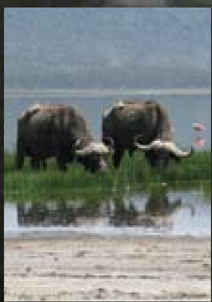
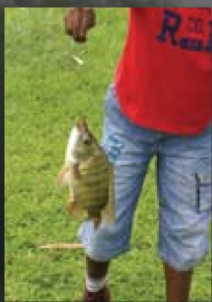
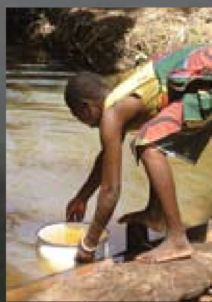
ASSESSMENT OF TRANSBOUNDARY FRESHWATER VULNERABILITY IN AFRICA TO CLIMATE CHANGE

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EXECUTIVE SUMMARY

CONTEXT

Managing the freshwater impacts of climate change in Africa is as much a political and development challenge as a technical climate change challenge. Even without climate change, many of Africa's water resources are facing overuse, pollution, and degradation. Poor land-use practices are contributed to this process. Large numbers of people living in poverty in rural and informal urban areas are already vulnerable to water-related risks, whether floods, droughts, poor water quality, or increasing water scarcity.

The status of water resources in Africa has been changing for many decades, whether through decreasing water quality, lowered groundwater, more or less rainfall, and changed timing of rainfall. Change is not new. Climate change, however, will profoundly accelerate the **rate of change**, affecting the ability of people and societies to respond timeously. The rate of change is compounded by **uncertainty** of the impacts of climate change. While there are a number of models that attempt to predict the impacts of climate change, many of these are at a very coarse scale and do not predict localised impacts, which may differ from the generalised picture. At the same time, different models predict different climate change trends in the same areas, some, for example, predicting an increase in rainfall, while others predict a decrease in rainfall. Managing for high rates of change in a context of uncertainty is thus what is demanded of African governments.

The key response to this must be to **build resilience**, at the household level, at the community level, at the national level, and at the transboundary or regional level. Increased resilience will enable people living in poverty, in particular, to respond more effectively to change and to recover faster from disasters. The key elements of resilience are poverty eradication and access to information, making adaptation to climate change primarily a development challenge.

> *"Water, the stuff of life and a basic human right, is at the heart of a daily crisis faced by countless millions of the world's most vulnerable people—a crisis that threatens life and destroys livelihoods on a devastating scale. Unlike wars and natural disasters, the global crisis in water does not make media headlines. Nor does it galvanize concerted international action. Like hunger, deprivation in access to water is a silent crisis experienced by the poor and tolerated by those with the resources, the technology and the political power to end it. Yet this is a crisis that is holding back human progress, consigning large segments of humanity to lives of poverty, vulnerability and insecurity. This crisis claims more lives through disease than any war claims through guns. It also reinforces the obscene inequalities in life chances that divide rich and poor nations in an increasingly prosperous and interconnected world and that divide people within countries on the basis of wealth, gender and other markers for disadvantage."*

KEY AREAS AND ISSUES

Africa has been recognised by the International Panel on Climate change as being the continent that is the most vulnerable to climate change. There is, therefore, an imperative for all African governments to manage the freshwater impacts of climate change. There are, however, three key areas in the continent that, because of the extent of the impact, the size of the population that will be affected, the vulnerability of the affected population and the lack of adaptive institutional capacity to manage the impacts, have been identified as being particularly at risk.

Coastal Areas: The coastal areas of West Africa (from Senegal to Nigeria), of eastern and southern Africa (from Mozambique to Tanzania) and the Nile delta, are at risk from flooding, sea level rise, storm surges (except the Nile delta), and saline intrusion into surface and groundwater. Currently over 70 million people are at risk in these areas, and the population of the coastal region of West Africa is estimated grow to around 100 million by 2050 because of population growth and migration from increasingly arid inland areas.

Great lakes: The great lakes of the Rift Valley (Lakes Victoria, Turkana, Tanganyika, and Malawi) and Lake Chad are extremely vulnerable to climate change. Around 50 million people are currently dependent on these lakes, most of which are already experiencing a reduction in fish stocks, decreasing water quality, and reduced water levels. Climate change will exacerbate these trends, with the possibility of the collapse of the fisheries, massive loss in biodiversity, increased eutrophication and decreased water quality. The impact of these lakes in terms of contribution to protein consumption in rural communities, and international trade through export of tropical fish, is significant, and a collapse of the lake systems will have massive impacts on local and national well being.

The semi-arid regions: In the semi-arid regions of the Sahel, central and eastern Southern Africa, and the Horn of Africa, large rural and peri-urban communities are largely dependent on rain-fed agriculture, and bio-mass derived energy. Their water supplies are often insecure and may be dependent on local rivers or groundwater. Increased climatic variability in these regions, combined with more intense droughts and floods, increased temperatures and lower rainfall overall, will put these communities hugely at risk. In southern Africa the vulnerability of these communities to climate change is exacerbated by extremely high rates of HIV/AIDS.

Protecting key water sources: On a more positive note, there is a need and an opportunity in protecting the critical 'water towers' of central, west and eastern Africa, (the Congo forests, the Fauta Djallon mountain areas and the Ethiopian highlands). Protection of these areas is important in protecting the quantity and quality of water, while also contributing to climate change mitigation through the conservation and restoration of critical forest areas, and protecting biodiversity.

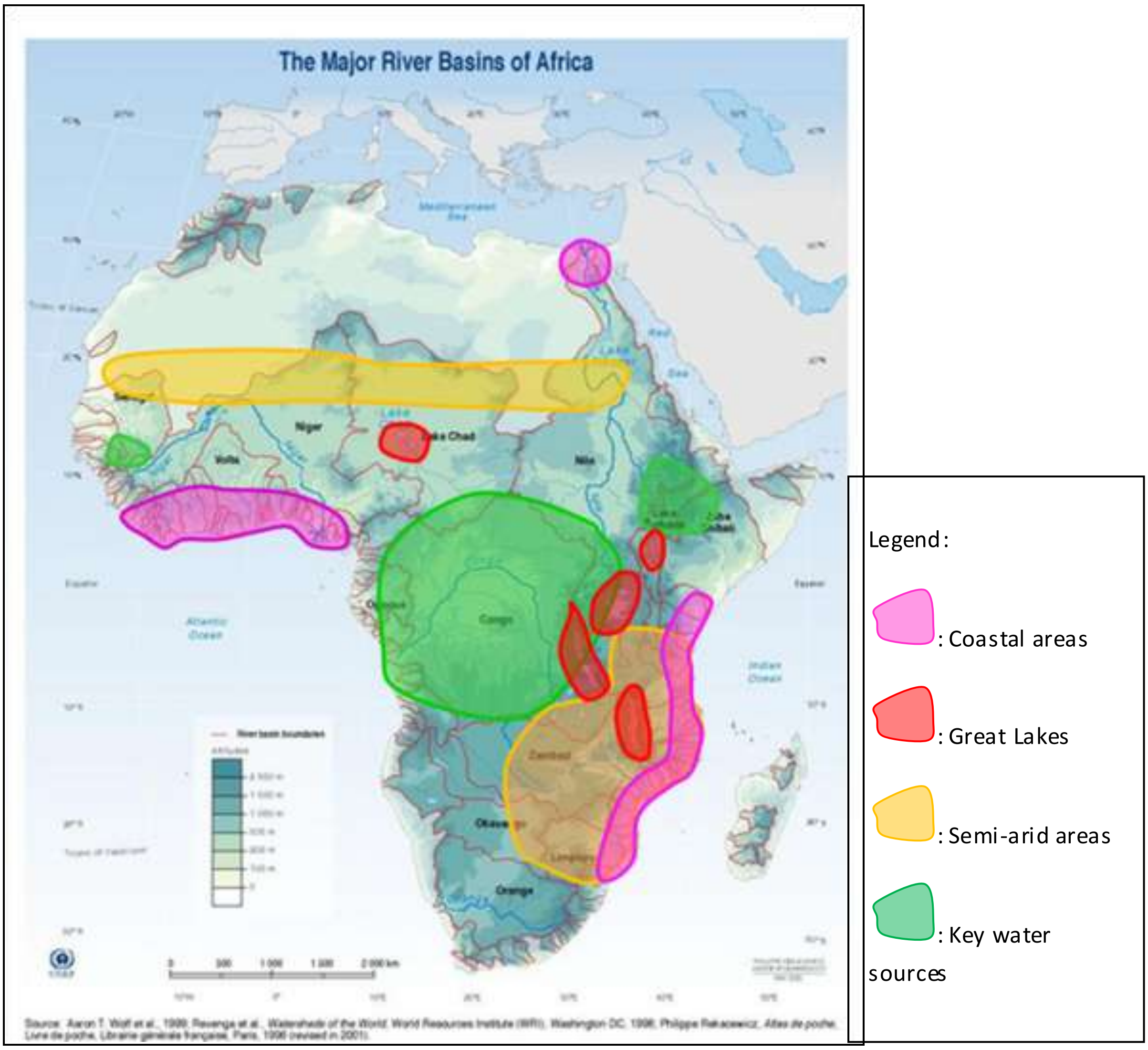

Figure 1: Map of areas most at risk from climate change, and key water sources requiring protection

OVERVIEW OF KEY RESPONSE STRATEGIES

While it is important to recognize many of the weaknesses across the continent that may complicate effective responses to climate change, such as poor institutional capacity, high levels of poverty, poor data, and limited modeling of climate change impacts at the local scale, it is equally important that immediate action is taken to improve the resilience of communities and societies to the impacts of climate change.

