Climate variability and change in Africa: a review of potential impacts on terrestrial water resources

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Abstract The climate in many parts of Africa may be classified as arid and semi-arid, with recurrences of severe droughts. The livelihoods of many in the society are largely nomadic pastoralist. The economies of many states in areas that receive reliable rainfall rely heavily on rain-fed agriculture. The Intergovernmental Panel on Climate Change (IPCC) assessment indicates that both droughts and floods have increased in frequency and severity in recent years, and are projected to increase in the future at many locations world wide, with far reaching implications on the demand and availability of quality freshwater resources. Increased recurrences of droughts in the future will force agriculture in Africa to introduce new demands for clean water through increased irrigation for sustainable agricultural production. IPCC (2007) has shown that the African continent is the most vulnerable continent to climate change. Other future challenges to freshwater availability in Africa include pollution by human activities, together with the ever-increasing demand for clean water by the fast-increasing population of the continent. Climate change will thus introduce new challenges to sustainable freshwater availability, conflicts/security and the general sustainable development of the continent of Africa in the 21st century. This paper provides some highlights of the climate variability and change in Africa, and some of the potential impacts on terrestrial hydrology. Lessons and experiences from the African regional climate centres in integrated climate risk management for coping with current climate variability and adaptation to future climate changes are also reviewed.

Key words terrestrial water resources; hydrology; ICPAC; regional centres; drought; climate variability; climate change

INTRODUCTION

Water is life, and is essential for sustaining all human socio-economic development activities, including hydropower generation, health, industry, tourism, agriculture and food security, and livestock systems, among many others. Precipitation and other climate parameters are important components of the hydrological cycle and the general balance of the available freshwater resources. In Africa, the distribution of precipitation is very uneven in both space and time. The climate of much of the continent can be classified as arid and semi-arid, receiving less than 700 mm of precipitation each year (Ogallo, 1988, 1994; Nicholson, 2000). Extreme arid conditions are found in both northern and southern parts of the continent (Sahara, Kalahari). The arid areas have limited surface freshwater resources, apart from locations near large rivers such as the Nile and Niger that flow through arid lands.

Substantial inter-annual variations in precipitation are observed throughout Africa (Ogallo, 1979; Nicholson, 2000). In some years extreme events (floods, droughts) lead to too much or too little surface water with far reaching physical, environmental and socio-economic impacts. In many countries of Africa a single drought or flood can draw back by many years national socio-economic development growth. Climate extremes are also linked to many regional conflicts and insecurity when societies compete over limited water, food and grazing lands. The recent IPCC Fourth Assessment Report indicates that climate change is real and that pollution from human socio-economic development activities are responsible for the observed anthropogenic climate changes. The IPCC assessment indicates that both droughts and floods have increased in frequency and severity in recent years, and are projected to increase in many areas of the world, with far-reaching implications on the demand and availability of freshwater resources. IPCC (2007) has further shown that the African continent is the most vulnerable continent to climate change. Climate change is therefore a key challenge facing sustainable freshwater availability, security and the general sustainable development of the African continent in the 21st century. This paper discusses climate variability and change in Africa, and some of the potential impacts on terrestrial hydrology.

CLIMATE VARIABILITY AND CHANGE IN AFRICA

Evidence of climate variability and change in Africa has been derived from instrumental climate, geological, remote sensing, and proxies of other climate sensitive parameters by various authors (e.g. IPCC, 2001). Climate modelling also provides complex tools that can be used to address various aspects of climate sensitivity. Details of these tools and methods are well documented by IPCC (2007). The results from the recent climate studies in Africa have shown among others that:

– increase in the mean temperature of the continent in recent years;
– increase in both maximum and minimum temperatures at many locations;
– rapid melting of the glaciers in the African glacial tropical mountains. The gradual dramatic disappearance of glaciers on Mount Kilimanjaro has been associated with global warming (IPCC, 2007); an estimated 82% of the icecap that crowned the mountain when it was first thoroughly surveyed in 1912 is now gone and according to recent projections, if recession continues at the present rate, the majority of the glaciers on Mount Kilimanjaro could vanish in 15 years;
– declining/increasing trends of rainfall at some locations including the Sahel (Tarhule & Lamb, 2003; Wang *et al.*, 2004); and
– declining levels of many lakes (Trauth & Strecker, 1996; Nicholson 1998, 1999; Cohen *et al.*, 2000; Osborne, 2000; Nicholson & Yin, 2001).

Apart from the long-term climate trends, there is substantial inter-annual variability in climate in Africa leading to droughts and floods with far reaching impacts. Recent observations show severe droughts being followed directly by severe floods or *vice versa*. Such climate extremes are linked to El Niño Southern Oscillation (ENSO) and dipole systems such as the Indian Ocean Dipole. Climate change leading to changes in the space-time patterns will bring new risk levels on society and livelihoods, water resources, ecosystems, and other natural resources that will threaten Africa's development and require new or modified adaptation strategies.

