ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/222015072

Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints

Article *in* Environmental Science & Policy · June 2009

DOI: 10.1016/j.envsci.2008.11.002

CITATIONS
298

READS
3,964

4 authors, including:

Elizabeth Bryan
Consultative Group on International Agricult…

29 PUBLICATIONS **678** CITATIONS

SEE PROFILE

Glwadys A. Gbetibouo
Stanford University

9 PUBLICATIONS **928** CITATIONS

SEE PROFILE

Claudia Ringler
International Food Policy Research Institute

213 PUBLICATIONS **4,648** CITATIONS

SEE PROFILE

All content following this page was uploaded by Elizabeth Bryan on 19 March 2017.

The user has requested enhancement of the downloaded file. All in-text references underlined in blue are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

Provided for non-commercial research and education use.
Not for reproduction, distribution or commercial use.

This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright

Author's personal copy

ENVIRONMENTAL SCIENCE & POLICY 12 (2009) 413–426

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Adaptation to climate change in Ethiopia and South Africa: options and constraints

Elizabeth Bryan [a,*], *Temesgen T. Deressa* [b], *Glwadys A. Gbetibouo* [b], *Claudia Ringler* [a]

[a] *International Food Policy Research Institute, 2033 K Street NW, Washington, DC 20006, USA*
[b] *Center for Environmental Economics and Policy in Africa, Agricultural Annex, University of Pretoria, Pretoria, South Africa*

ARTICLE INFO

Published on line 4 January 2009

Keywords:
Climate change
Adaptation
Ethiopia
South Africa
Perceptions

ABSTRACT

Climate change is expected to adversely affect agricultural production in Africa. Because agricultural production remains the main source of income for most rural communities in the region, adaptation of the agricultural sector is imperative to protect the livelihoods of the poor and to ensure food security. A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation strategies for the agricultural sector. Using data from a survey of 1800 farm households in South Africa and Ethiopia, this study presents the adaptation strategies used by farmers in both countries and analyzes the factors influencing the decision to adapt. We find that the most common adaptation strategies include: use of different crops or crop varieties, planting trees, soil conservation, changing planting dates, and irrigation. However, despite having perceived changes in temperature and rainfall, a large percentage of farmers did not make any adjustments to their farming practices. The main barriers to adaptation cited by farmers were lack of access to credit in South Africa and lack of access to land, information, and credit in Ethiopia. A probit model is used to examine the factors influencing farmers' decision to adapt to perceived climate changes. Factors influencing farmers' decision to adapt include wealth, and access to extension, credit, and climate information in Ethiopia; and wealth, government farm support, and access to fertile land and credit in South Africa. Using a pooled dataset, an analysis of the factors affecting the decision to adapt to perceived climate change across both countries reveals that farmers were more likely to adapt if they had access to extension, credit, and land. Food aid, extension services, and information on climate change were found to facilitate adaptation among the poorest farmers. We conclude that policy-makers must create an enabling environment to support adaptation by increasing access to information, credit and markets, and make a particular effort to reach small-scale subsistence farmers, with limited resources to confront climate change.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

Numerous studies have shown that atmospheric concentrations of greenhouse gases (GHG) are increasing as a result of human activity. Many scientists agree that some climate change is inevitable even if the international community would exert its best effort to mitigate GHG emissions. Poor countries, which rely heavily on agricultural production, are expected to be most vulnerable to climate change and climate variability. The IPCC (2007) projects that in Sub-Saharan

* *Corresponding author*. Tel.: +1 202 862 5605.
E-mail address: e.bryan@cgiar.org (E. Bryan).
1462-9011/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envsci.2008.11.002

Author's personal copy

Africa, warming is expected to be greater than the global average and in parts of the region rainfall will decline. Even in East Africa, where most climate change models predict increased rainfall due to climate change, recent research suggests that local circulation effects will result in decreased precipitation instead (Funk et al., 2008). These anticipated climate changes pose great threats to food and water security, public health, natural resources, and biodiversity (McCarthy et al., 2001).

Because agricultural production remains the main source of income for most rural communities, adaptation of the agricultural sector to the adverse effects of climate change will be imperative to protect the livelihoods of the poor and to ensure food security. Adaptation can greatly reduce vulnerability to climate change by making rural communities better able to adjust to climate change and variability, moderating potential damages, and helping them cope with adverse consequences (IPCC, 2001). A better understanding of how farmers' perceive climate change, ongoing adaptation measures, and the factors influencing the decision to adapt farming practices is needed to craft policies and programs aimed at promoting successful adaptation of the agricultural sector. Adaptation will require the involvement of multiple stakeholders, including policymakers, extension agents, NGOs, researchers, communities, and farmers.

Using data from a survey of 1800 farm households in South Africa and Ethiopia, this study examines farmers' perceptions of climate change, the extent of adaptation, barriers to adaptation, and the factors influencing adaptation and adaptation choices. The paper is organized as follows. Section 2 reviews the literature on adaptation to climate change and lays out the analytical framework for analysis. Section 3 describes the dataset and analyzes farmers' perceptions of climate change, the adaptations taken by farmers, the constraints to adaptation, and the characteristics of the farmers in each country. This section explores questions regarding how farmers actually perceive climate change and what motivates adaptation. Section 4 presents the methodology used to quantitatively analyze the factors influencing farmers' decisions to change their farming practices. The factors shown to have an influence on farm-level adaptation based on the probit estimations are presented in Section 5. This section explores the decision to adapt across and within both countries, and by the economic position of the household, defined by income terciles. Section 6 concludes with recommendations for policymakers.

2. Literature review

Agricultural adaptation to climate change is a complex, multi-dimensional, and multi-scale process that takes on a number of forms (Bryant et al., 2000). Bryant et al. (2000) identify four main components of adaptation: (1) the characteristics of the stress, (2) the characteristics of the system, including the cultural, economic, political, institutional and biophysical environment, (3) multiple scales, and (4) adaptive responses.

The first component, characteristics of the stress, refers to the stimulus to which actors and systems respond. These include climate signals (climate change and variability) as well as other drivers such as economic conditions, population growth, and government policies. One important question that arises in the literature is whether farmers adapt their behavior in response to short-term climate variability or long-term climate change (Smit et al., 1996; Burton, 1997; Bryant et al., 2000; Thomas et al., 2007). Some argue that adaptation to short-term climate variability may facilitate adaptation to long-term climate changes (Burton, 1997). However, some adaptations taken in response to short-term climate variability, which could be classified as coping responses, may not be well suited for or could increase vulnerability to long-term climate change (Smithers and Smit, 1997; Ziervogel et al., 2008). Such "maladaptations" may serve short-term goals, but come with future costs to society (Smithers and Smit, 1997). Thus, there is the need to anticipate long-term changes and make the appropriate adjustments in addition to coping with current climate conditions. This strategic adaptation should involve government intervention to promote and guide adaptation of the agricultural system (Smithers and Smit, 1997).

The system characteristics component refers the conditions of the agricultural system including its sensitivity, resilience, vulnerability, adaptive capacity, and other factors influencing its response to stressors (Smithers and Smit, 1997; Bryant et al., 2000). Other factors include the socioeconomic, cultural, political, and institutional characteristics, which can either facilitate or hinder the adaptation process. The third component refers to the multiple scales at which adaptation occurs. Climate impacts, adaptive capacity, and adaptation responses differ across multiple scales from the plot and farm levels to the country and international levels. Therefore, analyzing the adaptive capacity of a system and appropriate adaptation responses should take into account the scale of analysis (Vincent, 2007).

Numerous studies have identified, classified, and assessed adaptation responses, the fourth component in this framework (Burton, 1997; Smithers and Smit, 1997; Bryant et al., 2000; Dolan et al., 2001; Smit and Skinner, 2002; Svendsen, 2008). Responses to climate change can be either reactive or proactive (Smithers and Smit, 1997; Bryant et al., 2000). Adaptive responses can also be classified according to other characteristics including their timing with respect to the climate stress; duration (short- or long-term); form/type (technological developments, government programs and insurance, farm production practice, and farm financial management); and effect (enhanced stability or resilience) (Smithers and Smit, 1997; Smit and Skinner, 2002).

The nature of the response depends on the other components of adaptation discussed above: the degree of exposure to and nature of the stress, the properties of the system exposed to stress, and the scale and magnitude of the event (Smithers and Smit, 1997). Burton (1997) argues that willingness to adapt to climate change and variability depends on experience, time horizon, and the risk tolerance of individual decision-makers. Risk denial has been documented with respect to climate hazards—as the likelihood and frequency of extreme events increases due to climate change, adaptation can be expected to increase as well.