The following section describes some key actions that could be taken in response to the key risks identified in this report. This is by no means a comprehensive list, but offers some critical intervention points that should be addressed.

The actions that are provided here are actions that lie within the field of water management. However, some of the most successful responses to the water-related impacts of climate change and the building of resilience may lie outside the water sector, such as social grants for affected communities. It is, therefore, important for integrated adaptive approaches to be developed, not approaches limited only to the water sector.

DO GOOD WATER MANAGEMENT

The first point of intervention that is critical in addressing the key water related vulnerabilities to climate change in Africa, is to improve water management across the continent, particularly in the most vulnerable areas. There is no magic bullet that will help to address the impacts of climate change, and any response must be built on a foundation of solid and effective water management. A key issue is to ensure that water management plans are aligned with national development and poverty reduction strategies and that implementation of these strategies is driven hard to address the current development and poverty challenges.

A second issue is to improve the ability to manage the current challenges of climate variability. This will significantly improve the ability to manage the longer term impacts of climate change. Such measures include:

- ensuring that appropriate legislation (and agreements at the transboundary level) is in place,
- ensuring the institutional capacity to manage water effectively (both water resources and water services),
- developing sufficient skilled and experience staff to manage water effectively,
- ensuring sufficient financial resources to develop, operate and maintain the necessary water infrastructure to respond to climate change, and
- ensuring appropriate information is available, which requires effective monitoring and data collection. The latter is particularly important to be able to monitor climate trends.

Where human and financial resources are limited, as they are in many parts of Africa, it is important to identify and focus on managing the most vulnerable areas and the most critical issues, rather than attempting to spread limited resources over too large an area or too many issues.

It is also critical that water resources management is practiced in the context of the large number of transboundary basins that are vulnerable to the impacts of climate change. This will require improved relations between riparian countries, the sharing of information, and joint processes to address critical areas.

A number of areas that constitute good water management and that are critical in the face of climate change, are highlighted below.

INVEST IN INFRASTRUCTURE AND TECHNOLOGY

There are a number of areas in which investment in infrastructure is necessary to support development and thereby to build resilience to the impacts of climate change. These infrastructural responses will be appropriate in different areas depending on the vulnerabilities and challenges of those areas. Key to the building of infrastructure, however, is the understanding that infrastructure is required primarily to support development, and through that process, if designed and managed correctly, to increase the capacity to adapt to climate change. It is also important to recognize that infrastructure refers not only to large dams and Interbasin transfers, but to small scale infrastructure as well, such as wells and pumps, rainwater harvesting infrastructure, and small scale irrigation systems.

In many areas climate change is likely to bring increased likelihoods of floods, and increased flood intensity. A number of management actions are required to enhance flood management, including the development of early warning systems and the rehabilitation of degraded catchments. However, the development of flood attenuation infrastructure may be appropriate in some areas, while the protection of infrastructure against floods is also critical. In flood conditions, water services (water and sanitation) infrastructure may be damaged, leaving communities vulnerable to poor quality water or lack of drinking water, and lack of functioning sanitation facilities. The flood-proofing of water supply and sanitation infrastructure should be considered in vulnerable areas.

The other side of the coin is that some areas will see decreasing rainfall and increased droughts. In most of Africa, water storage is, in any event, insufficient to disconnect economic growth from rainfall. Even if climate change were not a reality, Africa requires increased storage (both large dams and small storage facilities) in order to overcome the impacts of frequent droughts in both rural and urban areas. With the potential for climate change to extend the period of drought and to increase the intensity of drought, the need to invest in increased storage becomes all the more important. In this regard, finding the financial resources for the development of infrastructure remains a critical challenge and one where African governments and international financing agencies all have a role to play.

At the farm level, increased investment in and access to information about appropriate irrigation technology, including drip irrigation and rain water harvesting, is required to improve water use and productivity in the face of climate change. In many areas, a shift from rain-fed agriculture to irrigated agriculture may be necessary to protect rural livelihoods and food security.

Investment in natural infrastructure, such as investment in protecting and rehabilitating aquifers and wetlands can also contribute significantly to building resilience to climate change.

Recognising the disproportionate burden that poor women will bear arising from climate change, it is critical that investment in infrastructure and technology is flexible enough to reflect women's priorities and needs and that women are actively involved in decisions relating to infrastructure development. Other technological developments designed to increase resilience to climate change should also take into account the specific needs and requirements of women.

DISASTER PREPAREDNESS

It is clear that, in many parts of Africa, climate change is likely to bring more frequent and more intense water-related disasters, in a continent already prone to floods and droughts. Disaster preparedness, including well developed early warning systems, and post-disaster intervention plans, are a critical part of the resilience of a society to climate change.

Women are particularly at risk from natural disasters, for a number of reasons, including their lack of savings, property or land to buy new shelter after a disaster. As a result, women are more likely to be put in crowded shelters than men, and face the possibility of rape and physical abuse in such circumstances. Women are also physically less able to escape from floods, for example, either due to the nature of their clothing, or their already weakened state in a context of food shortages. Cultural practices may also prevent women from seeking healthcare. Women in countries with high gender disparities are most vulnerable. As a result, it is critical that disaster plans are specifically gender-sensitive and address the particular needs of women.

FLEXIBLE / ADAPTIVE DEVELOPMENT PLANNING

Of key importance in managing the water-related impacts of climate change in Africa is the need to ensure alignment between national development objectives and water availability. Because of the difficulty of predicting climate change impacts on water with any accuracy at this point, the challenge is to ensure that a flexible approach is taken to planning which allows adaptation to a changing climate over the years. This requires access to relevant and updated climate change information for the key water-related development planning departments, (e.g. agriculture, mining, power generation, municipalities), and also requires strong alignment and cooperation between water departments and departments responsible for development planning.

Given the vulnerability of poor women in particular to climate change, development plans and climate change response plans should proactively address the issue of gender and the protection and support of women and girl children in particular.

FLEXIBLE AND CLEAR ALLOCATION SYSTEMS

Water allocation takes place at a number of levels. In the basins and aquifers under consideration in this report, the first level of allocation is between riparian states. While there are a number of transboundary agreements in place in transboundary basins in Africa, there are also a large number of basins in which there are no agreements in place. Even where agreements are in place, some are lacking effective dispute resolution mechanisms, and many lack effective institutional capacity at the national or transboundary level for effective implementation and optimal sharing of water resources and the benefits derived from water resources. In basins facing water stress as a result of climate change it is important that effective transboundary water allocation systems are put in place, supported by good, shared data on the status of the basi n.

At the sub-basin or local level, a range of water allocation systems operate in Africa, with parallel formal and customary systems in many countries. It is important that these systems are sufficiently flexible to enable adjustments in allocation to manage climate variability and climate change in support of national development objectives. It is also important, however, bearing in mind the limited institutional capacity in Africa, that these systems are sufficiently simple to be effectively implemented and managed within the capacity constraints.

RESPONSIVE INSTITUTIONS

Climate change in Africa will result in significant changes in the demand for and availability of water. As has been seen in the earlier part of this report, institutional capacity to ma nage this change is limited in most parts of the continent. Institutional capacity must be built, including ensuring that appropriate legislation and policy is in place, that a sufficient infrastructure platform is in place for storage and flood attenuation, and ensuring appropriate technical and managerial capacity is in place. The latter requires appointing and training people able to manage adaptively and in the face of uncertainty. This is a different mode of water management from the traditional approach, and requires the encouragement of innovation and creative responses to change.

