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Climate change scenarios and the development of adaptation strategies in Africa: challenges and opportunities

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ABSTRACT: Climate change is expected to intensify existing problems and create new combinations of risks, particularly in Africa, where there is widespread poverty and dependence on the natural environment. Accordingly, there is a growing need for proactive adaptation to climate change risks. In order to achieve this, the requisite competence needs to be developed on the use and interpretation of climate information to support informed decisions. The present paper assesses the extent to which climate change scenarios are currently used in developing adaptation strategies within the agricultural development sector, with a focus on Africa. The data, based on interviews with practitioners and donors working in the climate change field in Africa, suggest that although annual climate information (such as seasonal climate forecasts) is used to a certain extent to inform and support some decisions, climate change scenarios are rarely used at present in agricultural development. However, respondents suggest a number of ways to improve the application of climate change science in these endeavors; these include strengthening technical skills for downscaling climate models, as well as using scenario outputs to develop and prioritize robust locally relevant adaptation strategies to provide examples of 'good' adaptation practice. Improved understanding, packaging, and communication of climate scenarios are required between scientists, practitioners, policymakers and civil society, both within areas in the global south as well as between the global south and north. In addition, we argue that a paradigmatic shift is required from supply-driven activities to a user-focused approach that addresses decision makers' needs for climate change data. Such a shift would focus on generating the information required to provide actionable suggestions to formulate viable adaptation policies and reduce the negative consequences of climate change, particularly for Africa's most vulnerable groups.

KEY WORDS: Adaptation · Climate change science · Climate change data · Africa · Agriculture

1. INTRODUCTION

Climate change is expected to place considerable additional stress on the biophysical, economic, political and social systems that determine livelihood security in Africa (Leary et al. 2008). Accordingly there is a growing need for 'anticipatory adaptation' or proactive rather than reactive management of climate change risk. Successful anticipatory adaptation requires the best available information concerning the nature of future climate risks; therefore, it is vital that climate change scenarios are used more effectively in adaptation decision making.

Understanding how organizations are accessing and using climate scenarios is a priority (McNabb & Sepic 1995, Hassol 2008). This is necessary for coordinating climate science applications, as well as facilitating better coordination of donor-funded activities (Nyong 2005, Patt et al. 2007, Wilby 2007). The present study provides an assessment of the extent to which information from climate change models is being integrated into development practice and decision making in agri-

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cultural activities in Africa. Focusing on what is working and what is not working will help to steer future research aimed at supporting adaptation to climate change.

The paper begins by outlining the current availability of climate change scenario information for the support of adaptation activities in the agricultural sector. The methodological approach of the assessment is then introduced, after which the findings present the characteristics and different approaches of organizations using climate change information within the field of agricultural development. The insights from the interview material provide the context for the discussion that highlights the barriers and opportunities that need to be addressed so that climate scenarios can be more effectively integrated into climate change adaptation in Africa.

2. LINKING CLIMATE SCIENCE TO AGRICULTURAL ADAPTATION

Climate change refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer). Adaptation strategies and actions should aim to secure well-being in the face of climate variability, climate change and a wide variety of difficult to predict biophysical and social contingencies. Adaptation is most relevant when it influences decisions that exist in light of climate change and that have consequences on decadal time scales (Stainforth et al. 2007). Annual climate information, such as seasonal climate forecasts, has become widely available, and much research has been done on the opportunities and barriers to using this information in Africa (Ziervogel & Downing 2004, Vogel & O'Brien 2006, Washington et al. 2006, Patt et al. 2007). Yet, in the complex nexus of what actions to take and at what cost, the appropriate use of climate information in risk assessments is still lacking at time scales longer than decades, especially in the most vulnerable areas of the world. Climate change scenarios provide information relevant to planning beyond the next few decades, yet are not widely used. The present paper focuses on why this is so and what might be done to improve uptake.

Over 60% of Africans remain directly dependent on agriculture and natural resources for their well-being (FAO 2003). Agriculture is highly dependent on climate variability (Salinger et al. 2005), which is why the threat of climate change is particularly urgent in Africa (Boko et al. 2007). Despite the reliance of large numbers of the population on agriculture, agricultural development has, historically, not been a priority of governments, ≤1% of average national budgets going to agriculture (FAO 2003). However, many donors and non-governmental organizations (NGOs) have supported agriculture across the continent because of this reliance and the potential to improve yields. The Alliance for a Green Revolution in Africa (AGRA) is an example of such an organization that is supporting agricultural development from funding projects on seeds and soils to markets and policies (www.agra-alliance.org).

In spite of the documented exposure of agricultural activities to projected changes in climate, few agricultural organizations have made use of climate model output. A sound agricultural risk-assessment process should ensure that climate change is appropriately taken into account in planning and decision-making processes. On the basis of available data and information, it is possible to analyze the conditions and trends in climate parameters, from the most basic data (e.g. maximum and minimum temperature and rainfall) to more elaborate indicators (duration of the growing season) to complex indices (satisfaction index of water requirements for the growing season), in order to allow the identification of important thresholds and trigger points on short and medium time scales. This information can be used to assess potential impacts and identify anticipatory adaptation measures, allowing the responses available to be prioritized and compared equitably with other risks, resource availability and other decision-relevant issues. For example, only after a thorough description of any hazard (e.g. droughts) is obtained, can users evaluate the potential future change in these conditions across results of global circulation models. Historical patterns, biophysical constraints, socio-economic dynamics, adaptive capacity and resilience; these are all components that must be considered in determining the nature of adaptation efforts required with respect to climate variability and change. Describing conditions that can be tested in projected results of global circulation models for future changes first requires that these conditions are clearly defined.