A number of studies look particularly at the factors that influence farmers' decision to adapt to climate change at the

Author's personal copy

farm level (Granjon, 1999; Roncoli et al., 2002; Hansen et al., 2004; Vogel and O'Brien, 2006; Ziervogel et al., 2005). These studies examine farmers' perceptions, use of information, and other factors influencing the decision-making process. The literature suggests that farmers' perceptions of climate change and their behavioral responses may be more related to recent climate events or trends as opposed to long-term changes in average conditions (Smit et al., 1997; Granjon, 1999 in Bryant et al., 2000; Thomas et al., 2007). Moreover, many studies stress the importance of local knowledge in decision-making regarding climate risk (Roncoli et al., 2001, 2002; Vogel and O'Brien, 2006; Thomas et al., 2007). That is, farmers base their decision to adapt their farming practices not only on changes in average conditions, but on a number of other climate factors observed through personal experience such as extreme events; rainfall frequency, timing, and intensity; and early or late frosts. (Smithers and Smit, 1997; Roncoli et al., 2002; Vogel and O'Brien, 2006; Thomas et al., 2007).

Examining the role of forecast climate information in decision-making, Hansen et al. (2004) suggest that information derived from personal experience and information from external description yield different choice results under conditions of climate risk and uncertainty—decisions based on personal experience are likely to give greater weight to recent events. Ziervogel et al. (2005) find that the use of accurate climate forecasts can improve household well-being while poor forecast information can actually be harmful to poor farmers. In addition, the ability to respond to climate forecasts and the benefits obtained from their use are determined by a number of factors including the policy and institutional environment and the socio-economic position of the household (Ziervogel et al., 2005; Vogel and O'Brien, 2006). Given the potential for rural climate information to support adaptation and manage climate risk, there is a need to make climate information more accurate, accessible, and useful for farmers (Roncoli et al., 2002; Ziervogel et al., 2005; Hansen et al., 2007). Promoting the use of climate information for adaptation among the poorest farmers also requires resources needed to implement adaptation options (Vogel and O'Brien, 2006).

Many studies underscore the importance of formal and informal institutions and social relationships in facilitating or hindering adaptation to climate change (Agarwal, 2008; Agarwal and Perrin, 2008; Isham, 2002; Eakin, 2005). Many studies describe the ways in which institutions influence and shape adaptation as well as climate vulnerability: they structure the distribution of climate impacts, they shape the ability of individual actors to respond to climate change and the options they choose, and they deliver and govern access to external resources to facilitate adaptation (Adger, 2000; Agarwal, 2008; Agarwal and Perrin, 2008). These studies also highlight the potential for rural institutions to strengthen adaptive capacity and facilitate local level adaptation to climate change (Adger, 2000; Agarwal, 2008; Agarwal and Perrin, 2008). For instance, extension services have the potential to influence farmers' decision to change their farming practices in response to climate change (Maddison, 2007; Nhemachena and Hassan, 2007).

Based on case studies conducted in Mexico, Eakin (2003, 2005) argues that institutional change, such as economic restructuring, influences adaptive capacity and plays an even more prominent role in determining farmers' livelihood strategies than climatic risk. Similarly, Adger (2000) found that Vietnam's transition from state central planning increased social vulnerability to climate change by decreasing collective action for risk management by state institutions. This led to the emergence of civil institutions to mediate vulnerability to environmental change (Adger, 2000). Social networks and social capital make it possible for individuals and communities to organize collectively to manage climate risks (Adger, 2003; Pelling and High, 2005). Examples of how social networks can facilitate adaptation include providing informal sources of credit, and spreading information about climate change and appropriate adaptations.

A few studies also make use of household datasets to empirically examine the factors influencing adaptation. These studies of farm-level adaptation confirm that farmers respond not only to climate stimuli but a number of other factors as well (Smit et al., 1996; Brklacich et al., 1997; Bryant et al., 2000; Bradshaw et al., 2004; Belliveau et al., 2006; Maddison, 2007; Nhemachena and Hassan, 2007). Therefore, farm-level changes that might be expected given a certain climate signal may not actually occur due to other intervening factors, such as personal characteristics, economic conditions, and the policy environment (Bradshaw et al., 2004). Using data from over 15,000 Canadian prairie farms, the authors find that while crop diversification would reduce risks from climate change and variability, farmers in the region are actually becoming more specialized given economic considerations, such as the high start-up costs and implications for achieving economies of scale (Bradshaw et al., 2004).

Smit et al. (1996) find that some farmers in southwestern Ontario adopted short-term managerial adjustments or more strategic adaptations in response to having experienced recent dry years, while most farmers reported no purposeful response. The propensity to respond was related to farmers' perceptions of dry-year frequencies, indicating that the strength of the climate signal influences adaptation. The authors also indicate that the impact of climate changes and variations cannot be understood without considering the role of other economic policy and environmental forces that not only influence how the climate signals are felt, but also have a direct impact farm-level decisions. Similarly, Brklacich et al. (1997) find that despite having perceived climate changes, Canadian farmers did not adapt their farming practices. The lack of response was attributed to built in resilience of the agriculture system and declining relative importance of climate in relation to other factors influencing farm-level decision-making (Brklacich et al., 1997).

A study of Canadian farmers by Bryant et al. (2000) shows that farmers' responses vary when faced with the same climate stimuli, even within the same geographic area, given different agricultural systems and markets systems in which farmers operate as well as different individual characteristics and contexts such as personal managerial style and entrepreneurial capacity and family circumstances. Supporting the notion that personal characteristics and conditions influence adaptation, several studies find that farming experience, socioeconomic position, and access to resources, credit, and extension services increase the probability of uptake of

Author's personal copy

adaptation measures to climate change (Maddison, 2007; Nhemachena and Hassan, 2007). Furthermore, the nature of farmers' response to climate change and variability also depends on the socioeconomic position of the household—poor farmers are likely to take measures to ensure their survival while wealthier farmers make decisions to maximize profits (Ziervogel et al., 2006).

The literature on technology adoption also offers some important insights into the factors influencing farmers' decision-making process. Although agricultural adaptation involves far more than adopting a new technology, introducing new technology certainly plays a role in adaptation at the farm-level. This literature reveals that a number of individual, household and farm characteristics, and institutional (market, policy, social) factors influence farmers' decisions. Higher levels of education are associated with access to information on improved technologies and the adoption of improved technologies (Norris and Batie, 1987; Igoden et al., 1990; Lin, 1991). Some studies indicate that larger families may enable the household to accomplish a variety of agricultural tasks given fewer household labor shortages (Croppenstedt et al., 2003; Nhemachena and Hassan, 2007). Studies also tend to agree that households with higher income and greater assets will be more likely to adopt new farming technologies, given greater access to information and financial resources (Franzel, 1999; Knowler and Bradshaw, 2007).

Gender of the head of the household is also considered to influence the uptake of new technologies (Asfaw and Admassie, 2004; Tenge et al., 2004; Nhemachena and Hassan, 2007). However, depending on the context, studies differ on whether male or female headed households are more likely to adopt new technologies. Farming experience and age also appear to be significant determinants of technology adoption, although the direction of the effect varies across studies. Studies in Ethiopia have shown a positive relationship between number of years of experience in agriculture and the adoption of improved agricultural technologies (Kebede et al., 1990). However, a study by Shiferaw and Holden (1998) indicated a negative relationship between age and adoption of improved soil conservation practices, which suggests that older farmers may be less willing to take the risks associated with new farming practices and technologies.

3. Data

3.1. Data sources and description of the survey

The household-level data used in this study were collected as part of the project ''Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa'' implemented by the International Food Policy Research Institute, funded by the German Federal Ministry for Economic Cooperation and Development (BMZ). The survey in the Limpopo Basin, South Africa, was carried out in collaboration with the Center for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria between August and November 2005, covering the agricultural season April/May 2004 to April/May 2005. In Ethiopia, the survey was conducted during the 2004/2005-production year in the Nile Basin in collaboration with the Ethiopian Development Research Institute (EDRI).

The South Africa dataset contains 800 observations from 19 districts of 4 provinces of South Africa (Limpopo, North West, Mpumalanga, and Gauteng). The survey design aimed to capture all the diverse agricultural patterns in the basin area including farming strata, type of cultivation (dry land and irrigation), major and minor crops and livestock, and all the sub-catchment areas in each of the 5 water management areas (WMAs) located in the Limpopo River Basin. Farmers were carefully selected with the assistance from producers' associations and the National Department of Agriculture.

The Ethiopia dataset contains 1000 observations from 20 districts (woredas) in 5 regions in Ethiopia (Tigray, Amhara, Oromiya, Benishangul Gumuz, and Southern Nations Nationalities and Peoples (SNNP)). The sample districts were purposely selected to include the different attributes of the basin including traditional typology of agro-ecological zones in the country, degree of irrigation activity (percent of cultivated land), average annual rainfall, rainfall variability, and vulnerability (food aid dependent population). Peasant associations (administrative units lower that districts) were also purposely selected to include households that irrigate their farms. One peasant association was selected from every district making both the number of districts and peasant associations to be 20. Random sampling was used in selecting 50 households from each peasant administration within the 20 woredas. After cleaning the data, the pooled dataset contains a total of 1783 observations.

