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Micro-level Practices to Adapt to Climate Change for African Small-scale Farmers

A Review of Selected Literature

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ABSTRACT

This paper discusses micro-level practices for adapting to climate change that are available to small-scale farmers in Africa. The analysis is based on a review of 17 studies about practices that boost small-scale farmers' resilience or reduce their vulnerability to observed or expected changes in climate; it includes data from more than 16 countries in Africa, the Americas, Europe, and Asia. The review shows that African smallholders are already using a wide variety of creative practices to deal with climate risks; these can be further adjusted to the challenge of climate change by planned adaptation programs. We found 104 different practices relevant to climate change adaptation and organized them in five categories: farm management and technology; farm financial management; diversification on and beyond the farm; government interventions in infrastructure, health, and risk reduction; and knowledge management, networks, and governance. We conclude that adaptation policies should complement farmers' autonomous response to climate change through the development of new drought-resistant varieties and improved weather forecasts, the provision of financial services, improvement of rural transportation infrastructure, investments in public healthcare and public welfare programs, and policies that improve local governance and coordinate donor activities.

Keywords: climate change, adaptation practices, content analysis

1. INTRODUCTION

Climate change will have a significant impact on the livelihoods of the rural poor in developing countries. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) predicts that climate change is likely to have a significant effect on agricultural production in many African countries. Projected reductions in yield in some African countries could be as much as 50% by 2020, and net crop revenues could fall by 90% by 2100 (Boko et al. 2007). This amounts to a serious threat to food security and to the achievement of major developmental goals.

Farmers have a long history of responding to climate variability. Traditional and newly introduced adaptation practices can help farmers to cope with both current climate variability and future climate change. However, the debate about the adaptation of small-scale farmers in Africa to climate change has occurred in the absence of knowledge about existing and potential adaptation practices. Because prevailing ideas about adaptation are vague, conducting focused research on potential adaptation practices and formulating appropriate advice for implementing new practices is difficult.

Adaptation generally takes place at the micro- and macro-levels: Farmers introduce practices at the local level, and the main factors influencing their diffusion are seasonal climatic variations, the agricultural production system, and other socioeconomic factors; the government, NGOs, or private companies introduce practices nationally, and long-term changes in climatic, market, and other conditions influence their establishment (Nhemachena and Hassan 2007).

African smallholders use complex adaptation processes. In agriculture adaptation is evolutionary and occurs in the context of climatic, economic, technological, social, and political forces that are difficult to isolate, and most adaptation practices serve multiple purposes and are strongly interrelated (Smit and Skinner 2002; Adger et al. 2007). Furthermore, adaptation is an iterative, dynamic, multiscale, and multi-actor process, not a mechanical adjustment to a current state (Osbahr et al. 2008). The dynamic nature of adaptation makes it difficult to determine when, for example, the decision of a farmer to grow one crop variety instead of another is a coping response to short-term drought (climate variability) and when it is a planned adaptation to climate change (increased climate variability or gradual long-term changes in climate parameters). The multi-actor character of adaptation means that it involves a variety of stakeholders, such as rural households, private businesses, NGOs, and governments at local, regional, national, and international levels. Any realistic assessment of adaptation practices needs to take into account the linkages between actors and levels (Smit and Skinner 2002). In summary, adaptation is highly context sensitive, and determining when the climate is the driving force behind adaptation behavior is difficult.

Rationale

Identifying both the generic and climate-specific elements of farmers' adaptation behavior is vital in order to facilitate a societal response to the changes in climate that scientists have predicted. Tailoring adaptation practices to specific societies may make it possible to offset the adverse impacts of climate change (Fussel 2007). Moreover, assessments of economic adaptations show that in some cases returns on financial investments in adaptation are likely to exceed the returns from a baseline situation (Halsnaes and Traerup 2009; Kirschke and Noleppa 2008).

Several comprehensive studies of farmers' adaptation to climate change focus on a few study sites or regions in one or two countries (Osbahr et al. 2008; Osman-Elasha et al. 2006; Paavola 2004; Thomas et al. 2007). Other authors discuss particular aspects of farmers' adaptation to climate change, and some link their findings explicitly to adaptation to climate change. Mbilinyi et al. (2005), for example, discuss indigenous knowledge about rainwater harvesting; Halsnaes and Traerup (2009) assess the economic benefits of mosquito nets, road infrastructure, and rice production; and Siedenburg (2008) analyzes the implications of local knowledge for the adoption of agroforestry practices.

Another type of study compares adaptation practices in a comparative manner without going into much detail. Adger et al. (2007) provide a broad overview of adaptation practices concerning different sectors of the economy in Africa, Asia, Oceania, the Americas, and Europe. Boko et al. (2007) give general examples of adaptation options in Africa that enhance citizen's social and economic resilience. Finally, Smit and Skinner (2002) developed a typology for classifying and characterizing agricultural adaptation options in detail, focusing on Canada. However, the literature they reviewed contains no detailed classification or characterization of agricultural adaptation options specific to small-scale farmers in Africa.

Identifying Adaptation Practices

The goal of this paper is to review and classify findings related to existing micro-level practices and other practices that could help small-scale farmers in Africa adapt to climate change. The next step would be to identify areas of interest for detailed socioeconomic case studies of adaptation practices and provide policymakers with an overview of relevant practices that they might consider. However, we are not attempting to assess or recommend adaptation options. Such an assessment needs to be based on micro-level case studies within a broader range of data, perhaps using this typology as one way of looking at the data. Although this paper focuses on micro-level practices, it includes a number of adjustments that are dictated by governments and other national actors. This is necessary in order to draw a realistic picture of the adaptation context in which farmers are acting.

2. CLIMATE CHANGE AND ITS IMPACT IN AFRICA

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, the global average surface temperature is likely to rise by 1.8 degrees to 4.0 degrees Celsius by 2100. The sea level may rise by 30 to 60 centimeters. Climate variability will increase almost everywhere. Northern latitudes will experience more rainfall; many subtropical regions will see less.