The direct application of GCM (global circulation model) output has been relatively limited in impact studies, due to their coarse spatial resolution (which in many cases fails to adequately represent critical regional variations), their temporal resolution (the earliest future time period available for most GCMs — 2045 — is too far into the future for many users), the computational and technical requirements of using these data, and, until recently, difficulties with data access (Hulme et al. 2001). This has led to a growing recognition of the need for climate information at finer scales (Robock et al. 1993, Wilby & Wigley 1997, Islam et al. 2008, Pal et al. 2007, Stainforth et al. 2007). Understanding the relationship between large-scale climate signals and local or regional climate impacts is central to the volume of work aimed at downscaling climate model information for local and regional decision makers. Downscaled output is often a key piece of information for development practitioners, providing an avenue through which they can evaluate the impact of climate change on a specific site or region. Downscaling takes model output from GCMs and interprets them (via statistical techniques such as simple regression or more complex methods like those available in neural networks), in relation to local climate dynamics (Hewitson & Crane 1996, Wilby & Wigley 1997, Wilby et al. 1998, Giorgi et al. 2001, Tadross et al. 2005). Their relationship to each other and modeling in general are depicted in Fig. 1.

Two approaches dominate the downscaling efforts in Africa, each grounded on a specific set of assumptions and methodologies: dynamical downscaling (also known as regional climate models; RCMs) and empirical downscaling. Dynamical downscaling is a computationally and technically expensive method, a characteristic that has limited the number of organizations employing this approach (Rummukainen et al. 2004, Kay et al. 2006). One example, PRECIS, a product of the UK Met Office, until only recently relied exclusively on the GCMs from Hadley Centre, with several other models now in use, and is the most widely used downscaled model in Africa.

Empirical downscaling, which is less computationally intensive, makes use of quantitative relationships between the state of the larger scale climatic environment and local variations sourced from historical data. By coupling specific local observed climate data with GCM output, it provides a valuable solution to overcoming the mismatch in scale between climate model projections and the unit under investigation, which is often a much smaller area than that contained within a grid cell (such as a drainage basin or a coastline). Empirical downscaling can be applied to a grid or to a particular meteorological station. The later sub-set of empirical downscaling is more common and referred to as statistical empirical downscaling.

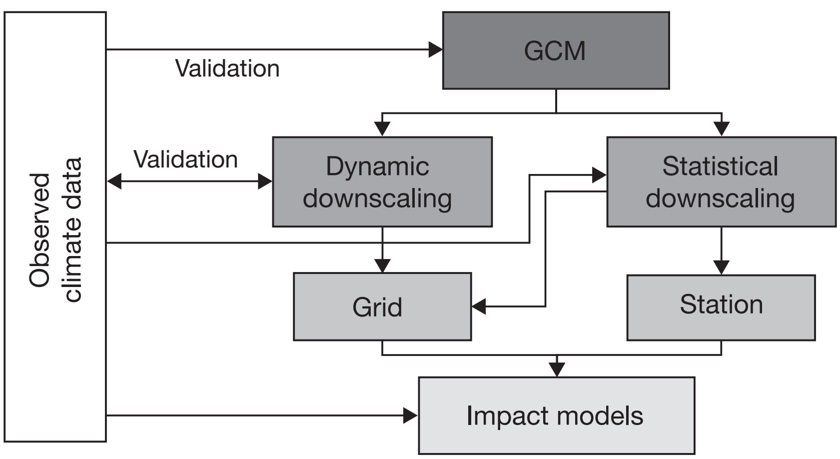

Fig. 1. Overview of different types of climate models. Grid empirical downscaling refers to the spatial interpolation of gridded GCM (global circulation model) and RCM (regional climate model) output

The Climate Systems Analysis Group (CSAG, www.csag.uct.ac.za), based at the University of Cape Town, South Africa, operates one of the few empirical downscaled models used for the whole of Africa, which simulates responses to global climate change at a growing number of meteorological station locations across the African continent. The approach, based on self-organizing maps, explained in detail elsewhere (Hewitson & Crane 2006), relates the daily atmospheric state, determined by historical NCEP (National Centers for Environmental Prediction) re-analysis data, to probability density functions that reflect the stochastic range of local responses. GCM climate change simulations, which project the change in daily atmospheric states, can then be used in the downscaling procedure to project the change in local climate. The approach delivers daily and monthly climate change information, including multiple rainfall and temperature parameters, for multiple models and 2 future time horizons (2046 to 2065 and 2081 to 2100).

Another empirical downscaling approach, statistical downscaling methodology (SDSM) has gained some applicability to Africa (Wilby et al. 2002). SDSM applies a single GCM model and requires the user to acquire historical local climate data in order to run the downscaling. Much of the use of SDSM in Africa has been restricted to students who have applied this approach in their masters and doctoral dissertations. For example, a research project used SDSM to downscale HadCM3 to estimate the impact of climate change on Ethiopia's Lake Ziway's hydrology to 2099 (Zeray et al. 2006). Changes in climate variables were applied to a hydrological model so as to simulate future flows.

Existing adaptation studies and programs have had limited awareness of the availability of downscaled model output. This is gradually changing due to the progress noted above, with a growing number of recent studies benefiting from the downscaled information provided by this and other downscaling approaches (Wilby & Wigley 1997, Prudhomme et al. 2003).

Nevertheless, organizations still tend to reference climate change as a backdrop to their work as opposed to integrating probabilistic future scenarios into their current planning and research approaches. Distinguishing the documented cases of climate change adaptation in Africa from general development and agricultural practice is therefore a challenging task. The impacts of the East African droughts, for example, have been countered in some instances by digging and maintaining sand dams at the bottoms of rivers. The dams allow for continued cattle watering during dry periods and have reduced cattle deaths and conflict. It is not possible, however, to establish climate change as the trigger for the construction of sand dams (or other adaptation measures), and the people constructing sand dams do not draw on climate change scenarios to target locations.

This apparent disconnection between adaptation efforts and climate model output exists in spite of efforts on behalf of climate scientists (including African Centre of Meteorological Applications for Development [ACMAD], Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationelle [AGRHYMET] and CSAG at the University of Cape Town, in Africa, and Walker Institute and Tyndall Centre, in the UK) to make their work more relevant to agriculture and the equally concerted attempts by the impact community to clarify their climate information needs. This can partly be attributed to a lack of understanding among agriculturalists of how climate model output can or should be applied. Many farming groups need to acknowledge how difficult it is to understand, interpret and use climate information. It is equally true, however, that much of the climate modeling work remains focused on gaining greater understanding of atmospheric dynamics and fails to appreciate the types of issues confronted by farmers or the manner in which model output needs to be packaged and communicated so as to make it accessible to agricultural decision makers (see Appendix 1).