The survey collected data on the socioeconomic characteristics of the household; household expenditures; shocks experienced by the household; land tenure; crop and livestock production (inputs and costs); access to extension, markets and credit; perceptions of climate change; adaptation responses; and constraints to adaptation. Farmers were asked open-ended questions about whether they had noticed any long-term changes in mean temperature and rainfall, and the direction of the change. Questions about adjustments made in response to perceived changes in temperature and rainfall and the constraints to adaptation were also posed. The survey module on perceived climate change, adaptation responses and constraints, which contains the exact wording of these questions, is included in the Supplementary Material section.

3.2. Farm-level adaptation to climate change, perceptions and barriers

As the literature suggests, agricultural adaptation is a complex process involving action on a number of scales. This study is based on a dataset which looks at a specific sub-set of adaptations at the farm level. That is, this study aims to describe actual adaptations taken at the farm level and to analyze the factors that influence the decision to adapt. Farmer's adaptation strategies were ascertained by asking farmers open-ended questions about the actions they take to counteract perceived changes in temperature and rainfall. The way in which the question was phrased aimed to separate out a farmer's response to perceived long-term climate changes from their response to other stimuli (such as short-term climate variability, economic factors, policies, etc.) Farmers

Author's personal copy

were asked ''Have you noticed any long-term changes in the mean temperature/precipitation over the last 20 years?'' If that question was too difficult farmers were asked ''Has the number of hot days/rainfall days stayed the same, increased or declined over the last 20 years?'' These questions were designed to get a sense of farmers' perceptions of long-term climate change. Farmers were then asked ''What adjustments in your farming have you made to these long-term shifts in temperature/rainfall?'' This variable, which intends to capture farm-level adaptation to long-term changes in temperature and rainfall versus short-term climate variability, is used to construct the dependent variable for the analysis. We then analyze farmers' responses to determine the factors which influence their decision to adapt or not.

3.2.1. *Farmers' perceptions of climate change*

In order to adapt to climate change, farmers must first perceive that changes are taking place. The survey data show that, in both countries, a large share of farmers perceive temperature has been increasing over time, and that rainfall has been decreasing. In South Africa, 86 percent of farmers responded that temperature has increased and 79 percent of farmers noted that rainfall has declined (see Fig. 1). A few farmers reported seasonal changes in rainfall patterns (i.e. changes in the timing of rainfall) (5 percent) and others reported both decreased rainfall and seasonal changes (7 percent).

The results for Ethiopia show a significant number of farmers also observed that temperature had increased (64 percent) and that rainfall had decreased (65 percent) (see Fig. 2). Compared to South Africa, a greater number of farmers in Ethiopia reported that temperature (27 percent) and rainfall (17 percent) conditions had not changed over the 20-year period.

For the most part, farmer's perceptions of climate changes appear to be in line with actual climate data. However, there is some evidence that farmers' perceptions of climate change may not be based entirely on actual changes in climate (Deressa, 2008; Gbetibouo, forthcoming). Statistical records of actual temperature data in South Africa show that temperatures have in fact increased over the period from 1960 to 2003, with the increase mostly in summer. According to data from South African Weather Service (SAWS), over this 43-year period, temperatures increased by around 1 °C. However, in contrast to farmers' perceptions, there is no clear statistically significant trend of declining rainfall over the 1960–2003 period (SAWS). The high proportion of farmers noticing a decrease in precipitation could be explained by the fact that during the last few years (2001–2003), there was a substantial drop in the volume of precipitation. Thus, farmers' perceptions may be based more on recent, short-term trends rather than long-term changes (Gbetibouo, forthcoming). Moreover, Gbetibouo (forthcoming) finds that having access to water for irrigation decreases the likelihood that the farmer perceives climate change in South Africa. On the other hand, having access to extension services increases the likelihood of perceiving climate change (Gbetibouo, forthcoming). This suggests that perceptions are not entirely based on actual climate conditions and changes but are influenced by other factors as well.

In Ethiopia, farmers' perceptions of climate change appear to reflect actual temperature and rainfall data obtained from National Meteorological Services Agency (2001), which show an increasing trend in temperature and decreasing trend in precipitation between 1952 and 2000. According to NMSA (2001), the average annual minimum temperature over the country has been increasing by about 0.25 °C every 10 years while average annual maximum temperature has been increasing by about 0.1 °C every decade. However, while there is a decreasing trend in rainfall, which matches farmers' perceptions, this downward trend is not statistically significant. Moreover, a number of household and individual characteristics were shown to influence farmers' perceptions of climate change (Deressa, 2008). For instance, age, farm and non-farm income, and access to information and extension services all influenced the likelihood of perceiving changes in climate (Deressa, 2008). Again, this suggests that farmers' perceptions are not fully determined by actual long-term changes in climate.

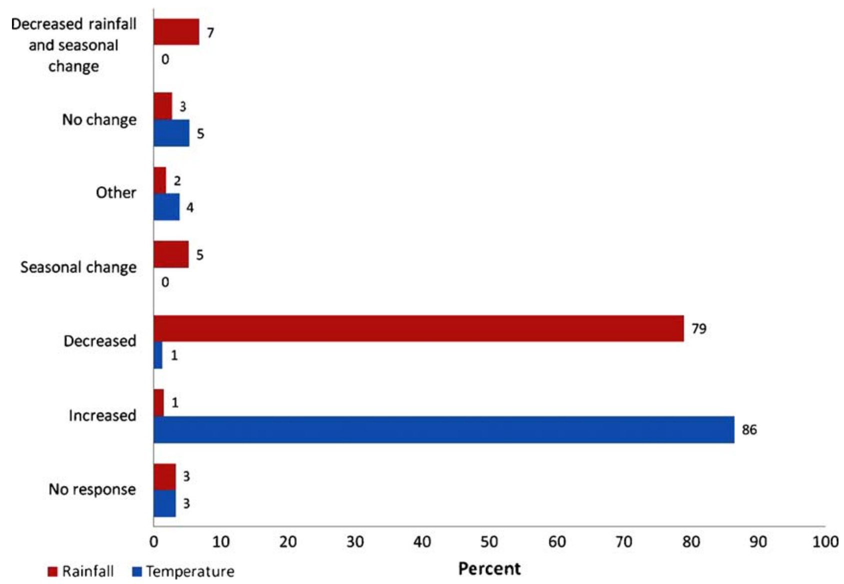

Fig. 1 – Farmers' perceptions of average temperature and rainfall changes in South Africa over the last 20 years (n = 783).

Author's personal copy

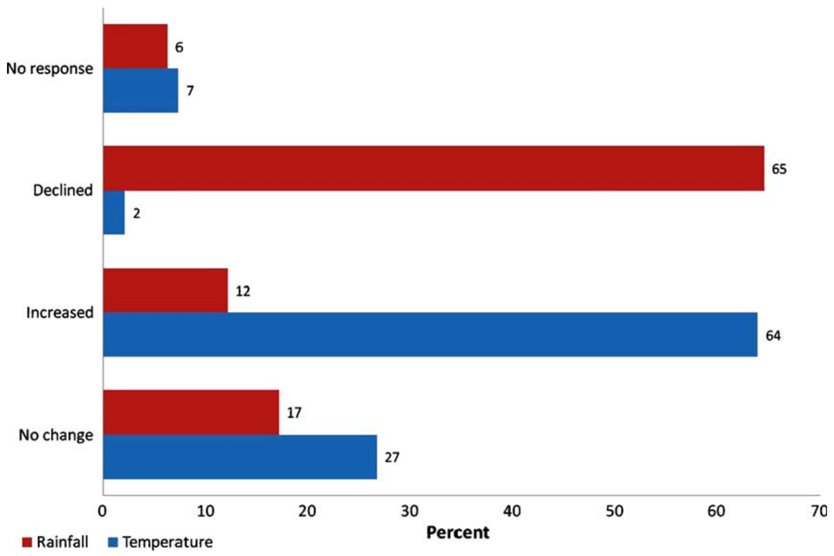

Fig. 2 – Farmers' perceptions of average temperature and rainfall changes in Ethiopia over the last 20 years (n = 1000).

