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UNDERSTANDING CLIMATE CHANGE ADAPTATION MECHANISMS IN AGRICULTURE IN SUB-SAHARAN AFRICA: A REVIEW PAPER

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ABSTRACT

Agricultural sectors in Sub-Saharan African, which have economies largely based on weather-sensitive agricultural production, are particularly vulnerable to climate change. This vulnerability has been demonstrated by the devastating effects of recent flooding and the various prolonged droughts of the twenty-first century. Thus, for many Sub Saharan African countries that are highly vulnerable to the effects of climate change, identifying different adaptation options to climatic variation is crucial in designing appropriate coping strategies. Adaptation at the farmer level requires three basic steps: detecting a shift in one's external environment, determining that it would favor a change in behavior, and undertaking that change. Therefore, understanding these events is important for decision making for climate change adaptation investment priorities which could yield high returns.

KEYWORDS: Climate Change, Adaptation Mechanisms, Agriculture, Sub-Saharan Africa

INTRODUCTION

Three out of four poor people in Sub-Saharan Africa live in rural areas, and most of them depend directly or indirectly on agriculture for their livelihoods. In the twenty-first century, agriculture remains a fundamental tool for lifting them out of poverty, as has been highlighted in the World Development Report 2008 (World Bank 2008). Agricultural sectors in Sub-Saharan African, which have economies largely based on weather-sensitive agricultural production, are particularly vulnerable to climate change (Mendelsohn 2000; IPCC 2007; Kurukulasuriya et al. 2006).This vulnerability has been demonstrated by the devastating effects of recent flooding and the various prolonged droughts of the twenty-first century. Thus, for many Sub Saharan African countries that are highly vulnerable to the effects of climate change, identifying different adaptation options to climatic variation is crucial in designing appropriate coping strategies to climate change in low-income countries, where adaptive capacity is perceived to be low (IPCC 2007; Di Falco et al. 2011).

It is now considered 'unequivocal' that the global climate is changing, principally as a result of burning fossil fuels and agriculture related land use change which contributes to the greenhouse effect. According to the IPCC Fourth Assessment Report (IPCC, 2007), the temperature of the earth's surface is expected to increase between 2 and 5 degrees Celsius (ºC) over the next century, assuming greenhouse gas emissions continue to rise at current rates. This is gradually warming the planet and having a number of knock-on effects in terms of changing rainfall patterns, rising sea levels, and more unpredictable weather events (Anyadike, 2009; Ozor, 2009).

Climate change is expected to lead to more frequent, more extreme or more unpredictable occurrence of existing natural hazards (such as temporal distribution of rainfall, floods, droughts, hurricanes, and cyclones). It can also result in the emergence of new hazards which did not occur previously in a particular locality, such as new types of pest outbreak or disease resulting from rising temperature (Ifeanyi-obi et al. 2012). Extreme rainfall events, drought events, and warming temperatures have all been shown to increase the incidence of diarrheal disease, often significantly (Checkley et al. 2000; McMichael et al. 2006; Confalonieri et al. 2007). Warming temperatures will likely also expand the range of important vector-borne diseases such as malaria and dengue (e.g., McMichael et al. 2006). Similarly, changes in rainfall patterns could also affect disease incidence, for instance with increasing drought heightening the risk of meningitis outbreak, or increased extreme rainfall events increasing the likelihood of cholera outbreaks (McMichael et al. 2006; Confalonieri et al. 2007).

The precise implications of climate change remain unclear: predictions of rainfall rates, amounts and patterns, the likely frequency of extreme weather events, and regional changes in weather patterns cannot be made with certainty. Regional climate models are becoming more accurate, but unfortunately too little effort has been invested into research on regional climate models in Sub-Saharan Africa. While the highest emission scenario in the IPCC's Fourth Assessment Report (IPCC, 2007) produces a most likely average temperature increase of 4ºC by the end of the 21st century, it is also possible that the increase might be as high as 6.4ºC or as low as 2.4ºC Currently, the impact of uncertainty can be seen most clearly in the failure of climate models to provide good agreement at the regional scale, and in particular on future levels of precipitation. In West Africa, for example, the impact of climate change on rainfall is unclear. Climate models sometimes fail to agree as to whether precipitation will increase or decrease in any season (Ifeanyi-obi et al. 2012).