It is also critical that stakeholders are involved in the water resources management process so that there is full support for the approaches to be taken and so that the exchange of information between stakeholders and authorities enables quick response to situations and optimal adaptive responses at both ends.

However, the key challenge in developing responsive institutions lies in building the adaptive capacity of such institutions. An effective response to climate change will not be based on the ability to accurately predict the changing climate and its water-related impacts, but rather on the ability to respond to change, to enable innovation at all levels, and to create flexible and responsive water management systems.

IMPROVED SCIENCE AND INFORMATION

The approaches mentioned above are dependent on improved science and information sharing across vulnerable transboundary basins and aquifers in particular. One of the chall enges in terms of managing climate change in Africa is the lack of models predicting climate change at the local level. It is critical that the capacity to model climate change is enhanced in Africa so that management options can be based on scientifically sound information. This will require increased investment in the science of climate change and in understanding the impacts in Africa, and there may be a role for an African centre of excellence in this regard.

A critical aspect of improved information is the ability to define the current state, to identify emerging trends, to anticipate the possible future path and the resulting vulnerabilities and risks. This requires an appropriate monitoring system, which can deliver the necessary information at the appropriate scale. This monitoring system should extend beyond simply monitoring climate trends, to also monitoring the status of the resource to detect emerging trends and to identify necessary management actions to be put in place.

A critical part of an improved information system is the development of early warning systems for floods, in particular.

That said, however, bearing in mind the limitations in institutional capacity in Africa, a key challenge is to develop monitoring and information systems that are appropriate to the financial and human capacity constraints and can deliver appropriate information without unsustainable resource demands. In this regard, a partnership with stakeholders, and the use of widely accessible technology such as cell phones, can be used to supplement limited government data and information.

It is also critical that information is exchanged widely across the continent, building the understanding of climate change and of adaptation to climate change between countries and within countries

INVESTMENT IN PEOPLE

Adaptation takes place at a number of levels, from the creation, say, of major storage infrastructure, to the household level, particularly in rural areas and areas where government fails to reach. In this regard, while government might not be able to extend the necessary services to vulnerable populations to protect them from climate change, the provision of information itself can assist communities and households to prepare themselves for the coming changes.

The provision of information and training to rural communities is particularly important because of their high levels of vulnerability and because they are often out of the information loop. Information might include new crops to use, improved cropping or livestock management techniques, and flood warnings.

It is important to realise that access to technology and information is not gender-neutral and that, in most African countries, girls and women have less access to information and communication technology than men, because of social and cultural bias, lack of technological infrastructure in rural areas, lower levels of education especially in the fields of science and technology, and the lack of disposable income to buy technological services.

There is, thus, a particular need to invest in the training and empowerment of women as the ones who protect family health and well-being, and who are key drivers of adaptation in their own right. Gender mainstreaming and understanding the particular vulnerabilities of women should form a key part of all climate change adaptation strategies.

TRANSBOUNDARY BASIN MANAGEMENT AND REGIONAL INTEGRATION

The building of trust, shared knowledge and a shared vision of the basin across boundaries is very important, particularly in highly vulnerable areas and areas that already lie in conflict zones. While there are a number of transboundary basins in Africa in which international agreements have been concluded, and transboundary institutions put in place, many of these agreements and institutions are weak, and are not necessarily appropriate to cope with the impacts of climate change.

In many areas the solution to the climate change and development challenges will come not only from transboundary co-operation, but from a greater exploitation of regional competitive advantage, seeing development opportunities within the context of a region, rather than a country. Climate change, in this regard, offers a key driver for the expansion of regional integration across the continent.

Regional integration should be seen in a broader context than simply the water sector. There is an opportunity for the development of regional public goods, such as transport infrastructure, markets, power pools, trade arrangements, and food security responses, that can provide substantial benefits in building regional and local resilience to climate change.

UNDERSTANDING THE ENERGY/WATER NEXUS

A number of African countries are dependent on hydropower, even though the hydropower potential of Africa is still hugely underdeveloped. However, as has been seen in the regional reports, hydropower is under threat in some areas from diminishing stream flow or increased variability in flow. As a result, the 'climate change-proofing' of current infrastructure is an importance measure to protect the energy supply of many African countries, and hence to protect economic and social development potential. At the same time, further hydropower potential is under development, but such development must take place within a clear understanding of the potential impacts of climate change, and in such a manner as to be able to withstand potential climate change impacts.

It is important to ensure both water and energy security in an integrated manner taking into account the likely impacts of climate change. It is particularly important, in the context of the large number of transboundary basins in Africa, for such understanding to take place at the basin level as well as the national level, for joint planning for a water and energy secure future. Energy sources that do not demand water should also be seriously considered.

HARNESSING GROUNDWATER

Large numbers of people in Africa are dependent on groundwater, and yet the management and knowledge of groundwater is extremely weak. Monitoring of groundwater availability and use, and understanding of groundwater recharge is poor, but is critical to the sustainable use of this resource. Groundwater is a particularly important resource in the face of increasing temperatures, since it is not vulnerable to evaporation in the same way as surface water. As part of the improved use of groundwater, appropriate technology, and artificial recharge should be strongly promoted.

CONCLUSION

The IPCC has recognized that Africa is the continent most vulnerable to the impacts of climate change – partly because of the actual climatic changes that are predicted to happen, but significantly because of the high levels of poverty and low levels of institutional capacity across the continent. The challenges of climate change overlay an already fragile human condition on the African continent, with high levels of poverty and hunger, poor service delivery, and, in many places, already stressed water resources. Not only is climate change is adding to the already existing pressures of development on limited water resources, but as the climate change pressures intensify, they do so in the face of growing populations and economies, both of which place greater stress on water resources. The challenge of managing water in Africa over the next decades is thus both a climate change challenge and a development challenge.

With this in mind, an overview has been provided that identifies some of the most vulnerable areas in Africa, and some approaches have been suggested that may help to ameliorate the impacts of climate change. The already vulnerable poor, particularly, but not only, in rural areas, are the people most at risk from the impacts of climate change. Any action which increases the resilience of these communities will assist them to respond more effectively to the impacts of climate change.

In some parts of the continent, a particular challenge remains the sharing of transboundary waters in the context of increasing stress, and high levels of political instability and conflict. And yet, there are areas where transboundary water sharing is working well. A key message is that, across the continent, there are important lessons that can be learned, about appropriate and indigenous approaches to improved water management and climate change adaptation. A key part of responding to the coming change will be the ability to learn from one another, to share information and experiences, and to develop a body of African experience and knowledge about managing the impacts of climate change.

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SETTING THE SCENE

1. INTRODUCTION

1.1. BACKGROUND TO CLIMATE CHANGE IN AFRICA

> ***"In the early 21st Century, prospects for human development are threatened by a deepening global water crisis ... poverty, power and inequality are at the heart of the problem. (Human Development Report 2006)***

Africa is a continent characterised by wide-spread poverty, high levels of political instability, and poor service delivery. 34 of the 53 countries in Africa are considered to be Least Developed Countries. About 58 percent of the population has access to piped water supply, and only about 37 percent of the population has access to improved sanitation (World Bank). It is estimated that one in three Africans is undernourished (USAID). Many communities in Africa experience water scarcity, both for domestic and productive purposes. The underlying reason for this scarcity in most cases is institutional and political, rather than simply a physical shortage of water. So too, the climate change challenges are primarily institutions, political and developmental.

In addition to the already existing challenges, Africa already experiences high levels of climate variability and is widely recognized as being the continent most vulnerable to climate change. Global warming will hit Africa harder than other regions with catastrophic impacts on human well-being and on economic development.

This vulnerability arises from the interplay of water resource stress, high climate variability, low adaptive capacity, poor governance and political instability, low levels of development and high levels of dependence on rain-fed agriculture. Given that many of the effects of climate change and variability manifest through impacts on the water sector, Africa's vulnerability to climate is particularly profound in countries or basins that demonstrate marked hydrological variability or that experience water stress.

The IPCC projects that by 2020 between 75 and 250 million people will be affected by water stress arising from climate change. This water stress will result in decreased agricultural productivity, particularly for rain-fed agriculture, which could see yields reduced by 50% by 2020 in some countries in Africa.

Many studies on climate and vulnerability in Africa have focused on either the climate science and the anticipated changes in future climate and its variability, or on the vulnerability of particular sectors or communities to a future climate. While work has significantly advanced the understanding of climate change impacts on the human and natural environment, significant gaps remain in the understanding of inter-sectoral risks and integrated adaptation responses. This gap is compounded by a combination of poor physical data on climate and water resources, and limited institutional capacity to generate knowledge products or implement adaptive management practices. As a result, climate change and its impacts on African economies and societies remains an elusive subject, with widespread recognition of its importance but little realization of responses.