Other studies confirm that while farmers report to be observing climate change, their perceptions of climate change are more related to recent experience (Smit et al., 1997; Granjon, 1999 in Bryant et al., 2000). In addition, farmers are often concerned with and adapt to climate characteristics observed through personal experience (Smithers and Smit, 1997; Roncoli et al., 2002; Vogel and O'Brien, 2006). These characteristics, such as rainfall frequency, timing, and intensity; early or late frosts; and extreme temperatures; which influence farmers' behavior are not captured in this study. Therefore, while this survey focused on measuring adaptation to changes in average climate conditions over the long run, it is clear that other climate variables and factors are important determinants of farmers' perceptions and behavior.

Moreover, Hansen et al. (2004) find that "... farmers' memory of past climatic variability may be distorted in systematic ways, reflecting wishful thinking by distortions consistent with decision goals as well as being shaped by personality characteristics and preexisting beliefs ..." Studies by Deressa (2008) and Gbetibouo (forthcoming) confirm this finding by pointing to a number of individual characteristics and factors which appear to influence farmers' perceptions of climate conditions.

More studies are needed to uncover the process by which farmers make decisions under uncertain and variable conditions and the relative importance of different risks to the decision-making process.

3.2.2. *Adaptation to climate change*

A number of studies describe the disconnect between farmers' perceptions of climate change and actual adaptation (Smit et al., 1996; Brklacich et al., 1997; Granjon, 1999). Similarly, this study shows that despite having perceived changes in temperature and rainfall, a large share of farmers in both countries did not take any adaptive measures. In Ethiopia, 73 percent and 83 percent of farmers perceived changes in temperature or rainfall, respectively, but 56 percent and 41 percent of farmers, respectively, did not undertake any adaptation measures. Overall, 37 percent of farmers in Ethiopia did not adapt to either perceived changes in rainfall or temperature. Fig. 3 presents the range of adaptation options employed by farmers in Ethiopia. Only adaptation responses mentioned by more than 1 percent of farmers are reported. Among those farmers who did adapt to climatic changes, the most common adaptation strategies include use of different crops or crop varieties, planting trees, soil conservation, changing planting dates, and irrigation. Other responses reported less frequently, such as seeking off-farm activities, migrating to urban areas, changing farming type, using new technologies, and water conservation, are included in the "other" category.

In South Africa, 95 percent of farmers perceived changes in temperature and 97 percent felt that rainfall had changed, yet 66 percent of those who responded did not adapt to perceived temperature changes and 65 percent did not adapt to perceived rainfall changes. Overall, 62 percent of farmers did not adapt to either changes in temperature or rainfall. In South Africa, common measures used by farmers include planting different crops or crop varieties, irrigation, changing planting dates, changing the amount of land under cultivation, and supplementing animal feeds. Other responses, such as crop diversification, which were reported by less than 1 percent of farmers, are included in the "other" category (Fig. 4).

Given that few farmers adjusted their farming practices in response to perceived changes in climate, it is clear that farmers' decisions are not based purely on the long-term changes in average climate conditions. Furthermore, a small number of farmers who responded that they did not perceive long-term climate changes responded that they did change their farming practices in response to climate changes (37 farmers). These findings suggest that a number of other factors influence the decision-making process as well, including changes in other climate signals, such as short-term variability, extreme weather events, and rainfall intensity, timing, duration and frequency. Other factors including

Author's personal copy

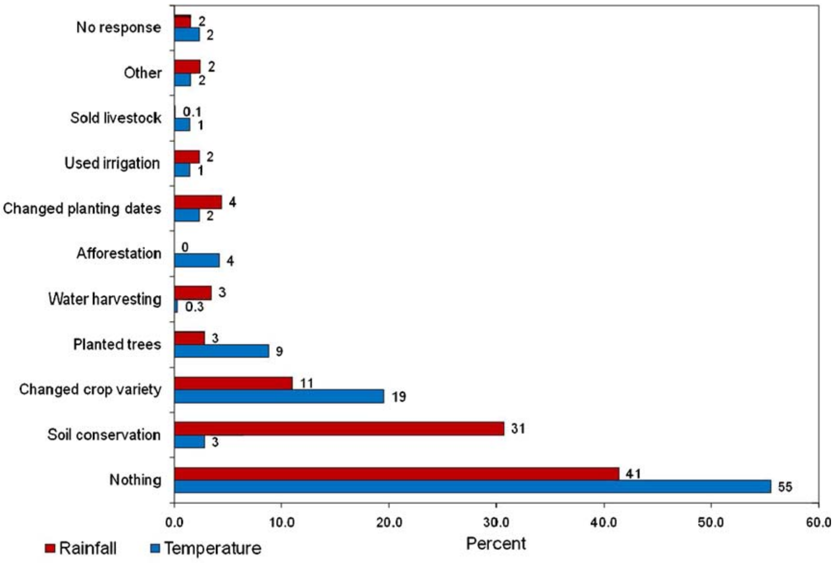

Fig. 3 – Adaptation to perceived temperature and rainfall changes in Ethiopia (*n* = 995).

the economic or institutional environment and the characteristics of the farm household also potentially influence farmers' decision-making. The factors influencing farmers' decision to adapt to perceived climate changes are further explored below in Section 5.

3.2.3. Barriers to adaptation

The literature points to many factors which affect farmers' ability to adapt to climate change. These factors include accessibility and usefulness of climate information (Roncoli et al., 2002), the policy and institutional environment (Eakin, 2003, 2005; Agarwal, 2008), and the socio-economic position of the household (Ziervogel et al., 2006), among others. The influence of many of these factors on adaptation is examined in the following sections using econometric techniques. However, in order to get a sense of the relative importance of the various factors shaping farmers decision to adapt and their adaptation response it is necessary to explore farmers own perceptions of the barriers they face.

The survey data on which this study is based contains information on which factors farmers perceive to be the most important barriers to changing their farming practices. Farmers that did not adjust their farming practices in response to perceived climate change were asked "what were the main constraints/difficulties in changing your farming ways?" While farmers referred to a number of barriers to adaptation, the most important barriers cited by farmers were shortage of land in Ethiopia (Fig. 5) and lack of access to credit/money in South Africa (Fig. 6). In South Africa, 36 percent of farmers pointed to the lack of access to credit/money as a serious constraint to adaptation. Other important barriers were: lack of access to water for irrigation (8 percent), lack of information

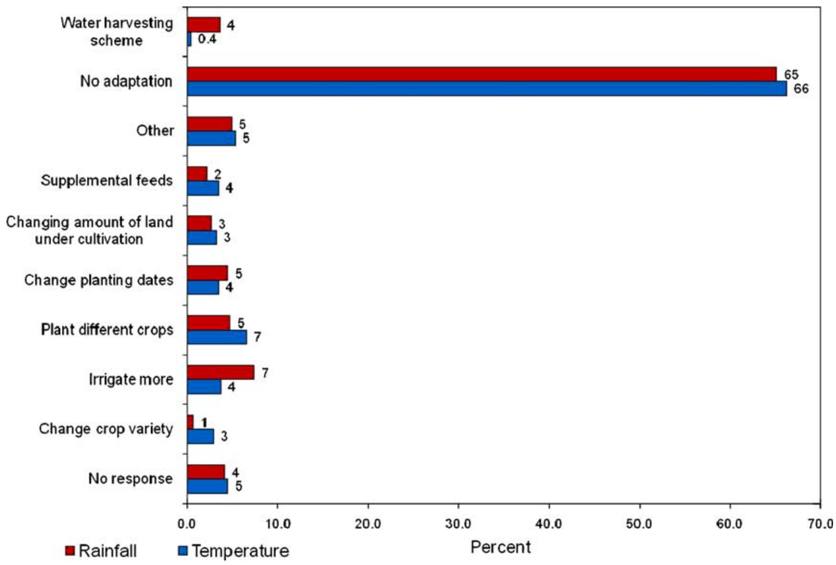

Fig. 4 – Adaptation to perceived temperature and rainfall changes in South Africa (*n* = 794).

Author's personal copy

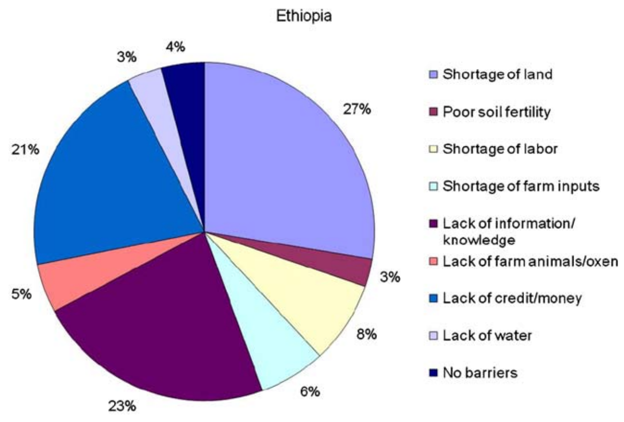

Fig. 5 – Barriers to adaptation in Ethiopia.

about climate change and appropriate adaptation responses (5 percent), lack of market access (3 percent), and insecure property rights (1 percent). In Ethiopia shortage of land was reported by 27 percent of respondents as a major constraint to adaptation, while lack of information (23 percent), lack of credit/money (21 percent), shortage of labor (8 percent), and lack of access to water for irrigation (3 percent) were also viewed as significant barriers. It is important to note that these results are responses to the survey question ''What are the main constraints/difficulties in changing your farming ways.'' However, the main barriers reported by farmers apply more to certain adaptation measures than others. For instance, shortage of land is more of a constraint to soil and water conservation but not necessarily changing crop variety. Detailed questions were also posed to farmers regarding their reasons for not adopting specific measures.