3. METHODOLOGY

The study commenced with a literature and web review to identify the key issues and organizations working on climate change modeling and agricultural development[1]. The organizational characteristics were summarized in a database using the following categories: the geographic scale of operation, the organization's focus (whether crop development, agricultural productivity, or a focus on food and livelihoods, for example); whether or not they use data on current climate variability; whether or not they actively use climate change scenarios; and whether or not the institution has developed climate adaptation strategies.

The database facilitated clustering of organizations according to their activities, geographic focus, scale and use of climate data, which enabled identification of the alignment of activities across stakeholders, as well as potential duplications, a task which has been identified as a priority according to previous studies (Nyong 2005, Wilby 2007). Furthermore, the resulting analysis allowed the research team to identify candidates for the second phase of the study, which involved in-depth interviews. Forty organizations were selected[2] across the disciplines of climate science, climate impacts, vulnerability and adaptation, agricultural development and climate variability. Semi-structured interviews were conducted with representatives of these organizations in person and on the telephone between 2007 and 2008.

The questions aimed to evaluate the institution's current and planned climate change strategies, strengths and adaptation pathways. A second objective was to understand how organizations currently access and use climate model output, identifying opportunities for improved delivery of information for adaptation in Africa.

From Fig. 2b it is evident that the study focused on specific donors addressing climate change adaptation. Interestingly most donors are internationally based, as are the majority of climate scientists. The national climate science activity that is taking place is linked to organizations including ACMAD (based in Niamey, Niger) and the ICPAC (IGAD [Intergovernmental Authority on Development] Climate Prediction and Application Centre based in Nairobi, Kenya). The figure shows a lack of adaptation-specific practitioners. Although there are practitioners in the agricultural sector who are exploring climate change impacts and there are climate scientists focusing on adaptation, there is a noteworthy lack of practitioners with knowledge of both climate change and agricultural adaptation.

[1]Including individuals and organizations focused on agriculture, a limited number of organizations supporting climate adaptation, development-oriented donors and agencies, researchers and climate scientists

[2]The researchers attempted to interview most of the organizations in the database that appeared to have an interest or involvement in both agriculture and climate issues, subject to the availability of interviewees. It is recognized that some organizations have presumably been excluded and that involvement in climate change activities is likely to have grown by the time the present paper is published, so the selection is a sample. See Appendix 2 for the list of organisations interviewed

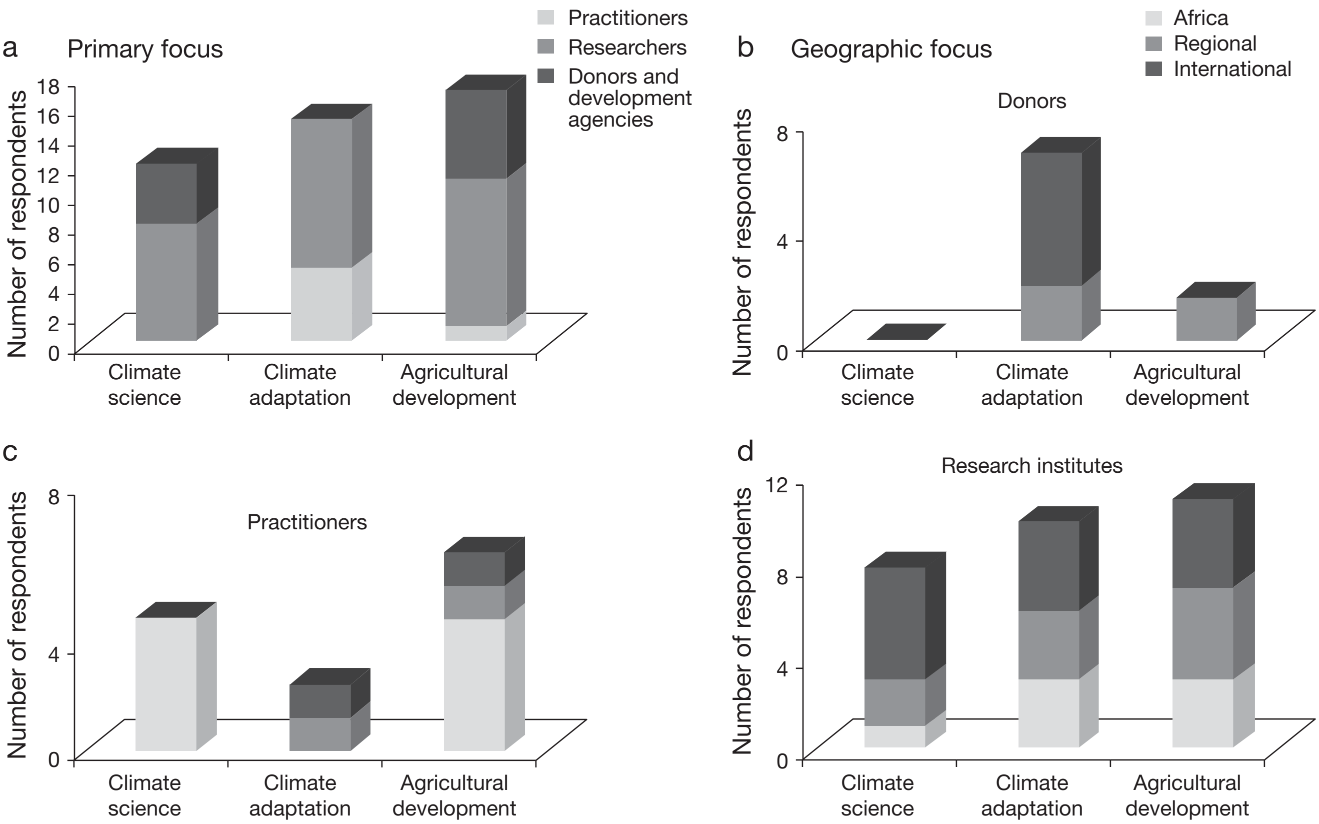

Fig. 2. Summary of stakeholder analyses. (a) Organizations were clustered according to their primary focus—climate science: stakeholders or organizations producing or using climate science in their respective areas of work; climate adaptation: stakeholders or organizations whose work incorporates or focuses on climate change adaptation; agricultural development: stakeholders or organizations whose work focuses largely on agricultural development (organizations interviewed are given in Appendix 2). (b,c,d) Summary of the mandates of respondents by cluster and the geographic focus of their work. Geographic focus — Africa: national activities based within African countries; regional: activities across a region of Africa; international: activities based outside of Africa