Water is recognized as a social good, an economic good and an environmental necessity. Few processes in the human or physical world are not dependent on water in one form or another, and the judicious management of water resources is increasingly recognized as a key requirement for sustainable growth and development. This is particularly true in water stressed environments, where access to water of adequate quality is a critical factor of production. Accordingly, a future that changes the amount, timing and / or quality of water has profound influences on a society's ability to determine its development future, and to protect social and environmental advances achieved.

Given the impacts of climate change on the water sector, and the links between water and economic, environmental and social well-being, an integrated perspective of risk and response is possible through considering the climate - water sector interactions, and the specific risks and vulnerabilities that arise as a result of a changing future climate. This is particularly true in Africa, where the limited institutional and infrastructural investments, and the heavy reliance on rain-fed agriculture, imply significant reliance on water.

There are two elements of the response to climate change – mitigation and adaptation. **Mitigation** concerns the measures being taken to reduce the emissions of greenhouse gases. However, the results of mitigation will only be felt over many decades, and, in the meantime, the effects of climate change will continue. **Adaptation** refers to those measures, usually local or regional, with more immediate effect than mitigation, which will enable communities and societies to adapt to and survive the coming changes. Within the water sector, the focus is on adaptation, rather than mitigation.

In order to assist adaptation, Least Developed Countries are expected to develop National Adaptation Programmes of Action (NAPA), an initiative established under the UN Framework Convention on Climate Change (UNFCCC) in 2001. The purpose of the NAPAs is to enable LDCs to identify their most urgent needs and communicate them to the international community. By April 2008, 27 African LDCs had completed and submitted their NAPAs, but since then, little funding has been made available for the implementation of the identified priorities.

UNESCO (2009) has identified a number of weaknesses with the NAPAs that have been submitted, including a lack of substantive links between the content of the NAPAs and Poverty Reduction Strategy Papers and National Development Strategies. A critical weakness is the lack of recognition of the institutional barriers and the lack of political will currently hampering the implementation of climate change adaptation strategies. A further challenge is the lack of specific actions in the plans, and poor assessment of implementation costs. However, the more recent NAPAs tend to be more strategic than the earlier ones.

1.2. BACKGROUND TO THE PROJECT

As a result of global concerns over the impact of climate change, and the particular vulnerability of Africa, UNEP, through the South African Water Research Commission, commissioned a high-level study on Climate Change Vulnerability in Transboundary Basins and Aquifers in Africa. This study builds on a previous report commissioned by UNEP, Our Freshwater under Threat - Vulnerability Assessment of Freshwater Resources to Environmental Change – Africa Report.

Africa is one of the most vulnerable continents to climate change and climate variability, a situation aggravated by the interaction of 'multiple stresses', occurring at various levels, and low adaptive capacity (IPCC AR4 2007)

The intention of the project is to produce a high level report identifying the key areas in Africa that are most at risk as a result of climate change. This report identifies the key risk factors in these areas and identifies areas for action. The report is intended to provide UNEP with the necessary information to engage with the African

Ministers Council on Water (AMCOW) on the issue of preparing for climate change adaptation in key transboundary basins in Africa.

1.3. STRUCTURE OF REPORT

This report sets out the results of the study on climate change vulnerability in transboundary basins and aquifers in Africa in the following way: Chapter 3 sets out the approach taken to climate change and adaptation in the water sector, looking at the framing considerations for the study, and the several different sectoral vulnerabilities. This is followed by Chapter 4 which describes five thematic risks which are used as the basis for telling the story of climate change vulnerability in Africa. These are rural community vulnerabilities, urban community vulnerabilities, environmental vulnerabilities, human security vulnerabilities and economic water use vulnerabilities. The final section in Chapter 4 deals with the methodology applied in the study.

Chapters 5 to 9 address the current status and climate change vulnerabilities in the transboundary basins and aquifers in each of the identified five regions in Africa: northern, eastern, western, central and southern. Chapter 9 highlights the regions most at risk in the continent, chapter 10 provides an outline of some key response strategies to the identified vulnerabilities, while Chapter 11 provides the conclusion to the report.

1.4. ACKNOWLEDGEMENTS

This report has been compiled on the basis of collaborative work by Pegasys Strategy and Development, supported by Prof Lekan Oyebande, who prepared a background report on the western region, Prof Maria Snoussi who prepared a background report on the northern region and the Nile basin, Nick Hepworth who prepared a background report on the eastern region, and Jean Boroto who prepared a background report on the central region. A three day workshop in November 2009, attended by a range of experts from around the continent also contributed to the development of this report.

2. APPROACH TO CLIMATE CHANGE AND WATER-RELATED ADAPTATION

2.1. OVERVIEW OF AFRICAN CLIMATE SYSTEMS

Africa straddles the equator, from 37^{o}N to 35^{o}S, and as a result is dominated by tropical and sub-tropical climate zones. These zones are largely the result of the impact and movement of what is called the Inter-Tropical Convergence Zone (ITCZ). The ITCZ appears as a bank of clouds and thunderstorms around the earth, near the equator. It forms where the trade winds of the northern hemisphere and those of the southern hemisphere converge, and force moisture-laden air upwards, resulting in heavy rain, typically as thunderstorms. These thunderstorms are often short but intense.

The ITCZ moves over time, following the sun's zenith point during the year (see figure 1). This variation in location affects rainfall in both equatorial countries and countries further from the equator. Longer-term changes in the ITCZ can result in severe droughts or floods.

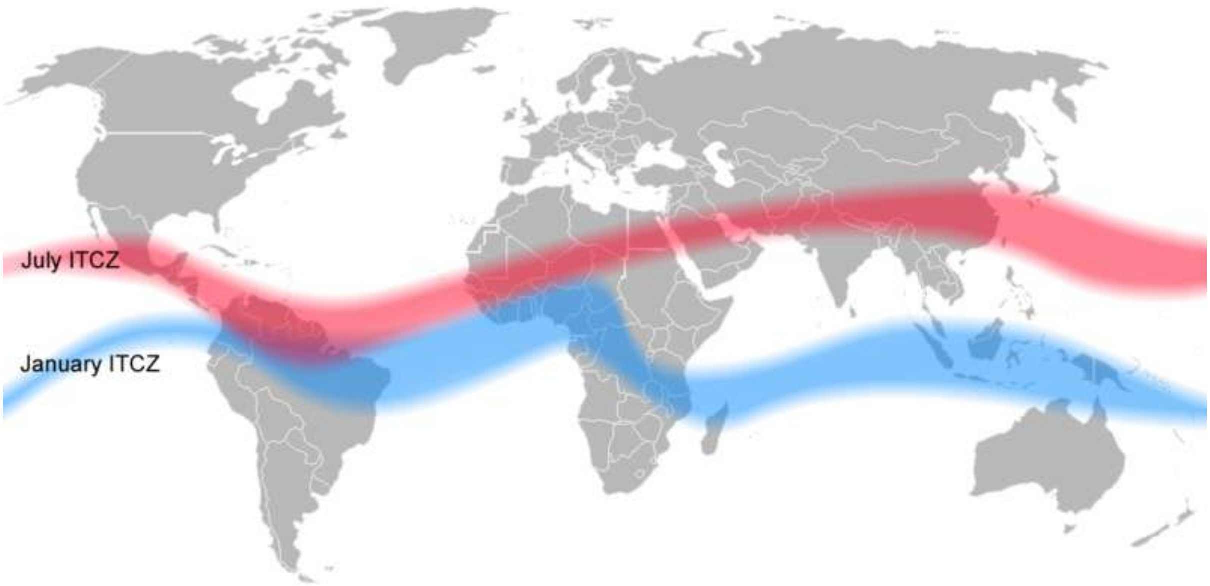


Figure 2: Map of the ITCZ in January and July. (Source: Wikipedia 2009)

The ITCZ moves to the south during the southern hemisphere summer months (November – March), bringing rainfall to the southern African sub-tropical countries. This effect is weakest in the western parts of southern Africa, as a result of the Atlantic and Botswana high pressure cells. During the northern hemisphere summer (May – September), the ITCZ moves north of the equator, bringing rain to west, northern and eastern Central Africa. Although the ITCZ lies over the Sahara desert during this period, very little rainfall occurs here as most of the moisture has already been lost before reaching this latitude.