3.2.4. *Characteristics of farmers in Ethiopia and South Africa*

As suggested by the literature and the descriptive statistics presented above, farmers' decisions to adjust their farming practices are influenced by a number of factors in addition to the climate stimulus. Therefore, several variables reflecting each of these categories were selected as independent variables for the analysis of farmers' decision to adapt and their choice of adaptation options. These variables include individual and household characteristics, socioeconomic status, farm characteristics, and contextual factors (such as access to extension and credit and distance from markets). For data on the independent variables used in the analysis please refer to Table 1 in the Supplementary Material section.

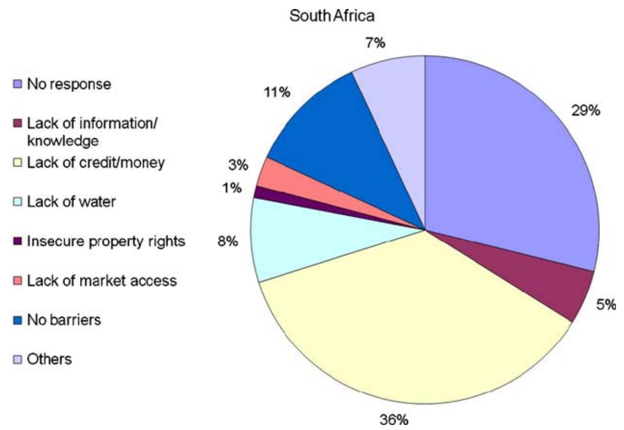

Fig. 6 – Barriers to adaptation in South Africa.

A comparison of the individual and household characteristics across the two countries reveals that farmers in South Africa tend to receive more education with an average of 7 years compared to 2 years in Ethiopia. Household size is relatively large in both countries with an average of 6 household members. In South Africa, farmers tend to be older on average (55 years) compared to Ethiopia (45 years). However, in this analysis, age is not viewed as indicator of experience because many farmers in South Africa began farming much later in life.

In terms of socioeconomic status, it is clear that farmers in South Africa are better-off economically than farmers in Ethiopia. While roughly the same percent of households have access to non-farm sources of income (26 percent in South Africa and 29 percent in Ethiopia), farmers in South Africa earn much more farm income than farmers in Ethiopia (7646 USD compared to 266 USD). A larger percentage of farmers in South Africa also have a greater asset base than farmers in Ethiopia—a larger percentage of households in South Africa own radios; cars; refrigerators; stone, brick or concrete homes; and cellular phones; and have electricity. Farm households in Ethiopia tend to receive more food aid (24 percent compared to 7 percent), while farmers in South Africa receive more farm support (21 percent compared to 5 percent). Farm support accounts for other inputs such as fodder for livestock, seeds, tools, machinery, and subsidies provided by the government.

The third set of variables, farm characteristics, shows that farmers in Ethiopia tend to farm on larger plots of land (3 ha vs. 2 ha in South Africa) and have more fertile soils. However, farmers in South Africa are more likely to have a public or private land title and more tools and farming equipment.

Variables capturing the context in which the farmers operate show that farmers in Ethiopia tend to have greater access to markets given their close proximity (6 km), while farmers in South Africa have to travel farther to reach input (34 km) and output (49 km) markets. Farmers in Ethiopia also appear to have greater access to both formal and informal sources of credit—26 percent of farmers in Ethiopia have access to formal sources of credit (from commercial banks, farmer associations/cooperatives, private money lenders, credit associations, microfinance institutions, NGOs, and the government) and 30 percent have access to informal sources of credit (from relatives, neighbors, and churches) compared to 16 percent and 8 percent in South Africa, respectively. However, the actual amount borrowed is much higher in South Africa—the average amount borrowed from both formal and informal sources in South Africa is 6322 USD compared to just 39 USD in Ethiopia. A majority of farmers in both countries have access to extension services, however, the percent of farmers with access is higher in South Africa where 78 percent receive training or advice from extension officers on crop and livestock production compared to 56 percent in Ethiopia.

Farmers' observations and actual climate data indicate that households in South Africa have been more negatively

Author's personal copy

affected by climate factors and extreme events. In South Africa, 63 percent and 33 percent of households claim to have experienced droughts and floods, respectively, in the last 5 years compared to 37 percent and 14 percent, respectively in Ethiopia. The data also show that farmers in South Africa received less rainfall on average during the growing season between 1951 and 2000 with 564 mm of rainfall compared to 972 mm in Ethiopia. However, the average amount of rainfall variability over the 1951–2000 period is the same for both countries.

4. Empirical approach

To analyze the factors which influence the decision to adapt to perceived climate changes across both countries, a discrete choice model is used. Data from both countries were pooled and the dependent variable for adaptation was created. The dependent variable is a dummy variable equal to 1 if the farmer adopted any of the adaptation options presented above in response to perceived changes in temperature or rainfall and 0 otherwise. Table 1 shows how the observations in the pooled dataset are divided across country and adaptation response.

Analysis of this dependent variable requires a binary response model. Two options for this analysis are the logit and probit models. Logit and probit models can be derived from an underlying latent variable model:

$$y^* = \beta_0 + x\beta + \varepsilon, \qquad y = 1[y^* > 0]$$

where y^* is the unobserved, or latent, variable; x denotes the set of explanatory variables, ε is the error term and $1[y^* > 0]$ defines the binary outcome. The main difference between the probit and logit models lies in the assumption of the distribution of the error term, ε. The error term is assumed to have the standard logistic distribution in the case of the logit, and the standard normal distribution in the case of the probit model. Economists tend to prefer the normality assumption of the probit model, given that several specification problems are more easily analyzed because of the properties of the normal distribution (Wooldridge, 2006). Therefore, a probit model is used to determine the factors which influence farmers' decisions to adapt to perceived climate change across South Africa and Ethiopia. A set of independent variables were used (discussed above), which were comparable across both countries.

The results are also estimated separately for each country to determine if there are differences in the factors that influence farmers' decision to adapt between the two countries. This analysis enables one to draw particular conclusions about the ways in which adaptation could be promoted within the given context of each country. To examine how farmers belonging to various income groups respond to perceived climate changes, the results are also estimated by income terciles using the pooled dataset. Marginal effects are reported for ease of interpretation. All specifications contain dummy variables to control for district-level fixed effects. Pooled specifications also contain a dummy variable to capture differences between the two countries.

Table 1 – Distribution of observations by country and adaptation response.

	South Africa	Ethiopia	Total
Adapted	296	623	919
Did not adapt	487	374	861
Total	783	997	1780

5. Results

5.1. *Pooled results*

The analysis of farmers' decision to adapt to perceived climate change across both countries shows that various socioeconomic characteristics, contextual factors, and recent extreme climate events influence farmers' decision to adapt. The results indicate that broad conclusions can be drawn about the factors influencing adaptation across countries and suggest there may be common avenues for promoting adaptation.

Table 2 presents the marginal effects - the expected change in the probability of adaptation given a unit change in an independent variable from the mean value, *ceteris paribus*. Only results that were statistically significant at the 10 percent level or greater are reported. The results show that larger households are more likely to adapt to perceived climate change. Increasing household size by one member (from the mean of 6 household members) increases the probability of adaptation by 1 percent. These results suggest that having additional household labor (i.e. husbands, extended family members, and older children) facilitates adaptation.

Table 2 – Pooled results, marginal effects reported.

Variables	Coefficient	P value
HH size	**0.012***	0.010
Radio	**0.056***	0.068
Land area (ha)	**0.016***	0.087
Land title	**0.061***	0.061
Distance to output markets (km)	**0.001****	0.030
Access to formal credit	**0.127*****	0.000
Access to extension	**0.081****	0.012
Flood in last 5 years	**0.138*****	0.000
Country	**0.585****	0.035
District fixed effects	Yes	
Obs.	1756	
Pseudo R^2	0.316	

Note: Only statistically significant coefficients are shown in the table. Variables omitted from the table include: age and education of the household head, whether the household receives food aid and farm support, whether the household owns a radio, toilet, and has electricity, whether the house is made of concrete, brick, or stone, whether the farm has fertile soil, current value of tools and equipment, distance to input markets, whether the household has access to non-farm income, informal sources of credit, and information on climate change, and whether the household has experienced a drought in the last 5 years. The full table is available in Supplementary Material.

