Chapter 7

Summary, conclusions and implications for policy and research

This study had two main objectives. The first main objective was to measure the aggregate impact of climate change on net revenue from all agricultural production systems (crop, livestock and mixed) in Africa, and to predict future impacts under various climate scenarios. In addition to measuring economic impacts, the second objective of the study was to analyse determinants of farmers' choices between alternative adaptation measures available to African farmers. The empirical estimations were based on a cross-section survey of over 8000 farming households collected by the GEF/WB/CEEPA Africa study on climate change and agriculture. The study covered eleven countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe.

Other studies based on the GEF Project estimated the economic impacts of climate change on African agriculture. These studies, however, analysed impacts on dryland crops, irrigated crops and livestock separately. This represents an important limitation, since the choice between crop and livestock production, or their combination (mixed systems), must be considered an endogenous decision made by agricultural producers in response to varying climates and other circumstances. The decision as to what to produce and how to produce it is accordingly an important adaptation mechanism in the face of changing climate and other ecological economic circumstances. This is of special importance for Africa, where the majority of poor small-scale farmers practise mixed crop–livestock agriculture and few depend on crops or livestock only (Dixon et al., 2001).

An important contribution of this study is measuring the aggregate impact of climate change on income from all agricultural production systems (crop, livestock and mixed) in Africa, and predicting future impacts under various climate scenarios. In addition to estimating impacts on mixed crop–livestock farms, the study also measured and compared impacts on specialised crop and livestock farms. The results were contrasted with findings of other regional studies using the same data, but generating different climate response functions for crop and livestock farming separately. Another important contribution of the Ricardian cross-sectional approach used in this study is its ability to incorporate autonomous adaptation mechanisms. Such private adaptation initiatives involve adjustments that have been made by farmers in response to changes in climatic and non-climatic conditions, to increase their profits.

To achieve the first objective, the study adopted the cross-section (Ricardian) approach to measure the impact of change in climate attributes (rainfall and temperature levels) on income from all agricultural production systems (crop, livestock and mixed) in Africa, controlling for other production factors. The analyses controlled for effects of key socio-economic, technology, soil and hydrological factors influencing agricultural production.

The results show that larger farm sizes appear to have a strong positive influence on net farm revenues across all farm types, suggesting that more land allows farmers to produce more crop and livestock enterprises per farm, thus leading to more income. Further, results show that larger families are associated with higher net farm revenues across all farm types. Better access to other farm assets, such as heavy machinery like tractors, appears to strongly and positively influence net farm revenues for all farms, mixed crop–livestock farms and specialised crop farms. These results suggest that capital, land and labour serve as important production factors in African agriculture. National policies need to invest more in improving factor endowments (i.e. family size, land area and capital resources) at the disposal of farming households, in order to enhance farm performances in the face of climate change.

Better access to extension services seems to have strong positive influence on net farm revenue on all farms, mixed crop–livestock farms and specialised crop farms. Improving access to extension ensures that farmers have the information for decision making to improve their production activities. Policies aimed at improving farm-level performance need to emphasise the critical role of providing information (through extension services) to enhance farm-level decision making.

Improving access to technology such as electricity has significant potential in improving farm-level production activities and hence net revenues. For example, the use of irrigation and intensive livestock production systems (which are usually capital intensive), increases when farmers have access to technologies like electricity and other machinery. Improving access to technology such as electricity and machines is therefore important to enhance agricultural production in the face of climate change.

Results from the marginal analysis of the impacts of seasonal climate variables show that net farm revenues are in general negatively affected by warmer and dryer climates. The small-scale mixed crop and livestock system predominant in Africa is the most tolerant system, whereas specialised crop production is the most vulnerable to warming and lower rainfall. For example, a one degree increase in summer temperature resulted in net revenue losses of $98, $189 and $195 per farm for dryland: mixed crop–livestock farms, specialised crop and specialised livestock farms respectively. In all farm types, dryland farms are the worst affected by increases in warming and drying, compared to irrigated farms. Predictions of future climate impacts also indicate that mixed crop–livestock and irrigated farms are less sensitive to climate changes and will experience fewer damages, compared to highly sensitive dryland and specialised crop or livestock farms.