Africa is among the continents most vulnerable to climate change and climate variability. Socioeconomic developments exacerbate the effects of climate change on ecosystems and humanity. Boko et al. (2007) mention endemic poverty, poor governance, limited access to capital and global markets, ecosystem degradation, complex disasters and conflicts, and urbanization as factors that may undermine communities' ability to adapt to climate change.

Effects of climate change and climate variability will continue to challenge vulnerable people. Droughts and dry spells will be more frequent, rain more inconsistent, and torrential downpours heavier, all phenomena that increase the risk of soil erosion and vegetation damage through runoff. Higher temperatures will increase the evaporation of soil moisture. Climate change will aggravate water stress, which the continent has already experienced; more people will be at risk of water stress.

The economies of many African nations are dependent on sectors that are vulnerable to climate conditions, such as agriculture, fisheries, forestry, and tourism. Agriculture and natural resources provide the livelihood for 70% to 80% of the population, and account for 30% of GDP and 40% of export revenue in Sub-Saharan Africa (Toulmin and Huq 2006). In Sub-Saharan Africa agriculture employs 60% to 90% of the total labor force (Thornton et al. 2006).

Although changes in climate may affect the whole continent, the distribution of those changes may vary. In the already arid north, climate change is expected to increase desertification and decrease forest cover. Climatologists are predicting rainfall shortages in the Sahara and Sahel, with soil degradation and an increasing number of dust storms. Scientists expect more frequent and longer dry periods in West Africa. Rising sea levels will affect coastal areas.

Overall, temperatures in Africa are expected to increase by two to six degrees Celsius by 2100 (Hulme et al. 2001). Regional projections vary significantly. The temperatures in the drier subtropical regions are expected to increase more than those of the moist tropics. By 2100 the temperature increase could be as much as seven degrees Celsius in summer and four degrees in winter (Hudson and Jones 2002), with an increase of as much as nine degrees Celsius for North Africa between June and August, and seven degrees for southern Africa from September to November (Ruosteenoja et al. 2003). The interior of the semiarid margins of the Sahara and central southern Africa is expected to see the greatest rise in temperature (Eriksen, O'Brien, and Losentrater 2008).

Mean annual rainfall is likely to decrease by 20% along the Mediterranean coast and extending into the northern Sahara (Boko et al. 2007), and to increase in tropical and eastern Africa by about 7%, with more variable and extreme weather events (Case 2006). In southern Africa winter rains will decrease by as much as 40% in the extreme west. In the eastern parts of southern Africa early summer rainfall (October to December) is expected to decrease, and late summer rainfall (January to March) is expected to increase (Tadross, Jack, and Hewitson 2005).

Western Africa is expected to see more rainfall variability and southern Africa less by 2100 (Hendrix and Glaser 2007). However, predictions for West Africa vary considerably, with no consensus on whether rainfall will increase or decrease (Hulme et al. 2001).

Climate models also predict the lengthening of drought periods (WBGU 2007). The Mediterranean coast and southern Africa in particular will be at higher risk of drought (Boko et al. 2007). Huntingford et al. (2005) assume the number of extremely dry and wet years in the Sahel region will increase. The amount of arid and semiarid land in Africa is expected to increase by 5% to 8% by the 2080s.

Changes in temperature, rainfall, and variability, and extension of drought periods in some regions, will have severe implications for agriculture. Climate change will likely reduce the length of the growing season and force large regions of marginal agriculture out of production. Assessments based on various climate models and Special Report on Emissions Scenarios estimate that by 2100, parts of the Sahara are likely to be the most vulnerable, showing probable agricultural losses of 2% to 7% of GDP. Agricultural losses caused by climate change in western and central Africa are expected to range from 2% to 4% GDP, and losses of 0.4 % to 1.3% of GDP are predicted for northern and southern Africa (Mendelsohn, Dinar, and Dalfelt 2000).

However, not all changes in climate and climate variability will be negative. In some areas, such as parts of the Ethiopian highlands or Mozambique, climate change may extend the agricultural growing seasons as a result of increased temperatures and rainfall changes (Thornton et al. 2006).

Thornton et al. (2006) show that under different scenarios, mixed rain-fed semiarid systems are going to be affected in the Sahel, as well as mixed rain-fed and highland perennial systems in the Great Lakes region and in other parts of East Africa. Benhin's study (2006) of climate change in South African agriculture, based on three scenarios, indicates that farmers' net crop revenues may fall by as much as 90% by 2100).

The model by Kurukulasuriya and Mendelsohn (2008) suggests that total cropland in Africa may not change much as climate change alters agroecological zones and the productivity of farms witin them. Cropping area in middle to high elevations is supposed to increase due to the shifting of agroecological zones. The dry desert and lowland semiarid agroecological zones are expected to lose cropland. The Egyptian desert is expected to have cropland with the highest net revenue for farmers compared to other regions as it has ample water and is irrigated from the Nile.

Moist savannahs at high elevations and subhumid forests at middle and high elevations are expected to yield the highest net revenues per hectare for farmers. The least fertile agroecological zones will be dry savannahs at high elevation, semiarid lowlands, and subhumid lowland forests that are too hot or too dry for cropland.

According to the model, central Africa is supposed to have the largest reduction in net crop revenue (-28% to -79%) in all scenarios, followed by West Africa with values of -7% to -32%. While southern Africa (-12% to -17%), East Africa (-11% to -12%), and North Africa (-4% to -7%) are expected to lose net crop revenues, some pockets of north and South Africa, in contrast, are predicted to benefit.

3. CHARACTERISTICS OF ADAPTATION PRACTICES

The literature proposes a large number of climate change adaptation practices. The review of 17 studies covering data from more than 16 countries in Africa, the Americas, Europe, and Asia found 104 different practices relevant to climate change adaptation (Table 1). The number of practices mentioned per study varies from one practice (explored in detail) to as many as 29 different options (analyzed comparatively). The practices address a wide range of adjustments in the behavior of individuals, groups, and institutions, as well as in the use and development of technologies. They include fundamental changes in the character of natural resource management, such as the construction of large reservoirs for irrigation, but also more subtle and less visible adjustments to ancient farming practices, such as the use of wild plants and animals as indicators of ecosystem variability and change. Because adaptation takes place at multiple levels and involves multiple actors, introducing or adjusting crop insurance—or even international grain futures markets—and making simple changes in the mix of traditional crops grown in a single field can also help smallholder farmers in Africa adjust to climate change.