* Significant at 10 percent probability level.

** Significant at 5 percent probability level.

*** Significant at 1 percent probability level.

Author's personal copy

The results also suggest that wealthier households are more likely to adapt to perceived climate changes. Households that own a radio and households with a larger area of land were more likely to adapt. The coefficients on many other household assets were positive, yet the results were not statistically significant. These results support other studies which find that wealthier households are better able to act quickly to offset climate risk than poorer households (Adger et al., 2001; Downing et al., 2005; Ziervogel et al., 2006). Similarly, the coefficients on food aid and farm support were also positive, but statistically insignificant. Farmers that have a public or private title to their land (as opposed to a communal or informal land rights) are 6 percent more likely to adapt. This suggests that creating stronger individual property rights would promote farm-level adaptation.

Access to rural services, such as extension and credit, also has a positive influence on adaptation. Farmers with access to extension services are 8 percent more likely to adapt to climate change and those with access to formal sources credit (from banks, NGOs, microfinance institutions, etc.) are 13 percent more likely to adapt. These results are not only highly statistically significant, but the magnitude of the effect is also rather large. These results indicate that improving market access for small-scale subsistence farmers would increase their ability to adapt to climate change. However, contrary to what one would expect, the results also show that adaptation increases with distance to output markets. This suggests that there is less of an opportunity cost for households in remote areas to adopt adaptation practices that may be labor intensive. That is, where fewer income earning opportunities are available, households in remote areas may be more willing to take up adaptation in order to reduce climate-related risk.

The coefficient on floods indicates that farmers' decision to adapt is greatly influenced by perceived extreme weather events. Those farmers that reported experiencing a flood within the last 5 years were 14 percent more likely to change their farming practices. Thus, while farmers are likely to employ coping strategies in response to shocks-coping responses reported by farmers in this survey included selling livestock, borrowing from relatives or the bank, receiving food aid, participating in food for work programs, migration, seeking off-farm employment, and reducing consumption-farmers also appear likely to take proactive measures to reduce the risk of shocks in the future. However, the coefficient of variation of rainfall between 1951 and 2000 is statistically insignificant, suggesting that farmers are not reacting to measured differences in the average amount of rainfall variability over the long-run. Rather, farmers appear to adapt to reduce the risk of future extreme weather shocks. These results also suggest that while farmers were asked about adaptations to long-term changes in average temperature and rainfall conditions, farmers' behavior depends more on short-term climate variations and extremes.

Finally, the country dummy shows that farmers in Ethiopia are more likely to adapt to perceived long-term changes in climate than farmers in South Africa. This result reflects the descriptive statistics presented above, which show that 62 percent of farmers in Ethiopia adapted to perceived climate changes while only 38 percent of farmers in South Africa adapted. These results are somewhat surprising given that Ethiopian farmers are poorer and more risk averse than South African farmers (Yesuf and Bluffstone, 2007). Moreover, the climate signal for Ethiopia is considered to be weaker (IPCC, 2007). These results indicate a greater awareness among Ethiopian farmers that the risk of not adapting is greater than the risk of adapting to climate change. As noted above, far fewer households in Ethiopia receive farm support from the government (equipment, inputs, subsidies, etc.) compared to South Africa. Given a more limited social safety net, Ethiopian farmers must take measures to reduce their vulnerability to climate change. The fact that households that experienced a shock within the past 5 years were more likely to adapt, also supports the notion that farmers act to reduce the risk of future climate shocks. Farmers are more willing to adapt when they are aware of the risks posed by extreme climate events.

We find that households that wish to reduce the risks associated with climate change and have the resources or access to resources needed to make the appropriate changes are more likely to take up adaptation. However, while we do not examine particular adaptation options in this analysis, it is important to point out that some adaptations may be risk reducing while others may be risk increasing. Poorer farmers may be less able to take strategic adaptations to reduce the risks imposed by climate change over the long run or to decrease their vulnerability to climate change by making decisions that would increase their economic position. Rather these farmers are forced to employ adaptations to cope with short-term climate variability in order to survive (Ziervogel et al., 2006), which may increase long-term risk.

The scope of the present analysis is limited in that adaptations are grouped into one dummy variable so that the decision to adapt could be compared across both study countries where adaptation strategies are different. As Bradshaw et al. (2004) point out, this type of analysis is essential to understand the likely uptake of adaptation among farmers. However, while this analysis reveals what factors induce farmers to change their behavior, it does not reveal the effectiveness of particular adaptations over the long run. Separate analyses of farmers' choice of adaptation options in Ethiopia and South Africa show that the factors influencing adaptation vary across the different adaptation measures (Deressa, 2008; Gbetibouo, forthcoming). Therefore, additional research is needed to distinguish between adaptations that are risk reducing and risk enhancing over the long run. This information would help policymakers and other stakeholders craft strategies to promote the kind of adaptation measures that will reduce risk to long-term climate change.

5.2. *Results by country*[1]

The pooled results reported above may mask the factors which influence adaptation in a specific country context. There are likely to be differences across countries not only in terms of

[1] The factors influencing farmers' choice of adaptation method are examined by Deressa (2008) and Gbetibouo (forthcoming) using multinomial logit models and this same dataset. For more detailed results on the determinants of adaptation in Ethiopia please refer to Deressa (2008) and for more detailed results for South Africa please refer to Gbetibouo (forthcoming).

Author's personal copy

the extent of adaptation but also in terms of the particular factors that influence adaptation. Therefore, the results were estimated individually for each of the study countries, using roughly the same set of explanatory variables. Given that households in Ethiopia tend to be poorer and have fewer large assets compared to South African farm households, the set of assets included in the analysis was limited to those owned by a significant percent of households in Ethiopia. Because information was available on the number of relatives in the local area in the case of Ethiopia, this variable was added as a measure of social capital. In the case of South Africa, because age is not viewed as an indicator of experience given that many farmers in South Africa began farming much later in life, the number of years farming was included as an explanatory variable. This variable was not collected in the case of Ethiopia. These results provide more insight into how policymakers in each of the countries can better promote adaptation given the particular context in which the farmers operate.

Table 3 in the Supplementary Material section presents the country-specific results. These results show that there are both similarities and differences regarding the factors that influence adaptation in South Africa and Ethiopia. Wealth, measured by the households' ownership of key assets, is shown to be an important determinant of adaptation in both countries. Households in South Africa that own cellular telephones and cars were more likely to adapt to perceived climate changes. In Ethiopia, where farmers do not tend to own cell phones or cars, radio ownership was shown to be an important factor influencing adaptation. Moreover, the current value of all farm tools and equipment is also an important determinant of adaptation in Ethiopia.

Government aid is also shown to have a positive effect on adaptation in both countries. In Ethiopia, where 24 percent of farmers surveyed receive assistance in the form of food aid, food aid is shown to increase the likelihood of adaptation by 5 percent. This finding shows that food aid relieves the consumption pressure many farm households face, enabling them to take up adaptation options. This result is supported by other studies which show that high consumption risk decreases the likelihood of technology adoption (Dercon and Christiaensen, 2007). In South Africa, where farm support is more common with 21 percent of farmers receiving this form of assistance, farm support increases the likelihood of adaptation by 12 percent.

Access to formal sources of credit is also an important determinant of adaptation in both countries. Farmers with access to credit were 11 percent more likely to adapt in South Africa and 6 percent more likely to adapt in Ethiopia. Another similarity is that farmers in both countries appear to be adapting in part in response to past experience with floods. Farmers that reported experiencing a flood in the last 5 years were 19 percent and 4 percent more likely to adapt their farming practices in South Africa and Ethiopia, respectively.

Despite many similarities between the two countries, there are also important distinctions. Having access to larger land area and fertile soils are shown to be important determinants of adaptation in South Africa. In addition, number of years farming is also significant in the case of South Africa, suggesting that farmers with more experience are more likely to change their farming practices in response to perceived climate change. In Ethiopia, access to extension services and information on climate change and appropriate adaptation responses are important, whereas these factors are not significant in South Africa.

Similarly, other studies have found that a number of factors discourage the uptake and use of climate information in the southern African region, including the type of information produced, the way in which it is presented, unequal access to information, and lack of attention to delivery processes (Vogel and O'Brien, 2006). This suggests that, in South Africa, government agencies, NGOs, extension agents, and other actors should work harder to ensure that information on climate change and appropriate adaptation responses is presented in a useful and acceptable way, enabling farmers to reduce the risks posed by climate change. Better communication and coordination between relevant actors and end users would also strengthen delivery mechanisms and increase the likelihood of use of climate information.