Generally farming systems located in dry semi-arid and arid regions (for example most southern parts of the continent) will suffer most from increases in warming and drying compared to more humid regions. This is likely because of farming systems that are based on natural rainfall (which is unreliable and inadequate) and the prevalence of mono cropping. The results confirm the negative impact of climate change on African agriculture (e.g. Kurukulasuriya & Mendelsohn, 2007a, 2007b; Seo & Mendelsohn, 2007a; Kurukulasuriya et al., 2006) with differing impacts for various systems and scales of farming. It is therefore important for Africa to enhance adaptation efforts both at the micro (farm) and macro (national) levels. Governments need to integrate adaptation strategies into national economic policies, and strengthen micro-level adaptations (such as: diversifying into multiple crops and mixed crop–livestock systems, switching from crops to livestock and from dryland to irrigation), to help farmers reduce potential damage from climate change.

These results have important policy implications, especially regarding the suitability of the increasing tendency toward large-scale mono-cropping strategies for agricultural development in Africa and other parts of the developing world, in the light of expected climate changes. Mixed crop and livestock farming and irrigation offer better adaptation options for farmers against further warming and drying predicted under various future climate scenarios.

For the second objective, the study employed a multinomial choice model to analyse determinants of farm-level climate adaptation measures in Africa. This analysis is different from the analysis carried by Maddison (2007) and all other adaptation studies, in that actual adaptation measures being taken by farmers were considered, using the same sample of African farmers, and based on farmers' perceived adaptations. This study also considered the choice between many adaptation measures simultaneously. This can be compared with studies that analysed such joint endogenous decisions in separate analyses for crop selection (Kurukulasuriya & Mendelsohn, 2007b), irrigation modelling (Kurukulasuriya & Mendelsohn, 2007c), and livestock choice (Seo & Mendelsohn, 2007b). The integrated approach of this study is very important in directing policy to influence the appropriate choice of adaptation mechanisms. Accordingly this study provides an important contribution to knowledge on the economics of climate and adaptation in the agriculture sector in Africa.

The results of the empirical analysis of determinants of adaptation choices indicate that specialised crop cultivation (mono-cropping) is the most vulnerable agricultural practice in Africa in the face of climate change. Based on these findings, there is a trade-off between economies of scale and vulnerability to climate change. Warming, especially in summer, poses the highest climate risk which tends to promote switching away from mono-cropping towards the use of irrigation, multiple cropping and integration of livestock activities. Increased precipitation reduces the probability of irrigation and will be beneficial to most African farming systems, especially in drier areas. Better access to markets, extension and credit services, technology and farm assets (such as labour, land and capital) are critical enabling factors to enhance the capacity of African farmers to adapt to climate change.

An important policy message indicated by the results might be the need for more within-country, region-specific adaptation plans depending on predicted changes in temperature and precipitation. Furthermore, government policies and investment strategies that supports the provision of and access to markets, credit, and information on climate and adaptation measures, including suitable technological and institutional mechanisms that facilitate climate adaptation, are required for coping with climate change, particularly among poor resource farmers in the dry areas of Africa.

As indicated above, the first part of the study assessed the impact of climate change on agricultural systems across Africa, and the second part evaluated the determinants of various adaptation mechanisms used by African farmers. The former applied a (cross-sectional) Ricardian approach, while the later used a multinomial logit model. The study differs from other studies in that the former objective considered the whole agricultural system and measured the impacts on a per farm basis, incorporating crop, livestock and mixed-farming enterprises, and correcting for the endogeneity problems associated with studies that focus on only crop or livestock farming. The results of the first analysis confirm the negative impact of climate change, with differing impacts for different systems and scales of farming. More important is the contribution of the latter analysis, relating to the clear categorisation of six possible adaptations options available to African farmers, and the degree of probability of choice among these options, given changes in precipitation, temperature and other socio-economic variables. These findings are very important in terms of directing policy to influence appropriate choices of adaptation mechanisms.