POTENTIAL IMPACTS ON TERRESTRIAL HYDROLOGY AND THE NEED FOR ADAPTATION

Precipitation, evapotranspiration, extreme events such as floods/droughts, and other climate parameters are important in addressing issues related to the hydrological cycle and the general balance of the available freshwater resources including groundwater recharge. Large variations in precipitation over the continent are also reflected in the distribution of surface water resources over Africa. With the uneven distribution of precipitation and surface water resources, groundwater resources drawn from springs, boreholes, and dugwells are critical in Africa as they support domestic water supplies and other socio-economic development including irrigation for agriculture, livestock, tourism industries, and other activities. It is also the most reliable water source for many urban centres.

Increasing population growth associated increasing water demands, environment degradation, pollution, and other human activities, also threaten the sustainability of the available water resources in Africa and will further continue to contribute to climate change. Figure 1 highlights the potential impacts of climate change on the hydrological cycle. Climate change will impact on almost all components of the hydrological regime in Africa, including water quantity, quality, and demand, with devastating socio-economic consequences. Changes in precipitation will, for example, affect the levels of water storage in lakes and reservoirs, as these respond to climate variability. Impacts of climate change can further affect surface runoff, soil moisture, and other changes that could lead to problems for the future clean water resources in many parts of Africa. Various studies show that both rainfall and streamflow both exhibit increasing and decreasing trends, but not all streamflow trends can be attributed to climate change. Some changes stem from land-use change and increased groundwater abstraction.

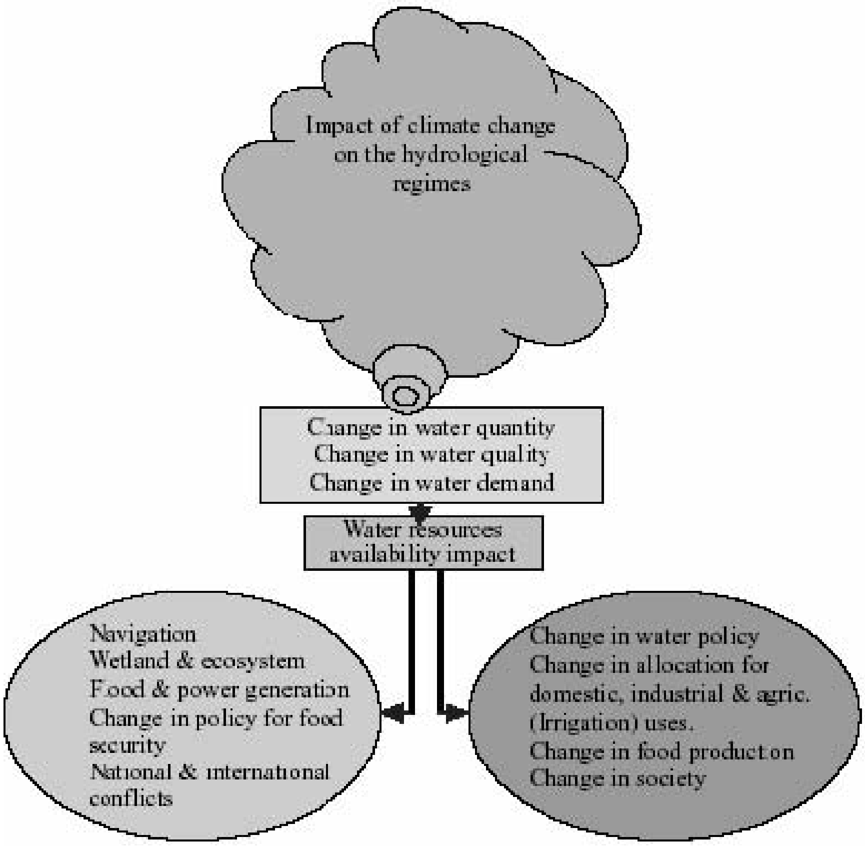

Fig. 1 Impact of climate change on the hydrological cycle (Ragab & Prudhomme, 2002).

The impacts of climate change, including changes in the patterns of the extreme events, have potential to destabilize livelihood systems and future development activities. It is expected that if society can cope with the current climate variability shocks, then it has a high probability of adapting to the impacts of future climate change. The threats posed by climate change increase the urgency of promoting adaptation strategies for sustainable management of the available water resources.

There is therefore an urgent need for Africa to develop realistic adaptation options to reduce vulnerability and cope with the consequences of climate change. Adapting to current climate variability and future climate changes requires the development of systems that are capable of adapting to current climate shocks, and at the same time integrate future climate change risks in society, economic and environment systems in order to ensure sustainability of social, economic and environment systems. Climate change will not be uniform in Africa, even within specific countries. There will be significant variations in both space and time. Adaptation strategies in Africa must recognize these large regional variations.

