optimum level of rainfall for winter, spring and fall season rainfall are 28mm and 48mm and 1024mm respectively. In general more rainfall is beneficial and increases land value. The finding also reveals that on average warming is beneficial and increases land value. The land value shows a U shaped response to temperature and land value is least at the temperature about 19.3°C.

The findings from land value regression show that climate change will have favourable impact on land values. In regional scale, it is harmful for Mountain region in all scenarios. Hill region benefits in nearly all scenarios but Terai gains extensively in all scenarios. The projections show that the magnitude of impact of climate change will increase over time. It will be between 2.64 to 4.83 percent of the current farmland value by 2030. The impacts will remain within 5.79 to 10.71 percent by 2060 and
remain between 8.74 to 25.67 percent of the current farmland value by 2090. The results are dominated by the outcome in Terai region where land value increases by large magnitude.

The net revenue regression indicates that farmers with more capital earn higher net revenue. Household with larger family size per hectare of cultivated land receives higher net farm income. Net income per hectare land decreases as the size of land holdings of the household increases. The results also indicate that lowlands are relatively more productive compared to upland hence get more net income per hectare. The year round irrigated lands are more productive than seasonally irrigated lands which in turn are more productive than rain-fed land. Therefore, household with larger proportion of such land in total land holding earn higher income per hectare. The estimated regression coefficient indicates more educated household heads realize higher net revenue. Households with female head get lower net revenue compared to the families with male household head.

Soil types also determine the productivity of the land, net revenues are found responsive to the different soil types. The results indicate larger proportion of sand or clayloam in the soil in the land increases the net income whereas proportion of silt and clay show no significant impact.

The results show that net revenue is sensitive to climate variables. The response of climate on net income is non-linear. The marginal impacts of seasonal rainfall variables indicate that rainfall increase in winter and fall seasons reduce net revenue, whereas more rainfall in spring increases net income. The winter and spring rainfall both have hill shaped response on net revenue and the optimum rainfall for winter and spring are respectively 32 mm and 494 mm. But the response of fall season rainfall on net revenue is U-shaped and the worst level of rainfall is 845 mm. In general, more rainfall is harmful and it reduces net income. Temperature increase reduces net income but the impact is not significant. The temperature possesses a hill shaped response on net income and the optimum temperature is 19.94°C.

Climate change will have an adverse impact on net farm income in Nepal. But in regional levels, the impact is severely negative in Terai and in Hills it is less so whereas in Mountain region it is beneficial. The projections show over time the
damage from climate change will become more severe. It will be between -1.67 to -1.98 percent of the current net income by 2030. The impacts lie in the range of -2.70 to -5.12 percent by 2060 and remain between -4.79 to -10.78 percent of the current farm income by 2090. The consequences are mainly due to effect of Terai region.

The Ricardian approach using land value and using net income gave results contradictory to each other. On average the climate change will have favourable impact on land values. The land values in Terai and Hill regions increase from climate change but it reduces the land value in Mountain region. But climate change cause adverse impact on net revenue on average. Mountain region will gain in terms of increased net revenue from higher temperature and more rainfall while Hill and Terai face adverse consequences.

In Nepal, land market is not perfectly competitive and land value does not only reveal agricultural productivity. Land in urban areas possesses high value for their location advantage and from non-agricultural use. Areas with good development prospects in future enjoy high price due to speculation. The influence of possible non-agricultural use of land is not captured in the net revenue. Therefore, the contradictory results might have been appeared in the impact of climate change.