The highlands of eastern Africa lie along the summer convergence of the southwesterly winds from the Atlantic and the southeasterly winds from the Indian Ocean, bringing heavy thunderstorm activity to this area and summer rains to the Ethiopian highlands. Warm water bodies, such as Lake Victoria and the other large lakes of the rift valley, feed a great deal of moisture into these storm systems of the ITCZ, enhancing the heavy precipitation.

High-pressure systems dominant the winter months in sub-tropical Africa, with the Atlantic and Indian highs linking with the Botswana high to form a more-or-less continuous high pressure band across southern Africa from May to September. Similar influences are exerted by the Azores high in the northern hemisphere, the high pressure systems over the Arabian Peninsula, and by the hot dry etesian winds coming from the north across the Sahara desert.

During winter, the westerly winds and frontal troughs of the mid-latitude cyclones shift sufficiently equator-ward to affect the fringes of the continent in the north and south, bringing frontal rain to the southern and northern tips of Africa.

Only the south-eastern portion of Africa, adjacent to the southern Indian Ocean, experiences tropical cyclone activity during the summer months (December to April). These storms describe parabolic paths, moving from the northeast towards Madagascar before curving to the south-east. Typically these storms only strike land over western Madagascar, but occasionally they travel down the Mozambique Channel making landfall along the Mozambique coastline, and occasionally up the Zambezi valley into mainland Mozambique and Zimbabwe.

Figure 3: Climatic zones in Africa (Source: World Book Encyclopedia (http://www.worldbook.com/wb/Students?content_spotlight/climates/african_climate)

As can be seen in figure 3, the greatest rainfall occurs in central Africa and coastal West Africa, which receive a great deal of ITCZ-driven precipitation (up to and even beyond 3000mm), almost throughout the year. This results from a combination of moisture off the Atlantic Ocean feeding into the convergence zone and the persistence of convergence in this area. When the ITCZ moves northwards, it brings rain to central and west Africa, and the Horn during the May – September wet season, with rainfall in the east in the order of 800 – 1600mm (exceeding 1600mm in some places, notably the Ethiopian highlands). A similar magnitude of rainfall is experienced in parts of Southern Africa during November to March, reflecting the southward movement of the ITCZ. Frontal rainfall in the winter rainfall areas, notably the Western Cape of South Africa and the Mediterranean coast of Morocco, Algeria and Tunisia, results in up to 800mm mean annual rainfall, although rainfall in some of the mountainous regions can be much greater (over 2000mm). Rainfall along the southeastern coast of Africa can be strongly influenced by tropical cyclones, with very heavy rainfall (in excess of 2000mm in some cases) associated with landfall of the Indian Ocean cyclones during the cyclone season (December to April).

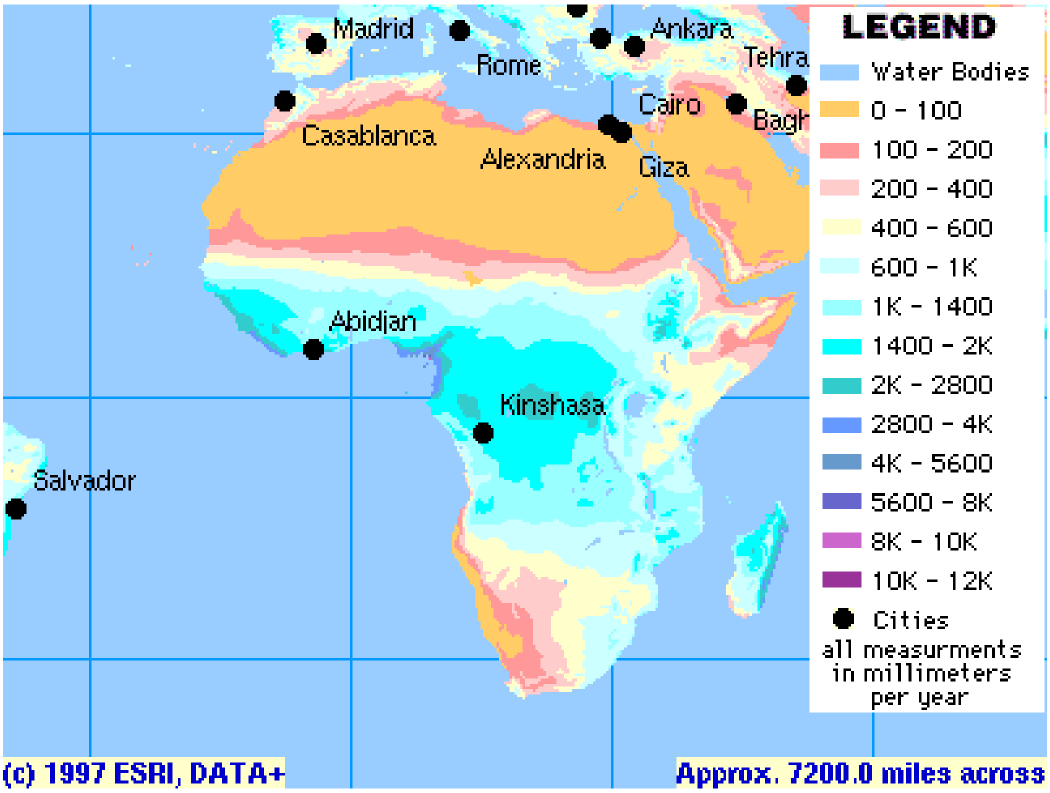
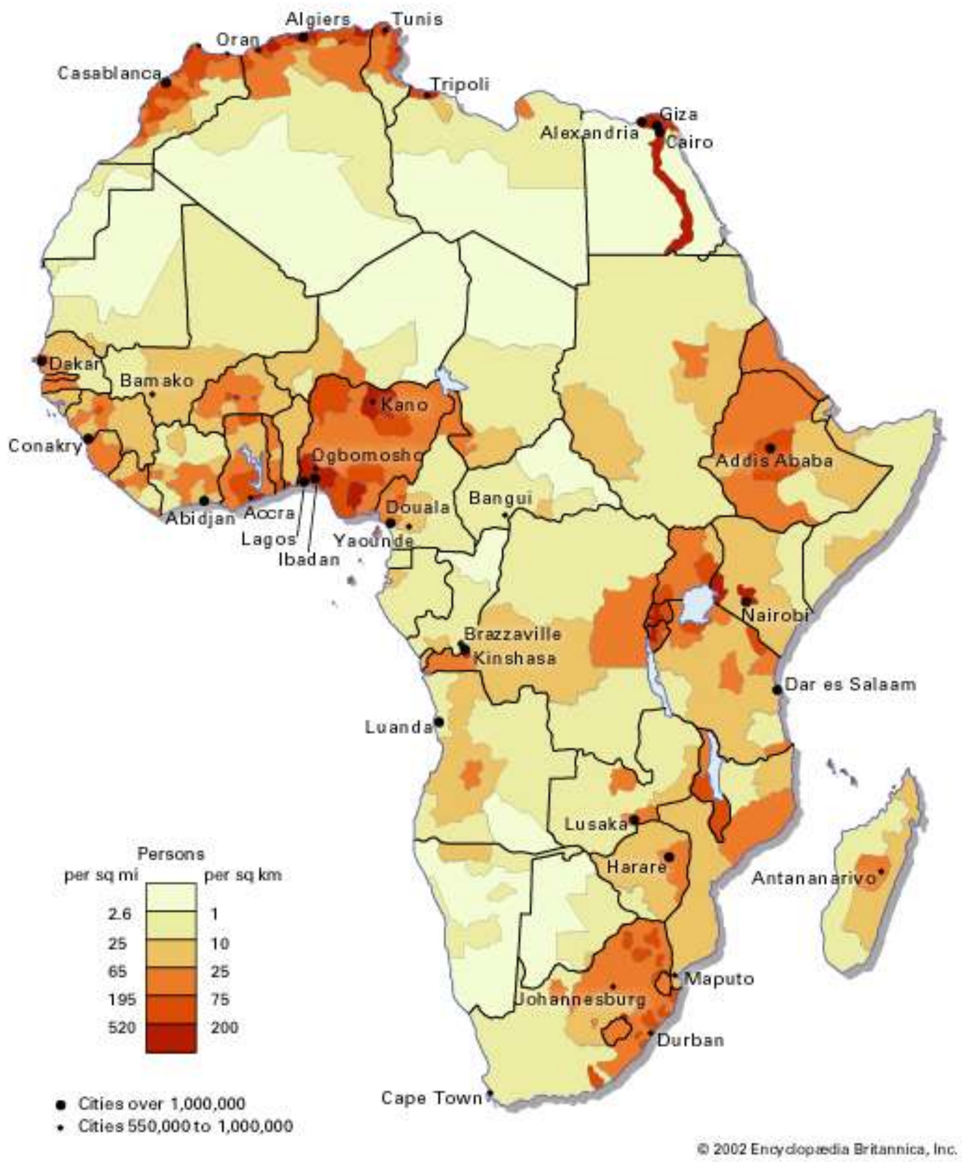


Figure 4: Average annual rainfall in Africa (source: ESRI 1997)



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2.2. CLIMATE CHANGE IN AFRICA

There is increasing certainty in some climate projections for Africa, with consensus between the major general circulation models (GCMs) and the regional circulation models (RCMs) emerging on many parts of the continent. Points of consensus are that temperature increases are very likely during this century, with increases of 1-3^{o}C by 2050 depending on the emissions scenario. This warming is higher than the rest of the world is likely to experience and will be experienced across all of the seasons, with the interior warming more than the coastal regions, and increases in the drier sub-tropics greater than in the moist tropics.