Climate change, then, provides a particular challenge: we know that change is coming, and we can even know the direction of change in many cases, but our ability to foresee that change depends on a number of factors. The degree of confidence with which predictions can be made depends on how far into the future we look, what region we are in, whether a local or national prediction is needed, whether we are concerned with temperature, precipitation or extreme events all have an impact on the degree of confidence with which predictions can be made. We need to differentiate climate change projections for short-term (10-20 years) medium term (20-40 years) and long term (>40 years) scenarios, as this will have different impacts on adaptation decisions. Climate change contributes to vulnerability through creating greater uncertainty and unpredictability in the environment within which poor people live and build their livelihoods. Importantly, it is changing the prediction schemes or prediction rules, i.e. old knowledge is no longer of the same use as it used to be (Di Falco et al. 2011).

For the majority of weather related hazards and stresses there has tended to be a considerable amount of knowledge and certainty about their characteristics based on historical experience (for example, the timing of monsoon rains, patterns of cyclones, seasons of heavy frost probability), climate change is rendering it 9 much more difficult to predict future climate characteristics using historical evidence. At a global level and for the long-term projections (>40 years) climate change predictions vary widely, depending on assumptions about future trends in industrialization and consumption patterns (resulting in increasing CO2 emissions) as opposed to more optimistic assumptions about the adoption of cleaner technologies and stronger policy lines on emission reduction (CO2 stabilization).Predictions of impacts at the national and local levels are extremely challenging, due to the range of factors and feedback loops that could affect future climate, and the inadequacy of capacity to gather and analyze data for all regions. At all scales, rainfall – which is critical to agriculture – is harder to predict than changes in temperature (Lobell and Burke, 2008). Over half a billion people are at extreme risk to the impacts of climate change, and six in ten people are vulnerable in a physical and socio-economic sense (Confalonieri et al. 2007).

But the magnitude and speed of climate change that is expected over the next century raises serious questions about how much agriculture can be adapted to new climates, how quickly, and at what cost. Unfortunately, there is little existing evidence on the ability of adaptation to improve agricultural outcomes in the face of climate change, with large uncertainties surrounding both the potential gains from various adaptation measures and the extent to which they will be undertaken autonomously. Particularly difficult is disentangling the relationship between farmer responses to climate variability, which occur continually, and their likely longer run responses to changes in mean climate (Maddison, 2007; Lobell and Burke, 2008).). Below we reviewed the existing theory and evidence surrounding agricultural adaptation to climate change, and attempt to draw lessons both for investment priorities and for future research needs.

REVIEW OF THEORETICAL LITERATURES AND EMPIRICS

Climate Variability

Year-to-year changes in climate variables (or "climate variability") play a central role in global and regional food systems and in food security outcomes. As a result, climate variability can both illuminate and constrain possible longer run adaptation to climate change. For instance, farmer and food system responses to past weather events are some of the only evidence we have to understand how farmers respond to climate shifts. At the same time, variability also makes production more risky, which might inhibit risk adverse farmers from undertaking broader adaptation measures. Finally, the year-to-year noise of climate variability might make it harder to recognize that climate is actually changing (Thomas et al. 2007).

Given the negative impacts of climate variability on economic livelihoods and food security in much of the developing world, helping farmers better adapt to this variability is a central concern of development. Many have also argued that a focus on adapting to climate variability is the best way to approach adapting to climate change. This is in part because most farmers and governments can more readily understand the threat of variability, and thus are more likely to engage in building knowledge and institutional capacity to cope with variability (Washington et al. 2006; Cooper et al. 2008). It is also because climate variability can have large effects on livelihoods, and thus that longer-run adaptations will only be undertaken if they do not compromise the ability to cope with variability.