4. FINDINGS: THE ROLE OF STAKEHOLDERS IN CLIMATE CHANGE ADAPTATION IN AFRICA

4.1. The role of donors in supporting adaptation

It is clear that adaptation is becoming more widely supported among donors. Government agencies are scaling up their adaptation commitment, and the number of people assigned to work on adaptation is growing. For example, when interviewed the GTZ (German Agency for Technical Cooperation) had 10 people working on climate change, with 2 dedicated to adaptation issues; the USAID (United States Agency for International Development) had 5 people working on climate change issues, with 2 of those focused on adaptation; and the SIDA (Swedish International Development Agency) had just started to intensify their adaptation focus. The World Bank had 15 people in its climate change group, 9 of whom worked on adaptation globally. The United Nations Food and Agricultural Organization (FAO), similarly, had launched a well-attended Inter-Departmental Working Group on Climate Change, with a specific adaptation focus. The number of people and donors working in this field is increasing steadily.

Many donors fund climate change adaptation work in some way. At the national level, the UK Department for International Development (DFID) fund a number of programs focusing on rural economies in Africa. The IDRC (International Development Research Corporation of Canada) and DFID have been supporting a £24 million, 5 yr program called Climate Change Adaptation in Africa (CCAA). The DGIS (Netherlands Ministry of Foreign Affairs/Directorate General for International Cooperation) has assisted developing countries through the Netherlands Climate Change Studies Assistance Program (NCCSAP), which began in 1996; a second phase (Netherlands Climate Assistance Program; NCAP) started in 2003, with the aim of influencing policy. It was active in 14 countries, including 5 countries in Africa.

At a multi-national level, the Global Environment Facility (GEF) provides grants to developing countries for projects that benefit the global environment and promote sustainable livelihoods in local communities. The GEF is an independent financial organization made up of a collaboration between the UNEP (United Nations Environment Program), the World Bank and the UNDP (United Nations Development Program). Assessments of Impacts and Adaptations to Climate Change (AIACC) was one of the GEF's key initial adaptation programs.

Donors are also recognizing the need to develop material to guide adaptation to climate change projects. Both the GTZ and USAID have developed guidance material to support the process of developing adaptation projects and implementing risk management strategies. Donors recognize the need to improve the capacity to communicate climate information and apply available climate information to responses and are starting to address this need.

Although START (Global Change SysTem for Analysis, Research and Training) is not a donor, they manage a number of donor programs that relate to climate change. The START representative highlighted a concern that many development donors are supporting flood, famine and conflict disaster responses and do not see it as their responsibility to support long-term research on climate science and adaptation, even though this research could assist them in their preparation for disasters. At the same time, many science agencies do not fund adaptation on the grounds that they expect this area to be covered by development donors. This leaves something of a gap in the available funding for programs focused specifically on climate change adaptation. As the START representative observed in our interview with him:

'It is important to adapt now but this should be supported by science, which requires science agencies and donors to cooperate more'.

Whilst climate scientists seem to be generally adequately funded, and traditional development agencies are all aware of climate change, there are very few programs specifically focused on linking climate science with adaptation efforts[3]. Instead, most current donor activities aim either to assess impacts and vulnerability to climate change, in order to determine priorities, or to integrate a measure of 'climate proofing'[4] in development projects.

Amongst the donors interviewed, agriculture was often not their main focus. The GTZ acknowledged that there has been a move away from focusing on agriculture to focusing rather on issues connected with nutrition, food quality and access to market. The SIDA has explored how adaptation to climate change can be integrated into poverty alleviation approaches within different sectors. The USAID has supported some agriculturally focused activities and explored what additional challenges climate change may present. The DFID maintains an agricultural focus in eastern and southern Africa, but, at the request of West African governments, has moved its focus in that region to urban issues.

To some extent the gap in funding for adaptation-specific activities is being filled by private sector funders. There has been a discernible increase in private sector funding for development and climate change activity. In the past 5 yr the activities of the Bill and Melinda Gates Foundation, the Google Foundation and the Rockefeller Foundation, among others, have moved beyond conventional corporate social responsibility and begun to engage systemically with global issues.

4.2. The state of research around climate change adaptation

Since the ratification of the United Nations Framework Convention on Climate Change (UNFCCC), various international research programs have been initiated in order to develop the capacity of developing countries to cope with the effects of climate change. Typically, these research programs are a collaborative effort of many different organizations involving research institutes, NGOs, as well as governmental organizations.

On the climate science side, the Intergovernmental Panel on Climate Change (IPCC) is the preeminent source of climate change information. The IPCC reviews and collates research on a range of climate-change-related issues and records climate data in its data distribution centre (DDC). No African climate research organizations are involved in producing GCM models. Because of the lack of the necessary tools, both human and instrumental, Africa depends, to a very large extent, on organizations based in Europe and North America for its operational climate forecasting capacity. Three organizations—the NOAA (National Oceanic and Atmospheric Administration, USA), UK Met Office/Hadley Centre (UK) and the CNRS (Centre National de la Recherche Scientifique, France)—routinely make seasonal climate forecasts for Africa based on their respective GCM models. Among these 3

[3] CGIAR (Consultative Group on International Agricultural Research) has requested funding for a program and Michigan State University's CLIP (Climate-Land Interaction Project) draws on local climate science

[4] 'Climate proofing' whilst in common use in the development discourse, is not a term that the authors support on the grounds that it is very difficult to predict all climate change impacts and then secure projects and programs against climate change. Whilst most development organizations recognize this, the term endures. 'Climate preparedness' might be more appropriate

institutions, the Hadley Centre, and specifically their dynamically downscaled PRECIS model, is the most widely consulted, especially in southern Africa.