We believe it is possible to classify adaptation practices in the following five categories (which are not mutually exclusive):

- Farm management and technology
- Farm financial management
- Diversification on and beyond the farm
- Government interventions in rural infrastructure, the rural health care services, and risk reduction for the rural population
- Knowledge management, networks, and governance

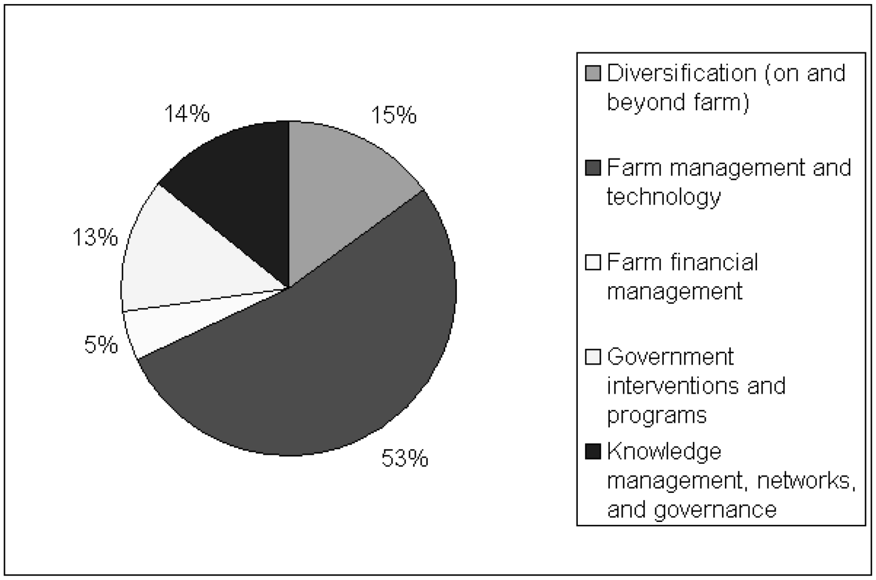
Table 1. Adaptation practices mentioned per category

Category of adaptation	Number of different practices mentioned	Number of practices mentioned, including multiple answers
Farm management and technology	51	117
Diversification on and beyond farm	7	33
Farm financial management	5	10
Government interventions in infrastructure, health, and risk reduction	22	29
Knowledge management, networks, and governance	19	31
Total	104	225

Source: Authors

The category of farm management and technology appears to be prominent in the literature—most practices mentioned were adjustments in farm management and technology (53%), followed by knowledge management, networks, and governance (15%); diversification (14%); government interventions (13%); and farm financial management (5%). However, the literature review is a qualitative analysis; all numbers are for illustrative purposes only and should not be taken as an indicator of the relative importance of the practices.

Figure 1. Adaptation practices mentioned by category (including multiple answers)



Source: Calculated by authors.

A common adaptation practice appears to be diversifying one's income stream through off-farm activities and migration (Table 2). Other frequently mentioned adaptation techniques are varying crops and varieties and adjusting the timing of processes like planting, weeding, and harvesting. Additional practices frequently mentioned in the literature are new and adjusted techniques for water conservation and irrigation as well as conservation agriculture.

Table 2. Most-mentioned adaptation practices

Practices in detail	Number of times mentioned
Diversification beyond farm	15
Migration	6
Different crops	7
Different varieties	8
Different dating of farm practices	9
Irrigation	8
Water conservation techniques	8
Conservation agriculture	6

Source: Authors.

In the sections that follow we describe different adaptation practices in greater detail, taking them up in the categories introduced earlier in this report.

Farm Management and Technical Options

Changes in farm management include a wide range of adjustments in land use and livelihood strategies that go beyond the usual agricultural practices available for coping with constantly varying biophysical and socioeconomic conditions. In the face of increasing climate variability and gradual changes in average climatic conditions, farmers may reassess the crops and varieties they grow, and they may consider shifting from farming to raising livestock (which may serve as a marketable insurance in times of hardship). They may also introduce different livestock breeds that are more resistant to drought. Changes in technology include, for example, the development of new crop varieties or improved climate information systems. These are typically introduced through macro-level research programs undertaken or sponsored by governmental or nongovernmental organizations and private companies. However, scholars of farmers' innovation behavior point out that agricultural producers also play a decisive role in the development of new technologies (Doppler et al. 2000). Thus strict discrimination between micro- and macro-level adaptations of farm management and technologies does not address the multilevel character of agricultural innovation. This is why we analyze changes in farm management and technology in the same subsection of this paper.

Adaptation of On-farm Management

The literature provides detailed examples of changes in cropping systems. Kurukulasuriya and Mendelsohn (2006) show that crop selection among African farmers varies significantly in cooler, moderately warm, and hot regions. Farmers select sorghum and maize-millet in the cooler regions of Africa; maize-beans, maize-groundnut, and maize in moderately warm regions; and cowpea, cowpea-sorghum, and millet-groundnut in hot regions (Kurukulasuriya and Mendelsohn 2006). In a case study covering villages in three South African provinces, Thomas et al. (2007) found that during dry spells farmers tended to reduce their investment in crops or even stop planting and focus instead on livestock management. Because climate change scenarios predict an increase in climate variability in many parts of Africa, farmers probably will turn to this temporary coping strategy more frequently and thus turn it into adaptation. Another finding based on the study by Thomas et al. (2007) is that farmers are increasingly trying to exploit the spatial diversity of their landscape. The villagers studied by Thomas and colleagues tried to gain access to land that gives good yields during times of drought because there is a water source for irrigation reachable at plot level (Thomas et al. 2007). By comparing cases in the Roslagen area of Sweden and the Mbulu Highlands of Tanzania, Tengö and Belfrage (2004) uncovered similarities in practices aimed at dealing with temporary drought at field level. For example, farmers in Sweden and Tanzania both use cover crops to enhance seedling survival. On the other hand, controlling erosion by using contour planting, mulching, and the construction of cutoff drains and sluices was popular only in the Mbulu highlands, where the fields are on a slope (Tengö and Belfrage 2004).