Adaptation strategies need to integrate climate variability/change concerns into the national planning and development processes. These require good knowledge of the past, present and future expectations of climate shocks. This will also require wide-ranging changes in government policies, including increased capacity in research, science and technology, and formulation of policies that are sufficiently flexible and receptive to constant change.

For the development of realistic adaptation strategies, there is a need for demonstration programmes/projects that employ well-reasoned projections of regional climate. The limited availability of realistic regional and local-scale scenarios is currently a major challenge to adaptation studies in Africa. Other critical issues needed to address adaptation challenges of the region include education and public awareness, institutional arrangement and networking. There is a need for formulation of actionable adaptation strategies that could support adaptation initiatives by vulnerable countries and communities. Resource mobilization strategies are critical in any adaptation strategy. Many of the adaptation needs are cross-cutting and may require demonstration projects and strategic partnerships/alliances amongst various sectors at national, regional and international levels. In general, technology and technology transfer will play a pivotal role in adaptation, alongside public policies that restructure the incentives and regulatory systems that govern energy generation and consumption. The integration of indigenous technologies that society in Africa has used to adapt to past climate shocks must also be considered.

LESSONS AND EXPERIENCES FROM ICPAC AND OTHER REGIONAL CENTRES IN AFRICA

Even without climate change, Africa is very vulnerable to current climate extremes such as the recurrent droughts and floods (Hulme, 1992; Hastenrath, 2001). Today, extreme climate events such as floods and droughts severely impact economic, social and environment systems in Africa. Such impacts lead to community conflicts over limited resources such as food, water, and grazing land; environmental refugees through mass displacement of communities and their domestic animals; loss of life and property; destruction of infrastructure; massive losses to livelihood systems, forcing communities to depend on emergency food relief; health issues including the presence and absence of vector- and water-borne diseases such as malaria, environmental degradation, and negative economic growth among many other socio-economic miseries. These have partially contributed to retarding economic growth in many countries in Africa. Furthermore, many floods/droughts in the region are often preceded or followed by severe extremes of the opposite nature, especially when such extremes are linked to El-Niño, La-Niña among other climate systems, some of which are now predictable with reasonable skill (Tarhule & Lamb, 2003).

Specially tailored climate services enhance decision-making in many socio-economic sectors, including groundwater resources planning and management. It is expected that if society can use such climate information to cope with current climate variability shocks, then it has a high probability of coping with the impacts of future climate change. In this regard, effective use of climate information is important for any sustainable hydrological system. Climate products required for adaptation for the hydrological systems can be grouped into three large categories, namely past, present and future climate information. Future climate information requires regional/local-scale scenarios for climate change impacts, vulnerability and adaptation studies.

Africa has a number of institutions that are capable of helping it address all aspects of climate risks ranging from current variability to future climate changes. These include the African Centre for Meteorological Applications for Development (ACMAD) located in Niamey (Niger); IGAD Climate Prediction and Applications Centre (ICPAC) located in Nairobi (Kenya); and Drought Monitoring Centre-Harare (DMCH), currently located in Harare (Zimbabwe) but being relocated to Gaborone (Botswana). These centres work closely with National Meteorological and Hydrological Services (NMHSs), and regional/national sector specific centres such as Agrometeorological and Hydrometeorological (AGRHYMET). The centres produce several climate products for addressing past, present and future climate risks. The climate prediction and early warning products of the centres include, among others, 10-days, monthly and seasonal rainfall outlooks. Most of these are derived from empirical methods that rely largely on sea surface temperatures, El Niño/Southern Oscillation (ENSO) and related variables. Products from General Circulation Models (GCMs) and high Regional climate models are also used in the three centres, but most of these products are based on model runs from the collaborating advanced climate centres of the developed countries. The skills of the models have been very high, especially for the months of June–December, and especially when there are persistent large-scale sea surface anomalies, as during ENSO and the Indian Dipole periods.

The three African centres in collaboration with the NMHSs release regular seasonal climate prediction products that have played important and useful roles in providing the region with climate advisories and timely early warnings for disaster risk reduction and support to regional sustainable development efforts. Over the last 10 years, an innovative process known as the regional climate outlook forum (RCOF) was initiated by WMO, NMHSs, and regional climate centres to provide consensus early warning seasonal climate information for reducing climate-related risks and to support sustainable development efforts of some specific regions. RCOFs bring together climate scientists, policy makers and the general user community to develop warnings of potential impacts of the climate on various socio-economic sectors. The RCOF process includes a capacity building component to strengthen the capacity of the regional climate scientists.

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