Perception on Climate Variability in Agriculture

Signal Detection

Adaptation at the farmer level requires three basic steps: detecting a shift in one's external environment, determining that it would favor a change in behavior, and undertaking that change (Hanemann 2000; Kandlikar and Risbey 2000). Farmers can easily recognize the short term variability in temperature and precipitation rather than the long term climate change. Thus the first step in adapting to climate change requires detecting the signal of climate change in the noise of climate variability. Given the amplitude of climate variability in many regions, this might be no small task (Lobell and Burke, 2008).

Short term rainfall variability is the most iconic whether event affecting smallholder producers in Ethiopia and can easily be testable by themselves (Di Falco et al. 2011).

Farmers in developed countries have access to a wealth of climate and weather data, and so presumably could learn about trends in climate without having to sense them independently. The same is often not true for farmers in poorer countries, who rely on various traditional methods for climate forecasting, and who might be more or less on their own in discerning longer-run climate shifts.The local weather and climate is assessed and predicted by locally observed variables and experiences using combinations of plant, animals, insects, and meteorological and astronomical indicators (Chang et al. 2010).

In northern Ethiopia, farmers' mainly utilize traditional weather forecasting technique. Strong wind during the month of July through October indicates less rainfall in the upcoming season. In parts of southern Ethiopia, appearance of many termites indicates near rainfall onset (Meze-Hausken, 2004).

Evidence is mixed on farmers' ability to correctly perceive such longer-run shifts. Meze-Hausken (2004) finds that farmers in northern Ethiopia report a decline in rainfall where rainfall gauges report no change. Maddison (2007) shows mixed results in farmers' ability to correctly perceive climate shifts across a range of African countries, with farmers in many countries correctly recognizing trends in mean temperature and rainfall, and others reporting trends in disagreement with observed climate data. Thomas et al. (2007) find qualitative evidence of South African farmers' abilities to detect subtle changes in mean state and variability of climate, but it is unclear whether this reveals actual recognition of trends, or the tendency to overestimate the frequency of negative events (Cooper et al. 2008).

Changing Behavior

Once a farmer is convinced that the climate has changed, he or she must decide whether and how to respond. Most humans exhibit a considerable bias towards maintaining old ways, even in new environments, with the thought that what worked in the past should continue to work in the future. A clear example of this from the business world is that very few firms survive for long periods of time; the economy evolves largely by new firms replacing old ones rather than firms themselves adapting (Beinhocker, 2006). In agriculture, there may be a tendency to underestimate the need to change management in a new climate. For example, a survey recently conducted in the Yaqui Valley of Mexico asked wheat farmers whether they perceived a change in temperatures over the last decade, whether this change was positive or negative, and whether it had a positive, negative, or neutral effect on their yields (Ortiz- Monasterio and Lobell, 2005). Out of 88 farmers, 85 (or 97%) reported a significant shift in temperature, but only 33 (or 38%) felt the change had an effect on wheat yields, despite the fact that temperatures exert a strong control on yields in this region (Lobell et al. 2005).

Other surveys suggest an opposite problem: that farmer might be too quick to update their beliefs about changes in climate. In surveys of Canadian corn farmers, Smit et al. (1997) show that these farmers tend to heavily weight the previous year's weather in deciding what varieties to plant for the upcoming season. Though surveys are an imperfect means to gauging farmers' perceptions, these results illustrate that recognition of a climate trend is only one step towards successful adaptation (Lobell and Burke, 2008).

Climate Change Adaptation: A Response to Variability and Change

Observed farmer adaptations to climate variability fall into two main camps: ex-ante measures, for which action is taken in anticipation of a given climate realization and ex-post responses, which are undertaken after the event is realized. Ex ante adaptations to variability often center around strategies of diversification, which attempt to capitalize on the differential effects that a given climate event might have on different crops and activities in a given year (Pandey et al. 2007). For instance, farmers growing rain-fed crops in a drought-prone environment might seek to diversify the location of their farm plots to take advantage of the high spatial variability of rainfall, grow a range of crops or crop varieties with different sensitivities to climate, or to diversify income sources into non-farm enterprises that are less sensitive to climate (Pandey et al. 2007). They could also choose to maintain flexibility with regard to input decisions until uncertainties about weather realizations are reduced, for instance by shifting when crops are planted. Where possible, farmers might also pay to insure their harvests against failure.