Technical Options: New Plant Varieties

Improved crop varieties have considerable potential for strengthening the adaptive capacity of African farmers. A prominent example of the development of improved drought-resistant varieties is the Interspecific Hybridization Project of the Africa Rice Centre (WARDA), begun in 1992. Scientists combined the useful traits of two rice species, *O. sativa and O. glaberrima,* and developed interspecific lines with desirable traits tailored to African conditions, dubbing them New Rice for Africa (NERICA). NERICA constitutes a wide range of varieties with different characteristics. Many are high yielding, early maturing, weed competitive, and tolerant of Africa's major pests, drought, and iron toxicity (Rodenburg et al. 2006). In the face of climate change, scientists from WARDA are doing additional work on drought tolerance in rice. Other examples of adaptation to climate change using new technologies include the development of improved weather forecasts and GIS-based decision support for rainwater-harvesting. Mbilinyi et al. (2007) present a GIS-based decision support system that uses remote sensing and limited field survey to identify potential sites for rainwater-harvesting technologies. In an evaluation of the opinions of representatives from the Regional Remote Sensing Unit of the Southern African Development Community, Archer et al. (2007) found three actions that are key to improving weather forecasts. First, forecasting models need to be improved so that they produce more timely forecasts; at present forecasts are often provided too late to affect planting decisions. Second, special forecasts need to be developed to support decisions in such problem areas as crop production and livestock breeding. These tailored forecasts may range from adding temperature to a rainfall prediction to identifying management options as a result of basic above-normal, near-normal, or below-normal precipitation forecasts. Finally, predictions of intraseasonal rainfall distribution should be made available to farmers (Archer et al. 2007).

Adoption of New Technologies

Although Boko et al. (2007) and several other authors highlight the critical importance of new technologies for adaptation to climate change, other authors express doubts about the extent to which farmers will adopt new technologies for this purpose. Because adoption is an often neglected, though fundamental, precondition for technological advancement, we will discuss some major adoption-related barriers in adaptation to climate change. McLeman et al. found from their retroactive analysis of adaptations to drought in rural eastern Oklahoma in the 1930s that farmers adopted no new technologies during the drought years. The study found that the main reasons for this were lack of money for investment in new technologies and high tenancy rates. Farmers in Oklahoma had already suffered economic difficulties before the drought and thus had no money to invest in new technologies. For historical reasons many farmers did' not own the land they worked and thus had few incentives to improve its fertility by, for example, terracing sloping fields (McLeman et al. 2008). In contrast Kato et al. (2009) suggest that farmers' desire to minimize production risks strongly influences their adoption of new technologies. In their analysis of soil- and water-conserving technologies in rural Ethiopia, Kato et al. (2009) found that farmers will reject even low-cost interventions if these do not minimize production risk.

Another explanation for farmers' limited adoption of technical options to adapt to climate change begins with their willingness and ability to accept new practices (Siebert, Toogood, and Knierim 2006). Farmers' willingness depends on their economic interests, social and ecological values and norms, awareness of the problem, and self-perception. A farmer's ability comprises all the objectively verifiable factors that influence his or her decision, including the type and organization of the farm, farm economics, tenure, and farm size, as well as the biogeographical conditions of the farmland and its surroundings. Furthermore, it includes specific characteristics of the farmer, that is, the farmer's age, education, and experience (Siebert, Toogood, and Knierim 2006). In the next section we use the concepts of willingness and ability to illustrate the nonadoption of weather forecasts by small-scale farmers in Africa.

Willingness to Accept Weather Forecasts

Roncoli and colleagues (Roncoli, Ingram, and Kirshen 2002; Roncoli et al. 2004, 2005) studied farmers' understanding of seasonal rainfall forecasts in Burkina Faso. They found that farmers think of rainfall as a process rather than in terms of a quantity, as scientists do. Thus, Roncoli and colleagues argue, farmers will not accept forecasts, unless they are adjusted to their understandings. Patt and Gwata (2002) confirm these findings. A study in Zimbabwe (Grothmann and Patt 2005) revealed that farmers' acceptance of seasonal climate forecasts increased when they were provided as part of local indigenous climate forecasts. Farmers are more likely to adopt external climate forecasts when they can see them in the context of existing practices.

A fundamental factor in farmers' willingness to take up climate forecasts is their appraisal of risk (O'Brien and Vogel 2003). Grothmann and Patt (2005) saw risk appraisal as well as farmers' self-perception as decisive factors in acceptance. On a conceptual level Grothmann and Patt developed the sociocognitive Model of Private Proactive Adaptation to Climate Change in order to address psychological factors that keep farmers from adapting to climate change. The Grothmann-Patt model is based on protection motivation theory, which Rogers (1983) developed in the context of health threats. Both models focus on two major perceptual processes. In appraising risk a person assesses the probability that the worst will come to pass and the damage potential to things the person values. In appraising adaptation the person judges his or her ability to avert harm from the threat and considers the costs of taking a certain action.

Grothmann and Patt (2005) applied their model to a case study in rural Zimbabwe. They examined processes of decisionmaking by subsistence farmers in four villages who had been given information about seasonal climate change; the authors also assessed the farmers' willingness to change their decisions on the basis of the information they received. Grothmann and Patt (2005) found that the farmers made no changes in response to the information and determined that this was because the farmers had no intention to adapt. Grothmann and Patt (2005) identified two factors that led to this lack of intention: The farmers judged the risk to be not high, and they perceived their adaptive capacity to be low (for a comparison see Ziervogel 2004). The authors suggest that policymakers take into account any cognitive barriers to adaptation that may exist.

Ability to Accept Weather Forecasts

Farmers' ability to accept and apply climate forecast information is influenced by farm characteristics on the one hand and by the individual farmer's disposition on the other.