7.1 Limitations of the study and areas for further research

The study has some limitations that readers should bear in mind. First, combining net revenue from crop and livestock production caused some problems. Crop net revenues could be calculated for each unit of land used. The same was not possible for livestock production, where many smallholder farmers rely on communal grazing lands. This required the analyses to be on a per farm basis, and not per hectare. Furthermore, categorising farms into specialised crop, livestock and mixed crop–livestock enterprises was based on a subjective assessment of the proportion of land under crops and the number of livestock units on a farm. Although this categorisation made it possible to assess the impacts on these different systems, future studies will need to capture the type of farming system at the outset. Despite this limitation, the results of the study generally show that agricultural production, especially dryland systems, will be adversely affected by climate change, which agrees with other studies based on per hectare crop/farm revenue (see Kurukulasuriya et al., 2006; Kurukulasuriya & Mendelsohn, 2007a, 2007b; Seo & Mendelsohn, 2007a).

Another limitation of this study is the restrictive assumptions of the Ricardian cross-sectional method used for the economic analysis. The method assumes that future economic structures and behaviour will replicate the past. However, economic variables such as prices, policy (e.g. trade restrictions, subsidies and taxes) and technology that may influence net revenue vary over time. Predicted impacts based on the Ricardian cross-sectional method reflect current agricultural policies, and fail to account for future policy and other structural economic changes. Further, the model fails to account for spatial and temporal variability in climate variables (temperature and precipitation). Future variations in climate variables may not follow the same past patterns, and variations in climate across space are not necessarily the same as changes over time.

The challenge for future research is to correct for the restrictive assumptions of the cross-sectional method. This analysis was based on cross-sectional data and assumed that prices remain constant. However, welfare calculations based on such an assumption underestimate damages and overestimate benefits as they omit consumer surplus (Cline, 1996). For example, if large and widespread changes in climate result in long-term sustained changes in crop prices, the Ricardian estimates would be inaccurate and the resulting price changes would determine the magnitude and direction of error (Schimmelpfenning et al., 1996). Estimations that fail to take price changes and other factors into account will produce biased estimates of impacts of climate change. Policy recommendations based on such results would be inaccurate and might lead to misdirection and mismanagement of limited resources.

However, Mendelsohn (2000) argues that it is difficult to include the effects of price changes using any method. Given that prices of most crops are determined in the world market, predictions of the likely effects of climate change on each crop would require a global model. However, global crop models are poorly calibrated, making it difficult to predict the likely impacts of the new climate on each crop. In addition, global models predict small aggregate changes on aggregate supply in the 21st century (Reilly, Hohmann & Kane, 1994; Reilly et al., 1996). Furthermore, assuming moderate aggregate changes in supply will have a relatively small bias on estimates of future impacts of climate change. The assumption of constant prices may not be a serious problem for the Ricardian approach, unless there are catastrophic changes in climate (Mendelsohn, 2000).

Furthermore, the Ricardian method fails to account for the effects of variables that do not vary across space, for example, the effects of carbon fertilization. To address this problem, although not done in this study, cross-sectional approaches can be used to provide experimental evidence of the likely impacts of higher carbon dioxide levels in the future.

Another important limitation of this study is the fact that it includes all crops in one category and all livestock types in another category. Different crop types and different animal species among livestock types are impacted differently by climate change and hence there is a need for further disaggregation. While the selection of animal and crop types was beyond the scope of this study, given the broad scale of the analysis conducted, it is recommended, as a second step, to conduct more crop and animal type-specific analyses. This is necessary since farm-level adaptation is conditioned by local circumstances and the specifics of the available options for various agricultural activities.

There are other adaptation options available to farmers that are not considered in the groupings considered in this study. For instance, under the above combinations of adaptation measures farmers may vary planting dates, use different crop varieties, and implement fertilizers, pesticides, soil and water conservation techniques, and insurance measures. Considering all these options however, would lead to a very large number of factorial combinations that would be difficult to analyse within one empirical model. Nevertheless, some of these factors measured by the survey were included as explanatory variables in the empirical analyses that were conducted (e.g. technology factors).