Terai region has better prospect for settlement and industrial development. There is a common observed tendency of migration of people from Mountain and Hill towards Terai. It is normally observed that settlements are developed in plain land with better road access and other facilities. Moreover, in recent time people are attracted towards non-agricultural activities and economy is also undergoing structural transformation from production of primary goods to secondary and tertiary. Such other reasons mentioned above are the cause of the higher land value in Terai region. Therefore, the result of land value regression demonstrated land with warmer and wetter conditions command higher value which is not the consequence of productivity only. Therefore, it can be concluded that regression result of net revenue per hectare demonstrates the actual climate change impact on agriculture sector. The result of land value per hectare regression is influenced by many non-agricultural aspects. Results of net income regression is also consistent to the general observation that increases in temperature and rainfall in relatively cold and dry Mountain region is beneficial whereas warm and wet Hill and Terai regions suffer from similar changes.
To achieve the second objective, the study employed a multinomial logit (MNL) model to analyse the choice of crop combination made by Nepalese farmers. By examining the crop choices that farmers made across different climatic and other conditions, the analysis identified how farmers in different climate conditions have adapted to current climate they face. The results are then used to predict how farmers in different regions will adjust their combination of crops as climate changes.

The result of the empirical analyses of MNL of crop choice indicates that farmers’ choice of crops depends upon the climate circumstances they confront. Temperature and seasonal rainfall are found to be important determinants of crop choice and the choice function is nonlinear on these variables. Farmers make their crop choices that suit to the climate and other conditions that they face. For example, farmers in cooler regions of Nepal choose barley-maize and wheat-maize, whereas farmers in hot regions choose potato-maize and mustard-paddy. Farmers in dry regions grow potato-paddy whereas in wet regions wheat-maize. As climate becomes warmer and wetter, farmers move away from wheat-paddy and wheat-maize and move towards lentil-paddy, mustard-paddy and potato-maize.

To attain the third major objective, the research developed yield response functions for barley, maize, paddy, potato, sugarcane and wheat. Crop yield function estimates the relationships between crop yield and seasonal temperature, rainfall as well as other variables. The crop yield per hectare is regressed on seasonal temperatures and rainfall variables, different soil type variables, time variable and regional dummies. In this way, the effects of temperature, rainfall, soil and time trend as well as the impact of regional dummies on yield can be isolated. Weighted regressions are estimated where acreages are used as weights. A quadratic functional form, with squared terms included for the climate variables to capture their non-linear impact but linear in all other variables is used to estimate the yield functions. Then, these yield response functions are used to estimate the impact of change in temperature and rainfall under various climate change scenarios. The projections of climate change impacts reveal that climate change is not likely to cause serious damages on the yields of the selected six major Nepalese crops. On the contrary, the results suggest that yields of paddy, maize and potato will increase, on average, over current levels in all regions. Yield of barley declines in all regions and that of sugarcane decreases in Terai and aggregate
whereas it increases in Mountain and Hill regions. In addition, the time trend is positive and significant for all crops studied which indicate a definite technological improvement in agriculture sector over time.

There are some important factors that must be considered while interpreting the results. The analysis is not a forecast of what will be the land value or net revenue or what crops will be grown and what will be the yield of various crops in Nepal in 2030, 2060 and 2090. The analysis is simply trying to quantify what role climate change might play in future on these aspects of agriculture. In order to make forecast about future outcomes, one would have to consider future changes in technology, prices, capital intensity, and other features of the farm that are likely to change over these time. First, the study takes the technology of each farmer as given. The importance of technology is indisputable. The irrigation facilities, the high yield varieties of seed, fertilizers and pesticides etc. are crucial determinant of agricultural output. What will happen to technology and other inputs are very important to future of Nepalese agriculture. Second important factor left out in this study is carbon fertilization effect. The cross-sectional Ricardian approach cannot measure CO\textsubscript{2} fertilization because all sites at one moment have the same CO\textsubscript{2} levels. The results of cross-sectional studies must consequently be adjusted for CO\textsubscript{2} fertilization (Mendelsohn, 2007). The experimental results suggest that yields increase on average if atmospheric CO\textsubscript{2} concentration increases. If these gains are realized in the field, the situation of Nepalese agriculture sector will be different from the estimates of this study. The study measures the consequences of changes in temperature and rainfall normals but do not count other possible changes to climate. For example, the study does not take into account possible changes in interannual rainfall and temperature caused by greenhouse gases.

The only adaptation option considered in this study is crop switching. The other adaptation measures taken by farmers for instance, adjustment in planting dates, use different crop varieties, and fertilizers, pesticides, soil and water conservation techniques are not included in this study.