Little literature exists on the characteristics that influence acceptance. Roncoli, Ingram, and Kirshen (2002) and Roncoli et al. (2004, 2005) found in their case study in Burkina Faso that cognitive factors, such as experience, influence farmers' processing of the probability of climate events, as well as their ability to apply climate forecasts (for comparison see Nicholls 1999; Kahneman 2003)'. Barbier et al. (2009) analyzed farmers' adaptation practices in northern Burkina Faso and undertook a study that used focus group discussions and two surveys among a random sample of 105 heads of farms in 2004 and 100 in 2006. The findings of Barbier et al. (2009) suggest that farmers had quite elaborate knowledge of climate-related factors, such as wind, rainfall, and heat, and their impact on crops.

Archer (2003) found for South Africa that gender is a determinant of farmers' ability to accept climate forecasts. She undertook a case study in Mangondi village in the Limpopo Province, South Africa, to characterize gender-specific household access to and use of seasonal climate forecasts. Group meetings, interviews, and a household survey revealed that one decisive factor in the ability to accept climate forecasts is the medium through which this information is transferred. While men said that they are flexible enough to listen to a radio broadcast at a regular time, women expressed their preference for the provision of seasonal forecasts by an agricultural extension officer, because their time is not flexible enough to allow them to listen to a radio program at a fixed time. Furthermore, the women stated that they like to ask questions rather than receive one-way information. Archer (2003) concluded that focusing on radio programs alone will exclude important user groups from seasonal climate forecast information. Several studies consider farm economics as a factor in acceptance of climate forecasts.

Archer (2003) cites several authors who have shown the importance of resources for both access to and use of climate forecasts (see Blench 1999; Klopper 1999; O'Brien et al. 2000; Phillips, Makaudze, and Unganai 2001; Valdivia, Gilles, and Materer 2000; Valdivia et al. 2001; Vogel 2000; Patt and Gwata 2002; Ziervogel 2004). Vogel (2000), for example, argues that access to resources such as credit is the decisive determinant for the ability to implement appropriate adaptation practices. Boko et al. (2007) also emphasize the point that access to credit is an important determinant in farmers' use of climate forecast practices. For resource-poor farmers access to land is another key factor (Vogel 2000). Phillips, Makaudze, and Unganai (2001) found in a case study in Zimbabwe that inadequate access to draft animals constrains a farmer's ability to vary planting times in response to seasonal climate forecast information.

During the focus group discussions that Barbier et al. (2009) carried out in Burkina Faso, it became apparent that land scarcity is a major factor limiting increases in crop production and that adoption of farming practices did not occur until the pressure to do so was considerable. Lemos et al. (2002) found that access to water storage facilities for irrigation and other technologies were decisive factors in farmers' acceptance of climate forecasts. They undertook research in Ceará, in northern Brazil. Qualitative interviews with decisionmakers and a quantitative survey of climate forecast applications with a random sample of 484 farm households in six different *municipios* revealed that the farmers have insufficient assets, resources, and ability to choose among alternative options for adapting to climate change. For example, they have no water storage capacity for irrigation.

In contrast Ziervogel (2004) suggests that smallholder farmers in Lesotho have a number of options for responding to forecasts, although they have few resources immediately available Farmers mentioned several adaptation practices that they use, such as reducing the density of field crops, planting drought-resistant crops, or sowing less maize and wheat. Ziervogel (2004) argues that resource-poor farmers may not use climate forecast information for other reasons, such as the socioeconomic or cultural environment. However, in their case study region in Bolivia, Valdivia, Gilles, and Materer (2000) and Valdivia et al. (2002) found that diversified production strategies and off-farm income are directly correlated to the economic ability to use climate data. Wealthy diversified households are sufficiently flexible to change activities in their household organization, and they may use other sources of income to underwrite their responses to forecasts.

Many authors see social networks as a decisive factor in acceptance of forecast information. The interest shown in social networks may arise from a corresponding tradition in research on developing countries. Scholars seem to agree that networks are stronger and more powerful than in postindustrial countries. Valdivia et al. (2001, 2002), for example, undertook research in the Bolivian altiplano to investigate peasant household strategies and the potential use of climate forecasts after El Niño of 1997–1998. In 1999 Valdivia and colleagues conducted a household survey of 45 families in the village of San José Llanga. In addition, they held focus groups, met with farmers, and conducted one-on-one interviews with key people from the communal farming group. The researchers found that the head of the household is the preferred source of dissemination of seasonal climate forecasts. Results also show that access to outside organizations and information enhances access to and use of climate forecasts. Valdivia et al. (2001, 2002) concluded that knowledge of El Niño from external sources reaches the farmers indirectly through personal networks.

Roncoli, Ingram, and Kirshen (2001) analyzed the information sources and networks used by farmers in Burkina Faso. The researchers organized experimental meetings to disseminate information at three study sites and arranged for farmers' representatives to attend a forum every May at which seasonal forecasts are presented and discussed. When the farmers returned home, they held meetings to disseminate the information. The researchers found that information circulated selectively. Several key groups did not receive the information. One village excluded women, and two others excluded lower-caste families as well as families opposed to the village leader. In all study sites the evolving information networks did not provide herders residing at the edges of the villages with forecast information.

Ziervogel (2004) used a role-playing exercise with smallholders in Lesotho in order to understand the decisions farmers might make in response to climate forecast information. She concluded from the information gathered that farmers learn to use climate forecasts through repeated exposure and that they prefer interactive dissemination methods. Farmers are more open to forecast information when they have an opportunity to ask questions and to assess its use on the basis of demonstrations.

According to Roncoli, Ingram, and Kirshen (2002), farmers combine their own experience with advice from agricultural extension services. To predict weather events farmers rely on traditional diviners on the one hand and on prophecies derived from Christian and Islamic scripture on the other. Climate predictions are not neutral technical information but are embedded in existing power relations. Orlove, Broad, and Petty (2004) show how the social context, like hierarchies based on ethnicity or gender, shapes the processing of climate information.