Within Africa, a number of organizations engage in climate work, although the need for regional modeling and downscaling of GCM outputs is yet to be adequately met from within Africa. The ICPAC, based in Nairobi, Kenya, is a regional climate center that was established in 1989 as the Drought Monitoring Centre in Nairobi (DMCN) in an effort to minimize the negative impacts of extreme climate events like droughts and floods along the Greater Horn of Africa. The major goal of the ICPAC is to improve and enhance the production and provision of sector-relevant climate information and applications in the region, focusing on decadal (10 d), monthly and seasonal forecasts. Whereas the focus of the center is primarily on the production of information about climate variability, the ICPAC has recently also started to work on generating climate change projection data, mainly through the use of the PRECIS dynamical downscaling model.

The ACMAD focuses on weather forecast information and does not yet interpret climate predictions from the model products. The CSAG is the only African institution currently engaged in empirical downscaling activities for climate change. In 2009 the CSAG made available downscaled data from 10 GCM AR4 (IPCC 4th assessment report) models, including downscaled daily data for the A2 scenario and for the 2046 to 2065 and 2081 to 2100 periods.

The National Center for Atmospheric Research (NCAR) has used the MAGICC/Scengen software package for future climate change prediction and, particularly, in drawing out the sources and magnitude of uncertainty (see Wigley 2004). The downscaled climate model applies a regionalization algorithm. It takes emissions scenarios for greenhouse gases, reactive gases and sulfur dioxide as input and gives global mean temperature, sea level rise and regional climate as output. The software also quantifies the uncertainties in these outputs. The regional results of the model are based on results from 17 coupled atmosphere–ocean general circulation models (AOGCMs), which can be used individually or in any user-defined combination (Hulme et al. 2000).

One continental effort to support climate observations, climate risk management and climate policy needs in Africa has been led by Global Climate Observing System (GCOS). An initial report, funded by the DFID and Defra (the UK Department for Environment and Rural Affairs), produced prior to the UK Presidency of the G8, reviewed Africa's science gap and the measures needed to reduce it. The report showed that we know remarkably little about Africa's climate and that the climate-observing system for Africa is the least developed of any of the continents and is deteriorating. The level of technical expertise available to support climate science in Africa, and, hence, the level of activity, is very low (Wilby 2007: p. 3). This process led to the emergence of ClimDev (the Climate for Development in Africa program; described further in the Section 4.3 below).

Research organizations focused on agriculture have started to explore links to climate change. The CGIAR (Consultative Group on International Agricultural Research), with a secretariat in Washington, has an exclusive agricultural focus (including forestry, fisheries, aquaculture, water management), and the bulk of the CGIAR's climate change work is aimed at Africa, supported through the Challenge program. When interviewed, they were developing climate change adaptation programs. The FAO has a widespread presence in Africa. They recently launched a climate change adaptation strategy, signaling internationally the FAO's intent to engage in climate change adaptation. The FAO has access to a wealth of agri-met data, but does not specifically apply climate change projections in its agricultural support programs. The ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), with regional hubs in Niger and Kenya, has used regional IPCC data to explore the impact of a 3°C warming on a variety of crops. Some of these IPCC data were obtained from the download options available from the DDC.

There are a handful of organizations that are trying to work across the science–society boundary. The Stockholm Environment Institute (SEI), which specializes in sustainable development and environment issues across scales, has supported and been involved in numerous adaptation projects (Thomalla et al. 2006, Klein et al. 2007, Ziervogel & Taylor 2008). The SEI Oxford center has recently been working on a collaborative platform for climate adaptation, weADAPT, that includes climate scientists, academics, practitioners and policymakers. This has involved developing novel approaches to link risk of future climate change, viewed within a multi-stressor context, to robust adaptation actions, supported by a range of stakeholders.

START International is another institution that has worked across the sciences and social sciences by supporting research activities in Africa, consistent with critical environmental priorities on the continent, which include food and water security and vulnerability to climate change impacts (Leary et al. 2008). START fosters regional networks of collaborating scientists and organizations in developing countries to conduct research on regional aspects of environmental change, assess impacts and vulnerabilities to such changes, and to provide information to policy makers.

START also provides a wide variety of training and career development opportunities for young scientists.

A more focused cross-disciplinary research approach has been undertaken by Michigan State University (MSU), which has a longstanding partnership with the International Livestock Research Institute (ILRI), based in Kenya. ILRI and MSU have conducted several joint programs in East Africa looking at local interactions of land use and climate (Smucker et al. 2007, Alagarswamy et al. 2008, Thornton et al. 2008). MSU's flagship adaptation project, CLIP (Climate-Land Interaction Program), focuses on unraveling the complexities of the climate system and the ways in which it is interacting with the biophysical environment. Researchers have developed a unique coupled modeling system integrating human behavior and biophysical factors that traces current and future land and climate change in East Africa, allowing for geographically explicit analyses of the impacts of land use and climate change on natural and agricultural systems (Torbick et al. 2006, Olson et al. 2007).

Even though it is hard to generalize about the different programs, a shift seems to have taken place in the past 18 mo, from a primary focus on understanding the nature of climate change towards the question who is vulnerable and why. More recently, a further shift has taken place towards increased attention to policy-relevant applications and the question of how to adapt. To some extent, these shifts are in line with the current developments in the climate change debate, which has gradually moved from a focus on awareness raising about the reality of the problem towards a focus on how to respond. Yet, the adaptation responses, whether focused on policy or practice, are not yet integrating climate science to the necessary extent.

4.3. Stakeholders involved at the grassroots level

The practitioners involved in actual adaptation initiatives appear to be fewer than those involved in research, but a number of agricultural programs have designed adaptation components.

United Nations Institute for Training and Research (UNITAR) is managing the implementation of the ACCCA (Advancing Capacity to Support Climate Change Adaptation) program with the scientific support of a network of partners. Through research and implementation, the ACCCA program seeks to support effective adaptation decisions for the reduction of vulnerability to climate and environmental change. There are projects in 19 countries, 14 of which are situated in Africa. Building upon past experiences, the program emphasizes the importance of developing strategies for communicating climate risk information in a way that is clear and understandable for policymakers.

ClimDev aims, among other goals, to improve the availability, exchange and use of climate information and services in support of economic growth and achievement of the Millenium Development Goals (MDGs), working at national, local and regional levels, through improving climate observing networks and services in Africa.