Projections of rainfall variation are more variable, although consensus is emerging for a decreased mean annual rainfall in much of Mediterranean Africa and the northern Sahara, with the likelihood of a decrease in rainfall increasing as the Mediterranean coast is approached. Similarly, rainfall in southern Africa is likely to decrease in the south west and on the western margins. These rainfall decreases are in the winter rainfall regions, with rain associated with the mid-latitude fronts and the winter equatorial shifts of the westerlies. Given that these regions are currently on the fringes of the frontal rain belt, a slight poleward displacement of these systems will result in the fronts passing to the south and north of African landfall, resulting in less rain falling on the land itself.

There is likely to be an increase in mean annual rainfall in East Africa, owing to the increased intensity of convergence in this area between December and February, and more moisture being brought in off the Indian Ocean. The topography of the area will also affect the rainfall, with the highlands forcing this moisture-laden air up into the atmosphere, resulting in increased rainfall.

Besides this consistency in mean annual and seasonal effects, there is increasing consensus that rainfall events will become more intense, as the energy of the climatic cells increases and greater amounts of moisture are transported in the air. This increased intensity also applies to the tropical cyclones of the Indian Ocean, with the proportion of higher strength cyclones anticipated to increase significantly. However, the effects on the frequency of the cyclones, and the likelihood of them hitting the land, remain uncertain.

Much uncertainty exists in climate projections for the remaining areas and seasons of Africa. Even within the areas outlined above, the localized effects driven by local topographic conditions or vegetation feedbacks remain uncertain. These effects can be significant, as they often occur in high rainfall headwater catchments that generate the bulk of run-off.

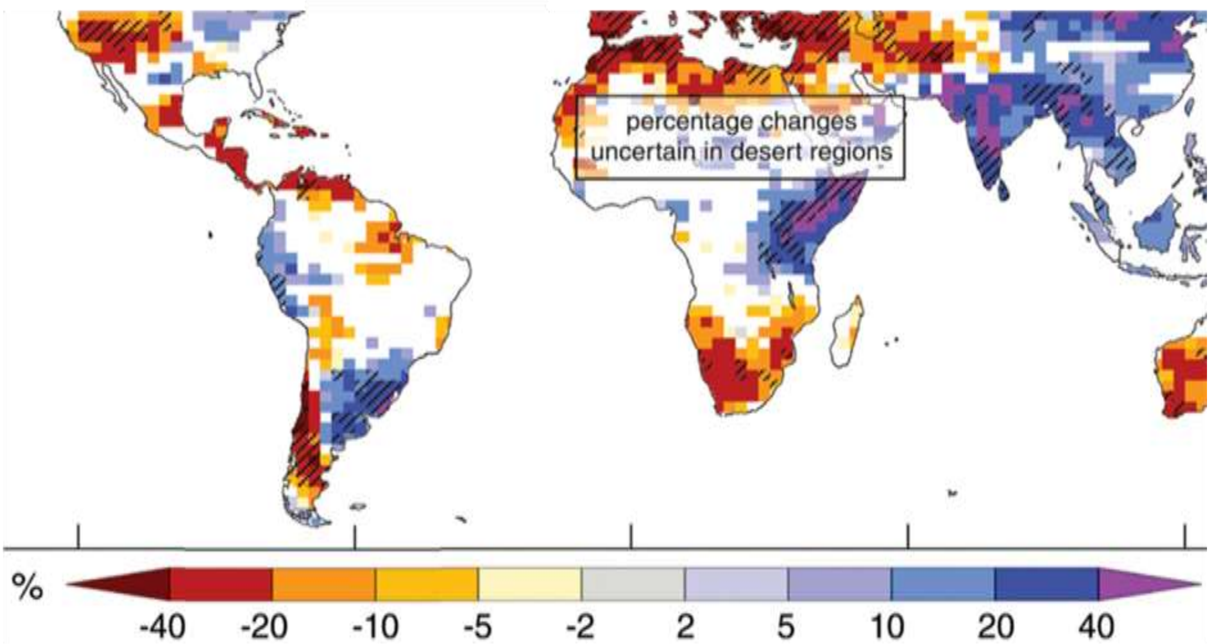


Figure 5: Large-scale relative changes in annual runoff (% water availability) for 2090-2099, relative to 1980-1999. Values represent the median of 12 climate models using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. The quality of the simulation of the observed large-scale 20th century runoff is used as a basis for selecting the 12 models from the multi-model ensemble. The global map of annual runoff illustrates a large scale and is not intended to refer to smaller temporal and spatial scales. In areas where rainfall and runoff is very low (e.g. desert areas), small changes in runoff can lead to large percentage changes. In some regions, the sign of projected changes in runoff differs from recently observed trends. In some areas with projected increases in runoff, different seasonal effects are expected, such as increased wet season runoff and decreased dry season runoff. Studies using results from few climate models can be considerably different from the results presented here. (Source IPCC Synthesis Report 2007)

The uncertainty in climate science arises from a number of key factors, including difficulties of modeling the complex and interrelated physical systems that drive climate, lack of data and incomplete knowledge on natural variability, unknown future greenhouse gas concentrations and a number of "unknown unknowns" that potentially skew results. Different models reflect different underlying assumptions, resulting in a range of future climate projections. While some models are better suited to predicting outcomes in certain areas, given more suitable underlying assumptions, reliance on a single model output is discouraged by the International Panel on Climate Change (IPCC) and it is widely recognized that assessment across a number of models is required.

In addition to uncertainty, understanding the limitations of GCMs is very important. GCMs provide the means for making global climate change projections based on global processes and coarse grid resolution, with the highly aggregated input data resulting in limited applicability to local conditions. Accordingly, whilst GCMs now accurately project changes in average global temperature, these projections are often of limited use to decision makers working on regional or local scales. The emergence of downscaling and regional climate models (RCMs) is starting to provide locally relevant climate predictions, although confidence in downscaled results is variable, and marked differences between downscaled future climates and the GCM predictions provide cause for uncertainty. It is telling that some of the leading climate scientists do not believe that climate science will advance sufficiently within the next 10 years to predict the future climate for much of Africa with any level of confidence. This recognition does not imply that further work on climate change vulnerability and adaptation is not required, but rather that the focus of adaptation and management actions should be on possible and plausible sets of vulnerabilities, and on adaptive ability, rather than on a single precise future. At the same time, it is critical that Africa enhances its ability to downscale climate models for Africa to a scale that is more useful in supporting decision-making.

What are GCMs?

There are a number of General Circulation Models (GCM) used by scientists to predict the effects of climate change. Each GCM attempts to simulate or model the changes in climate as a result of changes in various conditions, such as greenhouse gases.

GCMs are very complex and consider the effects of a range of factors. These include the reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean and land temperatures, and areas of ice. Since the different models use different assumptions and relationships between the range of factors, they don't always deliver the same results.

For this reason, it is important to look at the results of a number of models to see where they generate the same results for an area and where they disagree. Figure 5 shows where 21 GCMs agree on climate change predictions, and where they do not agree. As can be seen, there are large areas of Africa where there is agreement on climate change impacts in less than half of the 21 models, resulting in considerable uncertainty of the climate change impacts in these areas.