Farm Financial Management

Like Smit and Skinner, we understand farm financial adaptation options as "farm-level responses using farm income strategies (both government supported and private) to reduce the risk of climate-related income loss" (2002: 102). The study of drought adaptation in Sequoyah County, Oklahoma, by McLeman et al. (2008) illustrates the great need for adaptation to reduce the risk of such losses. When drought caused the loss of income from cotton crops in the mid-1930s, cash immediately became scarce as cotton was the major cash crop in Sequoyah County. Farm families' food security relied to a relatively high degree on purchased goods.[1] The crisis drove farmers to adopt a number of autonomous adaptation practices. The first adjustment was to replace the cash economy with a barter system. Then farmers went in search of credit. Because the financial crisis of 1929 had forced the closing of many banks in Oklahoma, access to credit was limited. Farmers had to rely largely on local merchants for credit. But because merchants had few opportunities to enforce the repayment of loans, they were reluctant to give credit to people other than those who had lived in the area for a long time, who had strong social ties and a favorable reputation. Hunting, illegal whisky production and seasonal migration were other common adaptations to climate-related income losses (McLeman et al. 2008).

The finance system has developed in many ways since the early twentieth century. Canadian farmers frequently use crop insurance to adapt to climate-related income loss. One example is the considerable amount (US$258 million) that insurance companies paid out to the farmers of Ontario after a major drought in 2001 (Smit and Skinner 2002). In the context of developing economies, governments, NGOs and banks have developed microinsurance and revolving funds. Boko et al. (2007) consider this proactive development of capital services to be an important element in climate change adaptation for African farmers and one that deserves further investigation.

The study by Osman-Elasha et al. (2006) confirms the relevance of access to credit in efforts to build adaptive capacity in the face of climate-related shocks. Osman-Elasha and colleagues investigated factors that enable farmers of three drought-prone Sudanese villages to sustain their livelihoods and that serve as de facto options for adapting to climate change. Donors like the Global Environment Facility of the UN Development Programme and SOS Sahel (UK) promoted some of the sustainable livelihood activities through their development projects. In general village leaders consider the development projects a success. According to Osman-Elasha et al. (2006), a significant factor in this success was that these organizations provided the farmers with access to credit. Even though only 12% of a sample in one village think that credit availability contributed directly to the success of the project, 36% actually benefited from seeds and small loans that an agricultural bank provided. Men and women enjoyed equal access to the credit, and credit repayment was excellent in the three villages (Osman-Elasha et al. 2006).

Diversification on and beyond the Farm

Diversification includes both nonagricultural livelihood strategies that are carried out on the farm, such as the sale of nontimber forest products, and activities that farm families undertake beyond the farm, such as petty trade or seasonal migration. The strategies are directed toward earning much-needed cash, although the perspective here differs from that in the previous section. Here we focus not so much on the substitution of barter for cash and the search for credit as on the multiple strategies that farmers deploy to diversify what they are doing in order to reduce risks.

Nonagricultural income sources are by nature extremely diverse. In a case study from Nigeria, Ilyia (1999) counted 89 nonagricultural activities performed by women and 79 by men. Furthermore, nonagricultural diversification is an extremely common phenomenon internationally and one that is motivated by a number of distinct drivers, including market pressure, demographic change, and climate risks. Additionally, diversification is highly opportunistic, involving quick responses to market opportunities, and households typically pursue more than one activity simultaneously (Bryceson 2002). These characteristics make it impossible to identify a limited set of diversification practices for adaptation to climate change. However, ethnicity and gender appear to be significant influences on the forms that diversification takes place and provide a good example of the issues involved.

In a study of three different ethnic groups in the Hayre of Mali, de Bruijn and van Dijk (1994) examined how drought drives farmers to use different forms of diversification to varying degrees. The

[1] Failures in the cash economy may affect cash-crop farmers and subsistence farmers in different ways. However, studies have shown that smallholder subsistence farmers in Africa also rely to a significant extent on purchased food (Bryceson 2002).

three ethnic groups—the Weheebe, Jalloube, and Riimaye—live together in the same villages, and traditionally their relationship was strictly hierarchical. The Weheebe were the local chiefs and served as administrators for the French colonists, the Jalloube were the herders and had little contact with the French, and the Riimaye served as domestic slaves for the first two ethnic groups. During the severe Sahelian droughts of the 1980s, the transhumant men of the Jalloube frequently migrated to other regions to serve as cattle herders, assistants to cattle traders, and traditional priests. Compared with the Riimaye group, the Jalloube had relatively few opportunities for diversification. As proud herdsmen, Jalloube men and women would feel embarrassed if a crisis drove them to cultivate the land and to gather bush products, because this was the traditional domain of the "inferior" Riimaye group. The remaining options for diversification for the women of the Jalloube were thus mainly petty trade, such as the sale of powdered milk, and activities in the third sector, such as hair plaiting and prostitution.

In contrast the Riimaye women had the opportunity to cultivate additional small plots of land, weave mats, and gather bush products such as wild fruits, rice, and fonio (a cereal), as well as to engage in small-scale trade. The men of the Riimaye generally tried to increase millet production and migrated in search of work in construction as a means of adapting to the drought. The Weheebe, the ethnic group of the former local chiefs, used a mixed strategy to adapt to the drought. Some of these men, who generally were better educated and had more social capital, managed to move to the towns and find jobs in the government administration and small tailoring enterprises. Weheebe women had the fewest opportunities for diversification. Because they were confined to the house for cultural reasons, they could not collect bush products, and their only opportunity for diversification was weaving mats (de Bruijn and van Dijk 1994).