The FAO has conducted pilot studies in a number of member countries, typically with local ministries of agriculture. The pilot studies have various aims, but broadly seek to combine better use of information with improved technology and greater care for the natural environment, so as to deliver enhanced and less risky agricultural production. Whilst FAO pilot studies are beginning to consider the implications of climate change, they do not make systematic use of downscaled climate data in their planning.

SouthSouthNorth (SSN), which has operated as both a local NGO (SSN Africa) and an international network (SSN group), was initiated in 1999, but has recently wrapped up its operations. Members worked on both adaptation and mitigation projects. Other stakeholders that fall under this category, but are not outlined in detail include World Vision, ENDA-TM, ALMP (Arid Lands Resource Management Project), AGRHYMET and FEWSNET (Famine Early Warning System Network).

In addition there are a number of private sector consultancies active in the field of climate change adaptation, and some NGOs now sell their services in this field alongside consultancies on a wide range of matters including social learning, emissions management and trading, bioenergy and capacity building. Examples include OneWorld Sustainable Investments, Environmental Resource Management (ERM) and D1 oils.

5. DISCUSSION

Although there is growing awareness of and references to climate change, much of these are based on media messages, or highly aggregated model output from the IPCC (DDC) and GCM models. The link between climate change information and adaptation practitioners on the ground remains largely non-existent, and many adaptation practitioners in the agricultural sector still rely on generalized assumptions about how the climate will change or they derive very general information about climate change and its impacts from IPCC reports, as they are unaware of where to access more detailed data and how to interpret it. Those who do access model output tend to rely on only one model creating the risk of drawing unsubstantiated, or at best sub-optimal, inference. Decisions are, more often than not, based not on that model's suitability to the research problem or adaptation challenge, but on its ease of access and use, with adoption by simple word of mouth the extreme — but nevertheless plausible — case. Only rarely have researchers provided a science-based rationale for choosing one model over another. It is clear that there is a long way to go before climate change scenarios are used effectively in developing adaptation strategies.

Although some respondents view climate change data as useful, other respondents suggested that there is a lack of perceived relevance of climate model data for agricultural stakeholders, which is why these data are not used more widely. Similar challenges were experienced when seasonal climate forecast information was disseminated for agricultural use (Patt & Gwata 2002, Vogel 2000, Archer 2003, Ziervogel 2004, Vogel & O'Brien 2006). Agricultural decision makers require information on a range of matters in order to manage their businesses and programs. Making the link between the type of data that are reported by climate change models (projections up to 2100) and the type of data that they perceive as being important to their activities (market demands, price, cost of inputs, labor availability, short-term weather) is not always possible, or, in some instances, is not considered a priority. Indeed, it posits a great challenge that is difficult to overcome.

In order to monitor progress on how climate change information is used, there needs to be a comprehensive baseline that characterizes and contextualizes the current adoption of climate change information in Africa's agricultural sector. Currently, contextualization is hampered in 3 ways. First, there appears to be a general tendency to isolate the climate change impacts from the broader context in which developments are taking place. There are several examples where climate change is assumed to be causing negative trends without considering the possible importance of other drivers. For instance, the ICRISAT respondent noted an example from the Machakos district in Kenya, where pastoralists blamed climate change and decreasing rainfall for decreasing crop yields, opting to downplay the detrimental effects of overgrazing on pasture resources. The meteorological records, however, indicated that rainfall had been increasing rather than decreasing. This illustrates the importance of putting climate change in a broader context, taking into consideration other possible (and often more directly probable) causes and explanations. Lack of understanding of these other drivers of change might unintentionally lead to misdirected projects and, in the long run, to 'maladaptation'.

Secondly, the vulnerability context is often not understood. Respondents from both SEI and START, who have provided technical support on climate vulnerability and adaptation projects in Africa, highlighted the tendency for organizations to adopt the adaptation mandate without first clearly understanding the climate change and vulnerability context. Many organizations tend to take certain climate impacts and vulnerabilities for granted without exploring which climate parameters and conditions are actually responsible for specific vulnerabilities to climate change and how these parameters and conditions might change under future scenarios (Ziervogel & Taylor 2008). This might again lead to misdirected adaptation and development measures.

Thirdly, climate change adaptation efforts often fail to contextualize climate change risks within the set of other climate information used in decision making, including historical data, real-time data and traditional knowledge, all of which are currently used and available to support decision-making processes. In fact, there seems to be an apparent tension between people working on future climate change and those focusing on current climate variability. Some climate change professionals argue that, although focusing on current climate variability might equip agricultural decision-makers over a short time horizon, they might then be caught off guard by climate change, particularly where the changes brought about by climate change are significant and can be abrupt. In modeling parlance this problem is viewed as distinguishing the climate change 'signal' from the climate variability 'noise'. In contrast, those who focus on climate variability claim that unless farmers in Africa can be helped to cope better with current climate variability, the challenge of adapting to future climate change will be daunting for most and impossible for many. We argue that these approaches are complimentary, rather than mutually exclusive, and they must, eventually, be integrated. A small-scale farmer, for instance, will be interested in seasonal climate forecasts that outline the expected rainfall in the coming season in order to make a decision on what crops to grow (Patt & Gwata 2002, Ziervogel et al. 2006). It should come as no surprise that these farmers do not prioritize climate change projections in their decision making. A crop breeder, on the other hand, might benefit more from an understanding of climate change patterns in the next 20 to 30 yr, because of the time delay between the development of new crops and the actual distribution and use. In this case, an understanding of climate change scenarios would be beneficial. Similarly a donor agency looking to promote sustainable rural development would be interested in climate-change-induced shifts in agro-ecological zones over a 10 to 20 yr period, so that their current initiatives are not undermined by future change.

It is clear that, in addition to capturing baseline information, there is a need to support increased development and uptake of downscaled climate change projections and multi-model approaches in Africa. All climate change modelers interviewed agreed that one of the main barriers to producing climate change information remains the lack of reliable meteorological data. This is especially true for complex environments in which higher concentrations of station data are needed to capture the complexity of the terrain. While many African countries have established extensive monitoring networks in the course of the 20th century to support daily weather forecasting, economic difficulties in the region, not to mention civil wars, have led to the deterioration of these networks in recent years. In fact, there are fewer rainfall monitoring stations in many African countries now than there were 20 or 30 yr ago (Washington et al. 2006). Ultimately, the lack of sufficient and clean historical data renders the task of developing sound and robust downscaling models difficult.