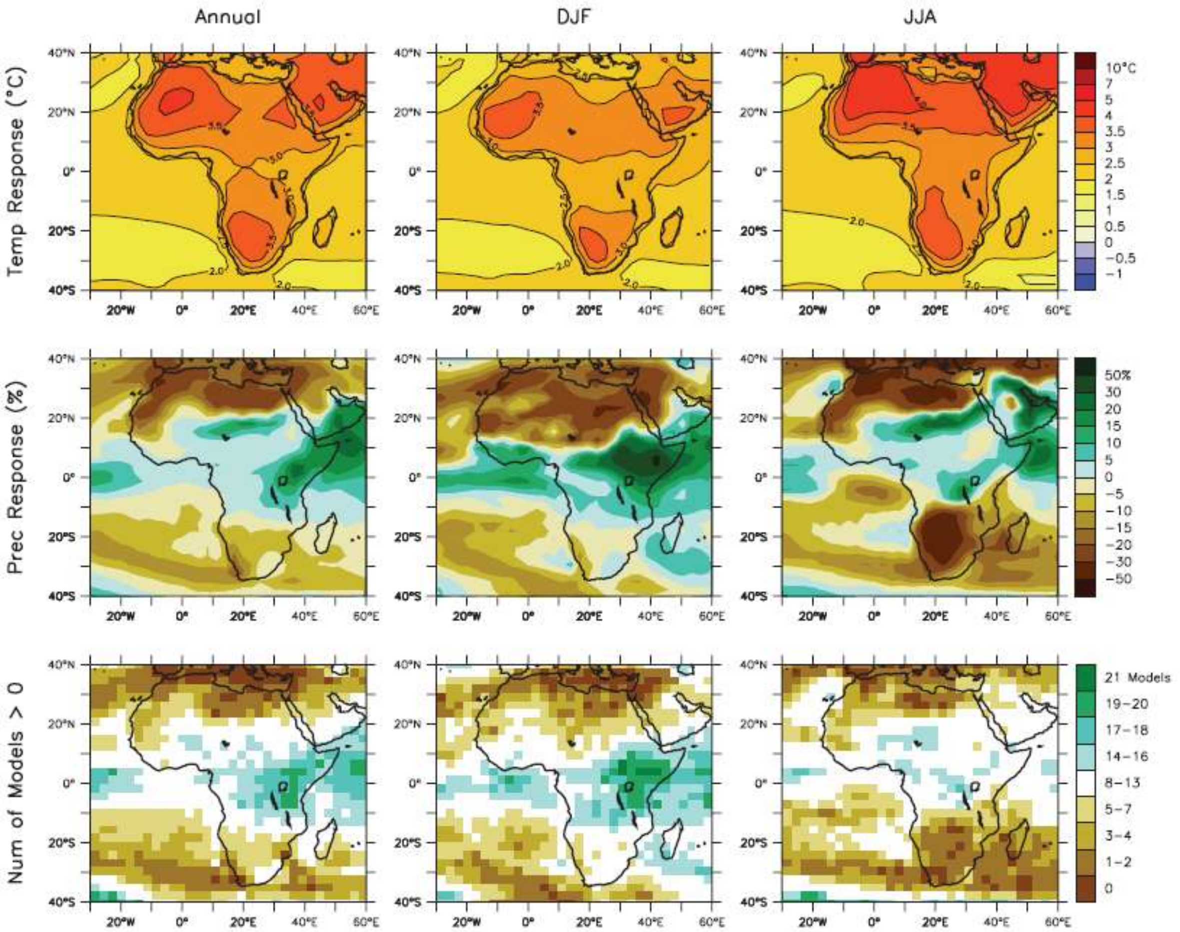


Figure 6: Temperature and precipitation changes over Africa from the MMD-A18 simulations. Top row; Annual Mean, DJF and JJA temperature change between 1980-1999 and 2080-2099, averaged over 21 models. Middle row, same as top but for change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation. Source: Christensen 2007 (IPCC 4th Assessment report)

2.3. FRAMING CONSIDERATIONS

In considering climate change and water, and in developing an approach to water-related climate vulnerability assessment, a number of framing issues on climate and its interaction with the human and natural environment require consideration.

- **Climate change and water are human rights and development issues**

Global warming and extreme weather conditions may wreak havoc on the economic and social human rights of millions of affected people, by exacerbating hunger, malnutrition, exposure to disease, and lack of access to water. The potential for greater or more frequent floods and migration as a result of climate change will negatively impact on the ability to meet the human right for shelter and housing.

Water stress and scarcity translate into impacts on society and the economy in a multitude of ways. The emerging paradigm of "Water for Growth and Development", which places water at the centre of national strategies to grow the economy, eradicate poverty and provide social goods and services, demonstrates the connectivity and interdependence between the nation's socio-economic objectives and the water sector. Whilst social and economic decision-making have historically been driven by the availability of resources other than water, water availability, quality and scarcity are increasingly impacting on development planning and on the development pathways of many African countries.

> *"Water, the stuff of life and a basic human right, is at the heart of a daily crisis faced by countless millions of the world's most vulnerable people—a crisis that threatens life and destroys livelihoods on a devastating scale. Unlike wars and natural disasters, the global crisis in water does not make media headlines. Nor does it galvanize concerted international action. Like hunger, deprivation in access to water is a silent crisis experienced by the poor and tolerated by those with the resources, the technology and the political power to end it. Yet this is a crisis that is holding back human progress, consigning large segments of humanity to lives of poverty, vulnerability and insecurity. This crisis claims more lives through disease than any war claims through guns. It also reinforces the obscene inequalities in life chances that divide rich and poor nations in an increasingly prosperous and interconnected world and that divide people within countries on the basis of wealth, gender and other markers for disadvantage."*
>
> UNDP Human Development Report 2006

Factors that change the availability, quality or timing of water markedly affect the local, national, basin-level and even regional development trajectory. Climate change is widely recognised as one such critical factor and, as such, the impacts of climate change extend beyond its direct effects on hydroclimatology to include developmental impacts that must be incorporated into development planning and implementation. In fact, the 'climate change' that really needs to be understood takes into account the combined effect of physical climate change, and political, social and economic change.

Through its effects on the water sector, climate change threatens the livelihoods and wellbeing of all people. The poor, and poor women in particular, are most severely affected, as the poorest communities are typically most exposed to the uncertainties of climate (droughts, floods, changing rainfall patterns) and simultaneously have the fewest resources and options to respond, and the lowest resilience in terms of withstanding extreme events. Similarly, through its effects on agricultural production, the power industry, and even urban and industrial activity, climate impacts on the water sector threaten economic growth through curtailed production, reduced productivity and reduced competitiveness.

The Millennium Development Goals:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a Global Partnership for Development

Thus, climate change threatens the ability of Africa to achieve a number of the Millennium Development Goals, and may even, in some areas, result in set-backs over current achievements. MDGs particularly at threat from climate change include those related to poverty and hunger, child mortality, maternal health, the spread of diseases, and environmental sustainability.

The effect of water on the MDGs, both progress towards achieving the targets and trend in progress, is typically either direct (i.e. water directly impacts on progress towards the MDG) or indirect (water impacts on progress towards the MDG via intermediate factors). The direct and indirect relationships between water and relevant MDGs are shown in **Error! Reference source not found.** Table 1.

Table 1: Relationship between water and MDG targets. (Source: MDG analysis: Assessment of Climate Change-related water impacts on Development in Southern Africa. Draft Report 2009)

MDG TARGET	• DIRECT EFFECT OF WATER	INDIRECT EFFECT OF WATER
1a. Poverty	• Water as a means of production: ○ a primary input to the economy, for productive means in agriculture, hydropower and industry ○ productive use to support livelihoods (typically small-scale agriculture) • Availability for domestic use and sanitation • Water-based harvesting, particularly fisheries • Water-based products, including tourism	• Various indirect effects through health, hunger, education, infrastructure etc.
1b. Unemployment	• Water as a primary input to the economy, for productive means in agriculture, hydropower and industry • Water based harvesting as a commercial activity, especially fisheries • Water-based products as a commercial activity, especially tourism	• Various effects through health, education and infrastructure
1c. Hunger	• Water as a primary input to agricultural production • Water as an input to economic production, increasing purchasing power • Water as a productive good to support livelihoods (particularly agriculture) • Water-based harvesting, especially fisheries	• Various effects through poverty and unemployment • Various effects through health, education and infrastructure • Various effects through economy and economic / institutional infrastructure
2a. Primary education	• Inability to attend school due to floods	• Effect of flooding on infrastructure and access, • Effects on poverty, hunger and health on ability to attend school • Children used in support of family livelihoods • Children used to collect water (supply)
3a. Gender disparity in education	• No direct impact	• Effects of poverty, hunger and health on ability to attend school • Use of girl learners to support family livelihoods • Use of girl learners to collect water (water supply) • Girl learners staying from school for health reasons (sanitation)
4a. Under-5	• Water-borne diseases (primarily diarrhoeal disease)	• Various effects through poverty, hunger, health effects on care-givers, other