Some scholars of livelihood diversification strongly question the relative importance of climate risks in the widespread phenomenon of nonagricultural income diversification among Sub-Saharan smallholder farmers. Bryceson (2002) identifies a marked increase of 20% to 40% in sources of nonagricultural income for this group in the last 15 years of the twentieth century.[2] The major drivers of diversification were structural adjustment and market liberalization policies that international financial institutions had initiated, and Bryceson (2002) identifies several perverse outcomes that resulted although she acknowledges that drought also has played a role in diversification in some cases.[3]

Though the weighting of different factors is problematic, smallholder farmers' urgent need to control the widespread risks in their livelihood system clearly is a strong driver of diversification. While commercial activities beyond subsistence agriculture often do reduce the risk of suffering as a result of climate hazards, sometimes they also have the opposite effect. For example, a greater degree of integration into the monetary economy may substantially increase the risk of being adversely affected by economic and political crises. Paavola (2004) reports that excessive use of natural resources in the Morogoro region of Tanzania undermines sustainable land use. In the face of drought people diversify into the production of charcoal, which increases rates of deforestation, and into artisanal mining, which leads to soil erosion and water depletion (Paavola 2004). According to Bryceson (2002), increased diversification has influenced the division of labor and decision making power within smallholder households and has caused a widening of wealth differentials between households.

Government Investments in Infrastructure, Health, and Public Welfare

Institutional responses to the risks associated with climate change primarily address issues involving infrastructure, health and public employment, and welfare programs. As macro-level interventions these responses have the potential to strongly influence farmers' risk management strategies and therefore belong in this analysis. One example of each of these issues may be useful in delineating the connections between government interventions and local dynamics.

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[2] Bryceson's conclusions are based on a comprehensive research project that included various qualitative and quantitative studies from six different Sub-Saharan countries.

3 International financial institutions originally implemented the structural adjustment policies to correct urban bias, to balance trade deficit and to reduce external debts.

Halsnaes and Traerup (2009) analyzed the costs and benefits of the construction of flood-proofed roads in the Limpopo basin of southern Mozambique. In 2000 a flood killed 500 local people, forced 200,000 into refugee camps, and disrupted the transportation infrastructure for more than six months (Halsnaes and Traerup 2009). The government and the World Bank responded with a rehabilitation and maintenance project for the road system that is expected to reduce flood damage to roads by 50%. A new drainage system is designed to accommodate a 20-year flood, and the improved bridges are designed to withstand a 40-year flood. While the upfront costs for revamping the road system are higher than for conventional construction, examples from Asia indicate that over 50 years the total costs of construction, maintenance, and repair for a road not designed to withstand unusual flooding are twice as high as for roads built to the higher standard (Halsnaes and Traerup 2009). Reconfiguring the roads reduces the vulnerability of the local population in multiple ways, including uninterrupted access to markets and improved accessibility in the case of future natural disasters. Additionally, the construction of redesigned roads and their maintenance may serve as a source of off-farm income for smallholders.

The prevention of malaria epidemics is another area appropriate for local government intervention in the context of climate change adaptation. Changes in temperature and precipitation patterns are expected to extend the distribution of malaria to new areas of the East African highlands. This would lead to significant economic losses associated with increased human morbidity and mortality (Halsnaes and Traerup 2009). Reducing the density of and disease transmission by Anopheles mosquitoes reduces people’s vulnerability to the effects of climate change. Protopopoff et al. (2007) studied the prevention of malaria epidemics in Karuzi Province, Burundi, by combining indoor residual spraying and nets treated with long-lasting insecticide. They concluded that vector control effectively reduces density of Anopheles mosquitoes and their transmission of disease. Although the authors did not explicitly study vector control in the context of climate change, the findings remain valid: Vector control activities significantly reduce people’s vulnerability to potential effects of climate change.

The U.S. example illustrates the potential usefulness of public employment and social aid programs in climate change adaptation. McLeman et al. (2008) found in their analysis of drought adaptation among U.S. farmers during the 1930s that four government programs became essential mechanisms for adaptation. None of these programs was designed specifically for drought relief. Congress originally enacted the Agricultural Adjustment Act to stabilize commodity prices. The government offered to pay farmers to reduce the acreage of certain cultivated crops such as cotton. The Works Progress Administration provided money to local governments to hire rural people to build new schools and community centers. The Civilian Conservation Corps employed people in forestry or nature conservation. The Farm Security Administration provided loans and subsidies to distressed farmers and ran camps for migrant agricultural workers in other regions of the country that needed agricultural labor (McLeman et al. 2008). In the context of Sub-Saharan Africa a lack of institutional capacity and insufficient funding often make these such government interventions impossible (Boko et al. 2007). However, public employment and social aid programs steered by national authorities rather than by a multitude of external donors likely would be effective in helping marginalized smallholders to adapt to the adverse effects of climate change. A promising example is the Bangladeshi Multi-Donor Trust Fund, established in 2008, which pools money obtained from different national and multilateral climate change funds and is managed by a board of trustees that includes representatives of the national government as well as international donors (Ayers 2009). The fund’s public-private framework could reduce transaction costs and ensure that the government establishes proper institutional structures to implement public employment and social aid programs.

Knowledge Management, Networks, and local Governance

Adaptation to climate change through knowledge management includes both macro-level practices such as all sorts of practical trainings for farmers and agricultural extension officers, and such micro-level practices as the use of decision support systems and weather forecasts, wild plants and animals as bellwethers of ecosystem variability or change, and generally increased experimentation by farmers and other stakeholders. Using networks for climate change adaptation involves investing in family ties and social networks, collective provision of farm inputs, collective marketing of farm products, farmer-to-farmer training, and establishing barter systems.

Evidence from case studies shows that local or indigenous knowledge can beneficial or problematic in the context of climate change adaptation. Siedenburg (2008) analyzed local knowledge about agroforestry practices in the context of rapid environmental change in the Shinyanga Rural District of Tanzania. He found that some smallholder households do not actively foster the regeneration of key farm-based natural resources, and he concluded that variations in local knowledge may be a key determinant of their use of this practice. Siedenburg (2008) found that Shenyang's farmers were unaware of the beneficial impact of trees and calls for providing them with tailored information about agroforestry and the role of trees for groundwater and soil conservation. In contrast Mbilinyi et al. (2005) emphasize that existing indigenous knowledge of rainwater-harvesting technologies in the Kilimanjaro region of Tanzania is an important asset for designing and implementing irrigation technologies in the future.