Farmers also undertake various ex post strategies to decrease crop or welfare losses once climate events have been realized. Such strategies include drawing down cash reserves or stores of grain, borrowing from formal or informal credit markets or family, selling assets such as livestock, or migrating elsewhere in search for work in non-affected regions. Ex post adaptations can also include changes to management after the growing season has started, such as replanting of faster-maturing varieties if early-season planting fails, or irrigating where possible if rainfall is meager. Not all strategies are available to all farmers unfortunately, nor are the available strategies always successful in buffering food security against a variable climate (Lobell and Burke, 2008).

In wealthier countries, farmers rarely go hungry as a result of drought or other adverse climate events. The existence of social safety nets and functioning financial markets ensure that farmers are either insured against losses, can borrow around them, or can receive help from the government to maintain livelihoods during bad times. Similarly, consumers in rich countries spend only a small percentage of their income on food, and are thus not very sensitive to the food price increases that often accompany droughts or floods. The same is not often true in poor countries (Madison, 2007).

Although both ex-post and ex-ante strategies can reduce climate-associated losses to some degree, the poorest households in particular are often unable to fully shield consumption from the effects of climate variability. This inability can be dramatic and devastating, as in the case of the drought-related famines in the Sahel and Horn of Africa in the 1980s, but they can also be more subtle, such as in the longer run documented negative effects of climate variability on health and economic outcomes in agricultural households, particularly for women and children (Hoddinott and Kinsey, 2001; Maccini and Yang 2008). Such effects are realized because ex-ante measures are insufficient, or ex-post measures such as insurance or savings are unavailable, or both. Also important are the perverse longer run effects of some of these adaptive measures on the food security of poor households. For instance, while ex-ante strategies can reduce the risk of catastrophic losses in bad years, they can also reduce the income earned in good years, because farmers might have planted a less-risky but lower-yielding (and typically lower-value) crop. The long-run costs in foregone income from this risk-mitigation can be high – as much as 15–30% of average income (Washington R, and Harrison M et al. 2006). Similarly, ex-post strategies can also avoid devastating declines in consumption in ways that harm longer run earning potential.

Distressed liquidation of productive assets such as livestock or land can prop up consumption in one year, but dampen the subsequent productivity and food access of households in later years, an effect again well documented in the Sub-Saharan Africa. These perverse temporal tradeoffs are a perennial and painful dilemma faced by farmers throughout much of the developing world (Cooper et al. 2008).

Prospective Climate Change Adaptation Mechanisms

In future an adapted world in 2050 will have some key characteristics to look for: widespread planting of new crop varieties; area expansion of crops and shifts in planting dates; expansion of irrigation and water harvesting; and effective institutions for anticipating and responding to droughts and local food production shortfalls (Lobell and Burke, 2008) . Realizing this adapted world, however, will require difficult decisions on the part of public and private sector agencies around the world with regard to how, where and when to invest. Further scientific research will be critical in informing this process, both to further reduce uncertainties surrounding likely impacts in the absence of adaptation, and to identify regions where producers and consumers will be unable to respond on their own and where investment could be most needed.

SUMMARY

Adaptation at the farmer level requires three basic steps: detecting a shift in one’s external environment, determining that it would favor a change in behavior, and undertaking that change. The local weather and climate is assessed and predicted by locally observed variables and experiences using combinations of plant, animals, insects, and meteorological and astronomical indicators. Observed farmer adaptations to climate variability fall into two main camps: ex ante measures, for which action is taken in anticipation of a given climate realization and ex post responses, which are undertaken after the event is realized. Ex ante adaptations to variability often center around strategies of diversification, which attempt to capitalize on the differential effects that a given climate event might have on different crops and activities in a given year. These perverse temporal tradeoffs are a perennial and painful dilemma faced by farmers throughout much of the developing world. This dilemma should be well clearly reviewed and identified before investing on climate change adaptation strategies in developing world.

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