5.3. *Results by income tercile*

Another way to examine the differential influence of the determinants of adaptation is to divide the survey households into groups according to their income level. Therefore, the adaptation decisions of households in Ethiopia and South Africa were examined at various levels of farm income. This analysis provides policymakers with information on how to best support adaptation among different groups of farmers. In particular, the results show how policymakers can best support poor farmers, who are most vulnerable to climate impacts given limited resources to make changes in their farming practices. See Table 4 in the Supplementary Material section for the results by income tercile.

The results show that the factors influencing adaptation vary by economic position. Among the poorest farmers, food aid and the value of farm tools and equipment are shown to increase the probability adaptation. This suggests that a slight increase in wealth and well being among the poorest farmers could significantly increase adaptation by enabling them to undertake measures that require the investment of resources. Wealth also appears to enable farmers in the middle income tercile to adapt. Farmers in this income group that own radios and have more land area were more likely to take up adaptation. This suggests that farmers in this income group are somewhat constrained by lack of financial resources in their decision to adapt.

Farm support (inputs and subsidies) is shown to have a negative influence on adaptation among the poorest while those that receive farm support in the highest income tercile are more likely to adapt. This suggests that government farm support is tailored to meet the needs of wealthier farmers and while the poor are less able to use inputs and subsidies provided by the government to make the necessary changes in their farming practices. Policymakers, therefore, should carefully consider the needs of poor farmers and provide support that enables them to reduce the risks of climate change.

Access to land and property rights are important determinants of adaptation for farmers in the middle and highest income terciles. From the mean, an additional hectare of land increases the likelihood of adaptation by 6 percent among

Author's personal copy

farmers in the middle income tercile and 2 percent among farmers in the highest income tercile. In addition, having a public or private land title increases the probability of adaptation by 14 percent among farmers in the middle income tercile.

Rural services increase the likelihood of adaptation across income terciles. Access to extension services appears more important for poorer farmers—farmers with access to extension services in the lowest and middle income terciles were 10 percent and 14 percent more likely to adapt their farming practices, respectively. Credit appears to be more important for wealthier farmers. Farmers in the middle and highest income terciles with access to formal sources of credit were 15 percent more likely to adapt. Receiving information on climate change also promotes adaptation among farmers in the lowest and highest income terciles by 7 percent and 9 percent, respectively. Thus, improving and expanding the provision of rural services, particularly extension and the dissemination of climate information, appear to have positive effects on all farmers. However, the information and material support provided to farmers would have to be tailored to the particular needs of the community based on their economic position, environmental features of the area, and the expressed need of farmers.

In support of the pooled results, the results by income terciles show that farmers respond to recent climate shocks (droughts and floods) rather than differences in the amount of rainfall over time. Farmers in the lowest income tercile were 7 percent more likely to adapt if they had experienced a drought in the last 5 years while farmers in the highest income tercile were 23 percent more likely to adapt if they had experienced a flood. However, recent drought appears to have a negative effect on adaptation among farmers in the middle income tercile. For these farmers, drought had a debilitating effect, reducing the likelihood of adaptation by 11 percent. This suggests that the poorest farmers are forced to adjust their farming practices to cope with climate shocks and minimize risks from future shocks in order to survive while wealthier farmers are better equipped to deal with shocks given the financial resources at their disposal. Middle income households, on the other hand, appear to be less willing to put safeguards in place to protect their livelihoods. This may be the case, particularly if adaptation options, such as crop diversification, have a yield reducing effect—middle income farmers may be less willing to take up such measures as they are not as desperate as the poorest farmers. More research is needed to uncover the types of adaptation options taken by rich, poor, and middle income farmers.

The coefficient on the country dummy variable reveals that Ethiopian farmers in the poorest and middle income terciles were much more likely to adapt their farming practices. Again this suggests that the absence of a strong social safety net increases the vulnerability of these farmers to climate change and variability, causing them to take steps to reduce the threat to their livelihoods.

6. Conclusions

This study examined farmers' perceptions of long-term climate change, adaptation measures undertaken, and the determinants of adaptation decisions based on household surveys conducted in Ethiopia and South Africa. This analysis aimed to strengthen understanding about farmers' decision-making process to enable policymakers and other stakeholders to support adaptation to climate change at the farm-level. While agricultural adaptation to climate change involves more than farm-level changes in farming practices, farm-level adaptations are an essential component of adaptation of agricultural systems. Therefore, it is crucial to understand how the social, economic, institutional, and ecological context mediates the climate impacts and influences the adaptation response.

The results show that farm-level adaptation involves more than adopting new agricultural technologies such as improved water storage facilities, additional irrigation, and new crop varieties. Given the importance influence of having access to extension services and formal sources of credit on farmers' decision to adapt, policy-makers should extend and improve upon such services, ensuring that they reach small-scale subsistence farmers. Providing support to the poorest farmers is critically important, given that this group is the most vulnerable to long-term climate change, and least-equipped to make the changes needed to sustain their livelihoods in the face of such a threat. Addressing these market imperfections, of lack of access to information and credit, and ensuring effective targeting requires strong leadership and involvement of the government in planning for adaptation and implementing measures to facilitate adaptation at the farm level.

The results by country and income terciles suggest that strategies should also be tailored to meet the particular needs and constraints of different countries and groups of farmers. There are no one-size-fits-all strategies for promoting adaptation of the agriculture sector. In Ethiopia, the results show that raising awareness about climate change and the available adaptation options is important to encourage farmers to adapt. Other policy tools for promoting adaptation in Ethiopia include providing farm support (including tools and equipment) and supporting the poorest of the poor with food aid and other forms of social assistance.

In South Africa, policymakers should make it easier for farmers to receive land titles and have access to more fertile lands. Given the fact that very few farmers adapted to perceived climate change in South Africa and the fact that the survey found a much wider array of adaptations being taken up by farmers in South Africa, policymakers should also focus on which adaptations are most needed and make an effort to promote uptake of those options. Because receiving climate information did not increase the likelihood of adaptation in South Africa, greater efforts should be made to improve the accessibility and usefulness of information provided to farmers to facilitate their adaptation. This would involve a large public relations effort aimed at making farmers aware of the need to adapt and the options available to them. It also entails presenting climate information in a manner that is understandable and useful for farmers.

The results by income terciles show that different factors influence farmers' decision to adapt to climate change depending on their particular needs and constraints. Government aid, extension services, and information on climate change appear to facilitate adaptation among the poorest farmers while wealthier farmers are more likely to adapt given

Author's personal copy

access to land, credit and information about climate change. This analysis masks important differences in the types of adaptation options chosen by different income groups. More research is needed on the types of adaptation options that are selected by various farmers, and the long-term implications of these choices.

While this study focuses on farm-level adaptations, actions on multiple scales are needed to promote adaptation. Additional actors, such as the private sector, NGO, local institutions, such as farmers associations, and the media, should become more involved in promoting adaptation. Government investments in enhanced and expanded water control, development of better crop varieties, and improved crop management practices, such as agro-forestry also require government support to be taken up by a larger number of farmers. Ultimately, given the constraints to adaptation highlighted in this study, many farmers may turn to adaptation options outside the agriculture sector, including migration, or finding wage employment.

While the purpose of this study is to examine the ways in which policymakers can facilitate farm-level adaptations, it is equally important to determine which adaptations are most effective at increasing farmers' resilience in a particular context. This will require more spatially disaggregated projections of climate change impacts and more information on the long-term benefits and risks of various adaptation options.

Acknowledgements

This work is supported by the Federal Ministry for Economic Cooperation and Development, Germany under the project ''Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa,'' and forms part of the CGIAR Challenge Program on Water and Food.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.envsci.2008.11.002.

REFERENCES

Adger, W.N., 2000. Institutional adaptation to environmental risk under the Transition in Vietnam. Annals of the Association of American Geographers 90 (4), 738–758.

Adger, W.N., Kelly, P.M., Ninh, N.H., 2001. Living with Environmental Change: Social Resilience, Adaptation and Vulnerability in Vietnam. Routledge, London, UK.

Adger, W.N., 2003. Social capital, collective action, and adaptation to climate change. Economic Geography 79, 387–404.

Agarwal, A., 2008.In: The role of local institutions in adaptation to climate change, Paper Prepared for a workshop on ''Social Dimensions of Climate Change'', organized by the Social Development Department, The World Bank, Washington, DC, March 5–6, 2008.

Agarwal, A., Perrin, N., 2008. Climate adaptation, local institutions, and rural livelihoods. IFRI Working Paper, W081-6. International Forestry Resources and Institutions Program, University of Michigan.

Asfaw, A., Admassie, A., 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agricultural Economics 30 (3), 215–228.