Local networks have multiple functions in reducing vulnerability and enhancing adaptive capacity. Campbell (1999) compared the response to drought among farmers and herders of the Kenyan Kajiado District in the 1970s and the 1990s and found that social cohesion strongly influenced the use of networks in adapting to drought. In 1977, 63% of herders and only 17% of farmers stated that they relied on help from relatives or friends in response to drought. However, by 1996 the difference had disappeared: 28% of herders and 29% of farmers stated that they relied on help from relatives or friends. Campbell (1999) explains this by noting that in 1977 farmers had only recently migrated into the region and thus had not yet established social networks as herders. Osbahr et al. (2008) found in a case study from the Gaza province of Mozambique that traditional labor exchange mechanisms have become more popular in the last 20 years. In particular, 70% of respondents stated that a local practice called *Kuvekala,* which allows those looking after other peoples' livestock to keep the firstborn animal as payment, had become more commonplace since the late 1980s (Osbahr et al. 2008). Thomas et al. (2007) found in their study from South Africa that collective action has emerged as an important way to enhance adaptive capacity. One village established a maize cooperative to address marketing risks and reduce production and transportation costs. Another village used existing cooperative structures to search collectively for new sources of agricultural income such as small-scale horticulture, poultry, and egg schemes (Thomas et al. 2007).

That climate change vulnerability is understood in the context of both suffering as a result of climate-related hazards and the absence of entitlements[4] highlights the importance of governance in climate change adaptation (Adger 2006). Governance issues include decisions about the use of natural resources, such as the number of farm animals that can be grazed on an area of land and the cutting of trees. Equal participation of marginalized societal groups in decision making enhances their adaptive capacities. Osman-Elasa et al. (2006) found the empowerment and participation of women to be critical for the success of sustainable livelihood activities that serve as de facto options for adapting to climate change. In one village they surveyed, more than 76% of respondents regarded women's participation in communal meetings as reasonably high after the project, compared with less than 7% before the project. However, the issue of participation does not end at the village boundary. Osbahr et al. (2008) found interactions between farmers and local authorities to be crucial in strengthening adaptive capacities. Since 1994 the government of Mozambique has promoted a governance system that encourages participation and increases communication among villagers, NGOs, and local governments. Regular meetings of village representatives, agricultural extension officers, NGOs, and local authorities have contributed to the successful shift of 45% of respondents to drought-resistant or faster-maturing crop varieties (Osbahr et al. 2008).

[4] Entitlements have been defined by Sen (1984: 497) as "the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces".

4. CONCLUSION AND POLICY IMPLICATIONS

The purpose of this paper was to review and classify micro-level practices available to small-scale farmers in Africa for adapting to climate change. The review shows that African smallholders are already using a wide variety of creative practices to deal with climate risks; these can be further adjusted to the challenge of climate change by incorporating lessons learned from other regions of the world as well as through the findings of innovative science. The adaptation practices identified can be divided into five different categories that are not mutually exclusive: farm management and technology; farm financial management; diversification on and beyond the farm; government interventions in infrastructure, health, and risk reduction; and knowledge management, networks, and governance. Within the literature reviewed, the category of farm management and technology appears to offer the most popular options, followed by knowledge management, networks, and governance; diversification; government interventions; and farm financial management. However, this ranking is for illustrative purposes only and is not an indicator of the relative importance of these practices, for two major reasons. First, the ranking is derived from a qualitative analysis that does not allow precise quantification of cause-and-effect relationships, and, second, the relative importance of adaptation practices is likely to vary by context, given the different constraints, biophysical characteristics, and differential effects of climate change, among other factors.

Looking at the five categories in detail reveals a considerable number of options for climate change adaptation. Adaptation of farming practices ranges from crop switching to introducing a mix of livestock and cropping at farm level to inaugurating antierosion measures and multiple practices for managing drought at the local level. Technological advancements can also play a significant role in climate change adaptation. Technology-related options include the development of new drought-resistant varieties, such as the NERICA varieties recently developed by the Africa Rice Centre, the GIS-based decision support system for rainwater harvesting, and improved weather forecasts that provide timelier cropspecific information, including intraseasonal rainfall distribution.

Improved provision of financial services is also critical for the long-term food security of African smallholders in the context of increasing climate risks, because even subsistence farmers rely to a significant extent on purchased food. Access to credit is an enabling factor in the sustainable development of rural societies, although in some cases micro credits have increased social inequalities. Practices designed to facilitate adaptation to climate change based on diversification on and beyond the farm are extremely diverse. Multiple drivers, including climate risks, institutional reforms, market pressure, and demographic change, strongly influence diversification. Farmers typically respond rapidly and opportunistically to new incentives and tend to pursue a variety of activities simultaneously. Societal norms and values attached to gender and ethnicity often influence who pursues what activity. However, greater integration into the monetary economy through commercial activities beyond subsistence agriculture may increase the risk of vulnerability to economic and political crises.

Governance interventions in infrastructure, public health, and public welfare are also important adaptation practices. Decades of development cooperation teach the importance of safeguarding from the outset the political coherence of funding for adaptation. The Multi-Donor Trust Fund of Bangladesh may serve as a good example of how to achieve this through a public-private partnership. Local knowledge can be both beneficial and problematic in adaptation processes. While a lack of local knowledge in times of rapid global change can promote the depletion of natural resources, local knowledge also may serve as an important asset in the design and implementation of adaptation practices. Rural households increasingly use their local networks to enhance their adaptive capacity. Examples are the use of traditional forms of labor exchange, cooperatives, and family ties. However, only well-established networks are productive. Studies show that older rural societies have more adaptive capacity than recently constituted rural populations of resettled migrants. The implication here is that the most vulnerable might not be able to benefit from local networks. Finally, governance plays a significant role in enhancing adaptive capacity. Given that vulnerability means lack of entitlements, it is fundamental to give a voice to the poor and marginalized for enhancing people's capacity.

The analyses of micro-level practices available to small-scale farmers in Africa for adapting to climate change suggest several different policy options, including the development of new drought-resistant varieties and improved weather forecasts, provision of financial services, improvement of rural transportation infrastructure, investments in public healthcare and public welfare programs, and implementation of policies to enhance good local governance and coordinate donor activities.

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