Another reason for the limited uptake of climate change information is the lack of capacity, both in terms of human resources and computational capacity, to expand the available databases. Running dynamical downscaling models requires considerable computational capacity. Currently CSAG and a handful of other organizations (including ICPAC and ACMAD) have some basic infrastructure and human resources in place. More needs to be done to support theses institutes in their evolution into fully fledged climate modeling centers.

Despite these barriers and shortcomings, the state of climate science and modeling has reached a point where it is able to adequately support local decision-making processes. This point was supported by representatives from START, SIDA, DFID and CSAG. The critical focus, however, should be placed on the development of sector-specific methods and examples of how the climate model output could be utilized to support robust adaptation responses. The modeling community needs to focus on expanding the modeling efforts within Africa, while working closely and interactively with the users of model information in the interpretation and understanding of climate model output.

For farmers and other agricultural decision makers, there are costs and risks involved when modifying their age-old activities and practices in order to adapt to what models indicate will happen. Some farmers and program operators noted that it makes more sense to react to observed (or historical) changes in weather than to alter their activities based on a predicted climate risk. It is further true that many decision makers are unable to contextualize the uncertainty that is inherent in climate projections and, therefore, stick to what they know. The reality is, however, that most models concur on the near-term direction of change. If used with the correct caution, these models can provide a sound, scientifically grounded basis for decision making. The challenge comes in the timing of the adaptation response, as it is unlikely that the models will be able to provide enough information on when the threshold will be crossed; thus, farmers will need to decide on timing themselves.

Increasing uptake is going to require bridging the gap between what scientists produce and what end-users require. The DFID representative pointed out that the majority of climate model data available have been produced without due consideration to the specific (and admittedly diverse) needs of the people that might need to use them and, therefore, is packaged in a way that makes it difficult for practitioners to utilize. A farmer, for example, may be less interested in mean annual temperature, but would be very interested in knowing how many years in an orchard life-time of say 25 yr sub-optimal rainfall or extreme temperatures might be expected, and how this number of years can be expected to change. This might be impossible to infer from a reported temperature increase, especially when the relationship between extremes and averages is not established.

Bridging the gap between climatologists and end-users will require augmentation of the people and organizations able to interpret and communicate this information effectively. These translation skills (of so-called boundary organizations) are necessary in order to engage a wide range of stakeholders with specific needs, as the limited number of climate scientists in Africa are unable to develop their science at the same time as meeting the growing need for model output interpretation and communication (Vogel et al. 2007).

At the same time, input from African scientists is needed to drive the climate change agenda. Currently, the growth in climate adaptation and agricultural development activity in Africa has been mobilized from outside of Africa, rather than from within. The GTZ respondent suggested that projects have emerged in response to foreign funding and so are 'supply driven'. He emphasized the need to be more focused on 'demand driven' approaches that address locally identified needs. It does not have to be one or the other, but rather flexibility is needed to enable demand-driven approaches to emerge alongside supply-driven approaches and in doing so promote buy-in (i.e. acceptance) from a wider local community.

In conclusion, as adaptation rises in prominence on the international agenda, so does the need to increase and, in many cases, develop the requisite competency for the use and interpretation of climate change scenarios to support informed decisions. A particular challenge for those tasked with the design and implementation of adaptation projects is in leveraging the best available data and synthesis tools to understand how the expected climatic changes will exacerbate or induce vulnerability of different activities under a changing climate. To date, few tools or exercises provide the much needed climate change information relevant to decision makers. Most discouraging is the paucity of work conducted at the nexus between climate scientists and those concerned with making decisions. It is against this background and with the ultimate goal of improving the understanding, packaging, delivery and communication of climate change scenarios that the present study intended to set a process in motion that will encourage the exchange of information among providers of climate data and users (Ward 2008).

The present study offers valuable insight into the challenges and opportunities for using climate change scenarios in agricultural decision making in Africa. Lessons from agricultural development stakeholders are likely to be relevant to other sectors, although further exploration is needed to establish the extent to which stakeholders in other sectors are using climate-change scenario information. Sustained communication and use of the data across organizations and disciplines will contribute to the development of linkages between information users and data providers in targeted ways. The authors expect that the analysis presented will contribute to the required paradigmatic shifts: from supply-driven activity to a user-focused understanding of the needs of decision makers according to long-term climate data. Providing data relevant to decision makers will support the development of appropriate climate change adaptation practice and policy that is particularly urgent for Africa's most vulnerable groups.

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Appendix 1. Uncertainty and interpretation in climate science

An important component of climate change science involves the description, understanding and representation of the inherent uncertainties in the modeling efforts (Stainforth et al. 2007). Whilst it is known that some models are more 'skilled' at predicting specific parameters in certain regions, without a comprehensive exploration of multiple model outputs choosing a single model for a specific region is not advisable (IPCC 2007). An analysis of a large set of models (also referred to as an 'ensemble' of models), rather than a single model, is currently the most robust approach applied to addressing the uncertainty inherent in making a decision that is influenced by the future evolution of the climate system, which is not entirely known or understood. These 'envelopes'—as the range of multiple model outputs are called — of climate change help define the climatological boundaries of potential climate change from a wide range of scenarios and ought to include an exploration of various scientific uncertainties. They are driven by the search for climate spaces that are relevant to the needs of specific localities and sectors (Hulme & Brown 1998, Stainforth et al. 2007).

Whilst envelopes do not provide the type of discrete answers that some decision makers seek, they do offer decision makers with valuable perspectives on what might be expected, which, in turn, can be used to attach the appropriate level of confidence to models and associated decisions. Wrongly assumed confidence levels in climate scenarios can be as dangerous (sometimes more dangerous) than having no projection at all. Fig. A1 provides an example of the envelope approach by considering 7 different downscaled precipitation anomaly scenarios for Bougouni, Mali. The outer range (light blue and purple lines) of the combined model projections provides the 'envelope' within which precipitation is expected to change in the early 21st century (to 2065). As such, it is the best estimate of expected future changes.