### 7.2 Policy Suggestions

The adaptation captured in the cross-sectional studies reflects private adaptation by individual farmers. This is expected to occur as each farmer seeks the crops and
production methods that are best suited for the climate they live in. However, there may also be opportunities for public adaptation as a result of governmental policies and actions. The government could help by monitoring climate and keeping farmers informed up to date information of the climate as it changes. The study suggests that Nepalese government should begin to plan for climate contingencies. If certain climate outcome come to pass, what government can do to help. Government should remain prepared to help farmers adapt to the changed new circumstances. Some actions can be taken before climate changes that make agriculture sector more immune to climate change.

New crops could be developed which are more suited for a warmer, wetter and carbon-enriched circumstances so that Nepalese farmers can switch to such crops to adapt from changed climate. New crops that can tolerate changed climate may help reduce potential damages. Policies that increase farmers’ flexibility would also help allow farmers to adjust to new conditions. The government could also help develop and disseminate new farming techniques that prove successful in the field. Governments have important roles in helping agricultural sectors adapt. The government could help develop irrigation facilities. As temperatures rise, the supply of irrigation water and the availability of modern irrigation technologies could become increasingly valuable. Developing suitable technological and institutional mechanism which enhance net farm income, government can help farmers to improve their conditions. Increasing capital equipment for farming also increase income of the farmers so household can focus to increase such equipments.

The findings show that agriculture sector is likely to be adversely affected by climate change. The government should formulate policies to protect farmers and farmland and at the same time should design policies to develop non-agricultural sectors such as development of industrial area. Focusing on balanced regional development and creating new opportunities in rural areas, government can check migration of people and conversion of farmlands into settlements.

It is likely that climate change will increase variability of river runoff or stream-flow (Aggrawala et al., 2003) which pose significant impacts on agriculture. It calls for increasing the efficiency of water management. The government can make the best use of available water, by reallocating water to its best use. This includes sending
signals of the economic value of water by establishing water markets or efficient quotas or regulatory policies. Water management may also involve storing water to deal with reduced dry season flows or transferring water from water abundant to water short regions.

Another important policy message indicated by the finding is that a region specific adaptation plans are needed. In addition, government policies and investment strategy that support the provision of information on climate and adaptation measures are required for coping with climate change. Government policy should focus particularly resource poor farmers in Nepal.

7.3 Future research

Typically, temperature and rainfall are the only climate variables included in the study. However, other important climate/weather-related factors for plant growth and development are soil moisture, ambient air temperature, solar radiations and climate variance are not included in the model. The models do not include important non-climatic variables like the price variables, slope of farmland etc. The impact analysis in this study only examines outcome of changes in climate. There are many other changes that are likely to take place as well. There is likely to be new crop varieties, changes in relative prices, new management practices, new technologies and changes in water availability. The analysis does not take into account of these possible future changes and these will be important subjects of future researches. All of these changes must be taken into account to obtain an accurate forecast of future conditions. Rainfall temperature interaction terms might be important aspects that influence agriculture performance so a study that incorporates the interaction terms also is needed.

In Nepal, data are normally available in district level and NLSS also carried out the survey on the district basis. Therefore, the study used district level average climate for all observations of the district. The district specific soil variables, per capita income, road density and population density are included in the study. The climatic conditions are quite different within the district in some districts. A plot specific soil type and road density and population density and climate data in a narrower scale might give more accurate results.
The analysis does not take into account water availability and future changes in water availability. Given that more than half of Nepal’s farms are irrigated, water availability is likely to be a very important issue. This is an important subject of future research. All of these changes must be taken into account to obtain an accurate forecast of future conditions. Availability of water for irrigation determines what will transpire to agriculture. Therefore, what will be the future supply of water is an important subject of future research.

Most of the farmers adopt crop farming as well as livestock rearing; they are in most circumstances complement to each other. The crop output or by-product becomes input for livestock whereas animal dung is source of manure and they are also used for tilling land as well as draft animals. The present study concerns only with crop farming to avoid the complexity. A study that includes both crop and livestock will be more appropriate to see the full impact of climate change on agriculture sector.