Belliveau, S., Bradshaw, B., Smit, B., Reid, S., Ramsey, D., Tarleton, M., Sawyer, B., 2006. Farm-level adaptation to multiple risks: climate change and other concerns. Occasional Paper, 27. University of Guelph, Canada.

Bradshaw, B., Dolan, H., Smit, B., 2004. Farm-level adaptation to climatic variability and change: crop diversification in the Canadian Prairies. Climatic Change 67, 119–141.

Brklacich, M., McNabb, D., Bryant, C., Dumanski, I., 1997. Adaptability of agriculture systems to global climatic change: a Renfrew County, Ontario, Canada Pilot Study. In: Ilbery, B., Chiotti, Q., Richard, T. (Eds.), Agricultural Restructuring and Sustainability: A Geographical Perspective. CAB International, Wallingford, CT.

Bryant, R.C., Smit, B., Brklacich, M., Johnston, R.T., Smithers, J., Chiotti, Q., Singh, B., 2000. Adaptation in Canadian agriculture to climatic variability and change. Climatic Change 45, 181–201.

Burton, I., 1997. Vulnerability and adaptive response in the context of climate and climate change. Climatic Change 36, 185–196.

Croppenstedt, A., Demeke, M., Meschi, M.M., 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics 7 (1), 58–70.

Dercon, S., Christiaensen, L., 2007. Consumption risk, technology adoption, and poverty traps: evidence from Ethiopia. World Bank Policy Research Working Paper, 4257. Available at: SSRN: http://ssrn.com/abstract=995078.

Deressa, T.T., 2008. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. IFPRI Discussion Paper, 798. International Food Policy Research Institute (IFPRI), Washington, DC, 36 pp.

Dolan, A.H., Smit, B., Skinner, M.W., Bradshaw, B., Bryant, C.R., 2001. Adaptation to Climate Change in Agriculture: Evaluation of Options. Department of Geography Occasional Paper, 26.

Downing, T.E., Patwardhan, A., Klein, R.J.T., Mukhala, E., Stephan, L., Winograd, M., Ziervogel, G., 2005. Assessing vulnerability for climate adaptation. In: Lim, B., Spanger-Siegfried, E., Burton, I., Malone, E., Huq, S. (Eds.), Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge University Press, Cambridge.

Eakin, H., 2003. Rural Responses to Climatic Variability and Institutional Change in Central Mexico. University of California at San Diego, Center for U.S.-Mexican Studies 1004, Center for U.S.-Mexican Studies, UC San Diego.

Eakin, H., 2005. Institutional change, climate risk, and rural vulnerability: cases from Central Mexico. World Development 33 (11), 1923–1938.

Funk, C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M., Hoell, A., 2008. Warming of the Indian Ocean threatens Eastern and Southern African food security but could be mitigated by agricultural development. PNAS 105 (32), 11081–11086.

Franzel, S., 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. Agroforestry Systems 47 (1–3), 305–321.

Gbetibouo, G.A. Understanding farmers' perceptions and adaptations to climate change and variability: the case of the Limpopo Basin, South Africa. IFPRI Discussion Paper, forthcoming.

Author's personal copy

Granjon, D., 1999. Ennquêtes et resultants sur l'adaptation de l'agriculture aux different types de stress: le cas de la zone de Napierville, Research Report Submitted to Singh, B. and Bryant, C.R. as Part of a Research Contract with Atmospheric Environment Services, Environment Canada, Downsview.
Hansen, J., Baethgen, W., Osgood, D., Ceccato, P., Ngugi, R.K., 2007. Innovations in climate risk management: Protecting and building rural livelihoods in a variable and changing climate. Journal of Semi-Arid Tropical Agricultural Research 4 (1).
Hansen, J., Marx, S., Weber, E., 2004. The role of climate perceptions, expectations, and forecasts in farmer decision making: the Argentine Pampas and South Florida. Final Report of an IRI Seed Grant Project. International Research Institute for Climate Prediction (IRI), The Earth Institute at Columbia University.
Igoden, C., Ohoji, P., Ekpare, J., 1990. Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. Agricultural Administration and Extension 29 (2), 149–156.
Intergovernmental Panel on Climate Change (IPCC), 2001. Climate change 2001: impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report of the IPCC.
Intergovernmental Panel on Climate Change (IPCC), 2007. The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.
Isham, J., 2002. The effect of social capital on fertiliser adoption: evidence from Rural Tanzania. Journal of African Economies 11, 39–60.
Kebede, Y., Kunjal, K., Coffin, G., 1990. Adoption of new technologies in Ethiopian agriculture: the case of Tegulet-Bulga District, Shewa Province. Agricultural Economics 4, 27–43.
Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32 (1), 25–48.
Lin, J., 1991. Education and innovation adoption in agriculture: evidence from hybrid rice in China. American Journal of Agricultural Economics 73 (3), 713–723.
Maddison, D., 2007. The perception of and adaptation to climate change in Africa. World Bank Policy Research Working Paper, 4308. The World Bank, Washington, DC.
McCarthy, J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, C., 2001. Climate change 2001: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.
National Meteorological Services Agency, 2001. Available at: http://www.ethiomet.gov.et/index.php?Page_No=1.1&item=5&PHPSESSID=c5db0a38883fe500388c8b3a20c469ee.
Nhemachena, C., Hassan, R.M., 2007. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper, 714. International Food Policy Research Institute (IFPRI), Washington, DC, 30 pp.
Norris, E., Batie, S., 1987. Virginia farmers' soil conservation decisions: an application of Tobit analysis. Southern Journal of Agricultural Economics 19 (1), 89–97.
Pelling, M., High, C., 2005. Understanding adaptation: what can social capital offer assessments of adaptive capacity? Global Environmental Change 15A (4), 308–319.
Roncoli, C., Ingram, K., Kirshen, P., 2001. The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso. Climate Research 19 (2), 119–132.
Roncoli, C., Ingram, K., Kirshen, P., 2002. Reading the rains: local knowledge and rainfall forecasting among farmers of Burkina Faso. Society and Natural Resources 15, 411–430.
Shiferaw, B., Holden, S., 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: case study in Andit Tid, North Shewa. Agricultural Economics 27 (4), 739–752.
Smit, B., Skinner, M.W., 2002. Adaptations options in Agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change 7, 85–114.
Smit, B., Blain, R., Keddie, P., 1997. Corn hybrid selection and climatic variability: gambling with nature? Canadian Geographer 42 (4), 429–438.
Smit, B., McNabb, D., Smithers, J., 1996. Agricultural adaptation to climatic variation. Climatic Change 33, 7–29.
Smithers, J., Smit, B., 1997. Human adaptation to climatic variability and change. Global Environmental Change 7 (3), 129–146.
South African Weather Service (SAWS). Available at: http://www.weathersa.co.za/.
Svendsen, M., 2008. Adaptation to Hydrological impacts of global climate change in developing countries. Study Prepared for the Climate Protection Programme for Developing Countries. Environment and Infrastructure Division, GTZ.
Tenge, A.J., de Graaff, J., Hella, J.P., 2004. Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. Land Degradation and Development 15 (2), 99–114.
Thomas, D.S.G., Twyman, C., Osbahr, H., Hewitson, B., 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. Climatic Change 83, 301–322.
Vincent, K., 2007. Uncertainty in adaptive capacity and the importance of scale. Global Environmental Change 17 (1), 12–24.
Vogel, C., O'Brien, K., 2006. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. Climate Research 33, 111–122.
Wooldridge, J.M., 2006. Introductory econometrics: a modern approach, Third Edition. Thomson South-Western.
Yesuf, M., Bluffstone, R., 2007. Risk aversion in low income countries: experimental evidence from Ethiopia, IFPRI Discussion Paper, 715.
Ziervogel, G., Bithell, M., Washington, R., Downing, T., 2005. Agent-based social simulation: a method for assessing the impact of seasonal climate forecasts among smallholder farmers. Agricultural Systems 83 (1), 1–26.
Ziervogel, G., Bharwani, S., Downing, T.E., 2006. Adapting to climate variability: pumpkins, people and pumps. Natural Resource Forum 30, 294–305.
Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M., Smith, B., 2008. Climate change and adaptation in African agriculture. Report Prepared for the Rockefeller Foundation by the Stockholm Environment Institute.

Elizabeth Bryan is a senior research assistant in the Environment and Production Technology Division of the International Food Policy Research Institute.

Temesgen T. Deressa is a PhD student at the Center for Environmental Economics and Policy in Africa, University of Pretoria.

Glwadys A. Gbetibouo is a PhD student at the Center for Environmental Economics and Policy in Africa, University of Pretoria.

Claudia Ringler is a senior research fellow in the Environment and Production Technology Division of the International Food Policy Research Institute.

View publication stats