It is in large part due to the issues outlined above that adaptation activities in the agricultural sector in Africa have focused more on perceived climate variability rather than climate change. Seasonal forecasting and drought early warning systems are increasingly used (especially among livestock farmers) on the continent (Benson & Clay 1998, Gadain & Funk 2003, Hudson & Vogel 2003, O'Brien & Vogel 2003, Johnston et al. 2004, Ziervogel et al. 2006, Patt et al. 2007). Whilst responding to historical change has proven worthwhile, there is a danger that farmers, agricultural policymakers, crop breeders and government officials who structure their activities around short-term climate variability will be caught unaware by the trends in climate change and their longer term implications.

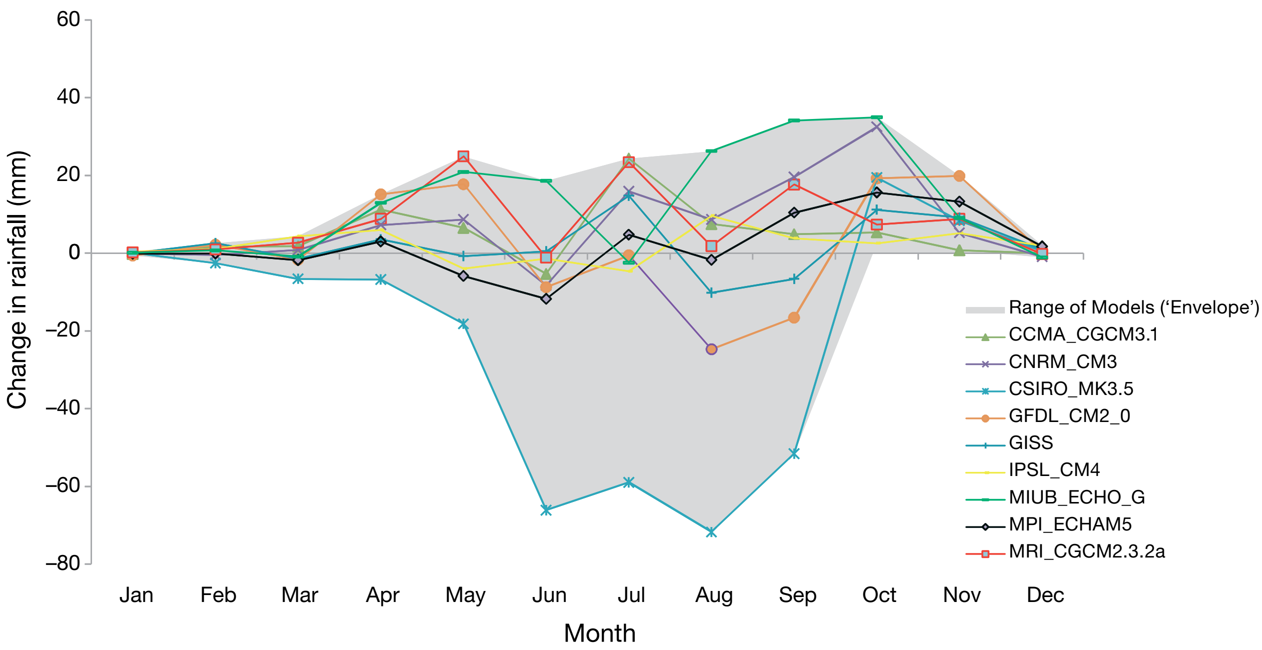

Fig. A1. Average monthly projected changes in rainfall, Bougouni, Mali (2045–2065) by model. Different colors represent different model projections according to the key; 2 additional curves (triangle symbols) represent the envelope range of the output. This output, from the Climate Change Explorer developed as part of the weAdapt platform (www.weADAPT.org), indicates model agreement in the changing distribution of rainfall from May through September, which comprises the growing season for this region in Mali, but less agreement for the start of the season in March. The graph clearly indicates that the changes are not uniform across the season, with agreement among models concerning the expected increase in rainfall in the middle of the year

Appendix 2. Organizations interviewed

Climate science

J. K. University, Kenya (ACCCA project — Advancing Capacity to Support Climate Change Adaptation); Federal Univ. Technology, Akure, Nigeria; Climate Systems Analysis Group, University of Cape Town; Michigan State University; SDSM (Statistical Downscaling Methodology); Tyndall Centre; Walker Institute for Climate Systems research; GCOS (Global Climate Observing System); Zambia Meteorological Services; ICPAC (IGAD Climate Predictions and Applications Centre); ACMAD (African Centre of Meteorological Applications for Development); Nigeria Ministry of Environment (special climate change unit).

Climate adaptation

GTZ (German Agency for Technical Cooperation); SIDA (Swedish International Development Agency); USAID (United States Agency for International Development); DGIS (The international cooperation department of the Netherlands Ministry of Foreign Affairs); DFID (UK Department for International Development); ACCCA project Burkina Faso; ACCCA project Malawi; Zambian Red Cross Society; Ministry of Environment and Sanitation, Mali; CLIP (Climate-Land Interaction Project) and EACLIPSE (ILRI); CCAA (Climate Change Adaptation in Africa); LEAD Network; START (Global Change System for Analysis, Research and Training); SEI (Stockholm Environment Institute); IIASA (International Institute for Applied Systems Analysis); IIED (International Institute for Environment and Development); SSN (SouthSouthNorth) Africa, SSN Group.

Agricultural development

DFID; Buea University (ACCCA) project; Cameroon; Lake Chad Research Institute; University of Pretoria, Economic Department; Centre for Arid Zones Study; IAR&T (Institute for Agricultural Research and Training); IITA (International Institute for Tropical Agriculture); AGRA (Alliance for a Green Revolution in Africa); AERC (African Economic Research Consortium); CGIAR (Consultative Group on International Agricultural Research); ICRAF (International Centre for Research in Agro Forestry); ALMP (Office of the President, Ministry of State for Special Programmes, Arid Lands Resource Management Project); Jabenzi; World Vision; FAO (UN Food and Agriculture Organization); FEWSNET (Famine Early Warning System Network); AGRHYMET (Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationelle).

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