mortality		infectious disease (malaria)
5a. Maternal mortality	• Inability to get to hospitals or clinics due to flooding	• Various effect through poverty and hunger • Effect through access to healthcare services
5b. Access to reproductive healthcare	• Inability to get to hospitals or clinics due to flooding	• Flood effect on infrastructure and access to services • Effect through poverty / economic situation (affordability of service) • Economic effect – availability of government resources to provide services
6a. Spread of HIV / AIDS	• No direct impact	• Effect through water supply and sanitation • Effect through poverty and hunger • Effect through education
6b. HIV / AIDS treatment	• No direct impact	• Effect through healthcare provision and physical infrastructure to reach infected • Effect through economy (affordability) • Economic effect – availability of government resources to disburse treatment
6c. Incidence of malaria and other major diseases	• Water-borne and water-dependent vectors	• Various effects through poverty, health and healthcare, infrastructure, economy (affordability and government resources)
7a. Sustainable development	• Aquatic, wetland and riparian ecosystem goods and services	• Various effects through poverty, economic situation (national resources) and education
7b. Biodiversity loss	• Aquatic and water-dependent ecosystems	• Various effects through poverty, economic situation (national resources) and education
7c. Water supply and sanitation	• Water availability effects • Water quality effects • Water infrastructure	• Various effects through poverty, economic situation (national resources) and education
7d. Slum-dwellers	• Damage to housing and infrastructure through local flooding	• Effect through access to water services • Effect through infrastructure provision • Effect through economy
8a. Trading and financial system	• No direct impact	• Trade in water-related and water consumptive goods and services
8b. LDCs	• Addressed through the above direct and indirect drivers	• Addressed through the above direct and indirect drivers
8c. Land-locked and island states	• Addressed through the above direct and indirect drivers	• Addressed through the above direct and indirect drivers
8d. Sustainable debt	• No direct impact	• Support to economic development

- **Development is a key determinant of future scenarios**

Climate is not only a development issue in that the level of development of a society influences its ability to respond to that impact. While it is true that climate change is a reality of today, it is equally true that many of the dramatic changes in climate are expected to occur some distance into the future (2050 and beyond). Assuming that other elements of the social and physical environment will not change during that period is inappropriate – it is clear that technological advances, levels of development, increased resource utilization and demand, as a direct result of national development and population growth, will profoundly affect the vulnerability of future societies to the future climate. Understanding climate change vulnerabilities must take cognizance of development trajectories that may enhance or minimize resilience and the ability to adapt. Although the development trajectories cannot be predicted with certainty, particularly over the longer time frames (40+ years), increased pressure on natural resources because of population growth end economic development is certain. Climate change will be layered over this increasing pressure.

- **Climate change and gender**

Women, particularly poor women in rural areas, are at greater risk from the effects of climate change than their male counterparts, for a number of reasons, one of which is that they constitute the majority of Africa's poor, and are most dependent on natural resources for their livelihoods. Women are over-represented amongst the very poor, and as such, women and women-headed households are particularly vulnerable for food shortages and rising food prices. Women and girl children's health declines more than that of men in times of food shortage. They also face social, economic and political barriers that undermine their resilience and their coping capacity.

Shrinking water resources means that women and girl children in particular will have to walk further to collect water. Declining water quality and increased disease from the spread of water-related diseases such as malaria means that women, as the primary care givers, will have to devote more time to looking after ill family members - a particular challenge in the face of the extremely high levels of HIV/AIDS in sub-Saharan Africa.

Migration as a result of climate change puts women and girl children at risk in a number of ways, including increased exposure to rape, sexual violence, and exhausting journeys leading to illness and death.

Women, on the other hand, play a crucial role as the custodian of natural resources, and as such, should be deeply involved in the process of responding to climate change and in the process of developing solutions and adaptations. In most of the rural areas of Africa, women are charged with the responsibility of finding water, food and fuel, despite having weaker access to resources than their male counterparts, less access to decision-making, and often, limited mobility. Women farmers account for up to 90% of those engaging in agriculture in some African countries, and as such, are not only vulnerable to climate change, but key actors in adaptation as well. They often have a strong body of knowledge that can be harnessed to build resilience and to support adaptation, particularly on the basis of local and indigenous knowledge.

- **Uneven distribution**

Whilst largely self-evident, it is important to note that climate vulnerability and risk is it is not evenly distributed across a landscape or a system. Particular elements of the basin are at risk at particular points in time, and are at risk to particular kinds of changes or stressors. Accordingly, risk and vulnerability is not evenly distributed across time and space, with particular risks manifesting at different locations in a basin, at different points in time. It is also important to note that there is little science at the moment that can accurately predict local level impacts from climate change.

- **Climate science, uncertainty and certainty**

Uncertainty is a central element of the future…

One of the profound challenges of climate change is the uncertainty associated predictions of the future climate to which adaptation is required. Such uncertainty increases the further one looks into the future. While global consensus is emerging on the temperature and sea-level effects, such consensus is lacking for in many areas for rainfall and run-off effects. Significant resources have been deployed in recent years to research on rainfall / run-off modeling for climate change. Whilst this body of work is a significant contribution, it is widely recognized that the levels of uncertainty are extremely high, as a result of limited consistency between climate models in the direction and magnitude of rainfall effects (increase or decrease) and similar uncertainty regarding the hydrological responses to rainfall, with run-off a complex function of topography, vegetation, geology, antecedent rainfall and other factors. Accordingly, a deterministic approach to the future climate is fraught with challenges, and a scenario-based approach that reflects the envelope of possible future climates is more appropriate.

However, it is certain that change will take place, and at an extremely rapid rate. It is also certain that temperature will increase across Africa, populations will grow, and demands for water and electricity will grow as a result. Growing economies will also place increasing demands on limited water resources. Thus, the uncertainty of climate change predictions must not be allowed to prevent immediate and concrete action in developing the resilience of communities and societies to change and in addressing the current water management challenges in Africa.

- **A risk based approach**

Uncertainty over climate change impacts increases the further one projects into the future. Deterministic approaches to the future are fraught with difficulties and are proven incorrect more often than not. Accordingly, a risk-based approach to the future must be deployed which builds on the idea that the future is not perfectly known, but that enough is known to identified key risk areas.

It is also clear that exposure through climate change alone is often only part of the picture, and that it is usually the interplay of a number of stressors, of which a changing climate is one, that will result in profound changes in water quantity, quality and timing. The other stressors are typically developmental in nature, and refer to changes in land-use, demography, socio-economic conditions informing urban and agricultural demand, and resource exploitation. Like the climate futures, these development futures are relatively uncertain across the longer time horizons relevant to climate change, although some predictions can be made with fair certainty. Accordingly, an approach built on multiple development pathways, with multiple development and water futures, is more appropriate than reliance on a single, deterministic development and water future. Methodologically, this approach is rooted in development scenario planning.

Defining these future water trajectories leads to the identification of indicators that can be tracked over time and supports the development of an appropriate monitoring network that enables the early identification of particular stressors or changes in the system. Adaptation responses that are common to all scenarios are easily prioritised, while those responses that are particular to a specific future can be delayed until the reality of that future becomes evident. Given that both development and climate scenarios change and evolve over time, so water futures should be regularly reviewed to reflect emerging understanding and the state of knowledge. These frequent reviews should similarly be fed into the monitoring systems.

2.4. EFFECTS OF CLIMATE CHANGE ON WATER RESOURCES

Climate and water resources interact in two obvious ways:

- Rainfall drives run-off and recharge; and

- Temperature, wind, humidity and other climatic factors drive evapotranspiration and water demand.

Changing these dynamics can have profound effects on water resources management:

- Changes in mean annual rainfall change runoff and system yields;
- Changes in the onset of rain affect the duration and timing of low and high flow periods;
- Changes in the intensity of rainfall events changes flood patterns and groundwater recharge;
- Changes in variability affect the length of droughts, requiring additional storage where this length is increased;
- Water demand patterns may change because of changing temperature and humidity regimes; and
- Diversification of water resources and conjunctive use may become more widespread as uncertainty increases.

Thus the planning and management of water resources requires the consideration of many uncertainties, including the extent and nature of future requirements, and the inaccuracy of our knowledge of both rainfall and runoff. This knowledge slowly improves as our historical record grows and as our ability to remove future uncertainties increases. However, with climate change, historical demand trends, river flows and rainfall and run-off data have declining relevance, placing increasing focus on adaptive management and flexible responses.

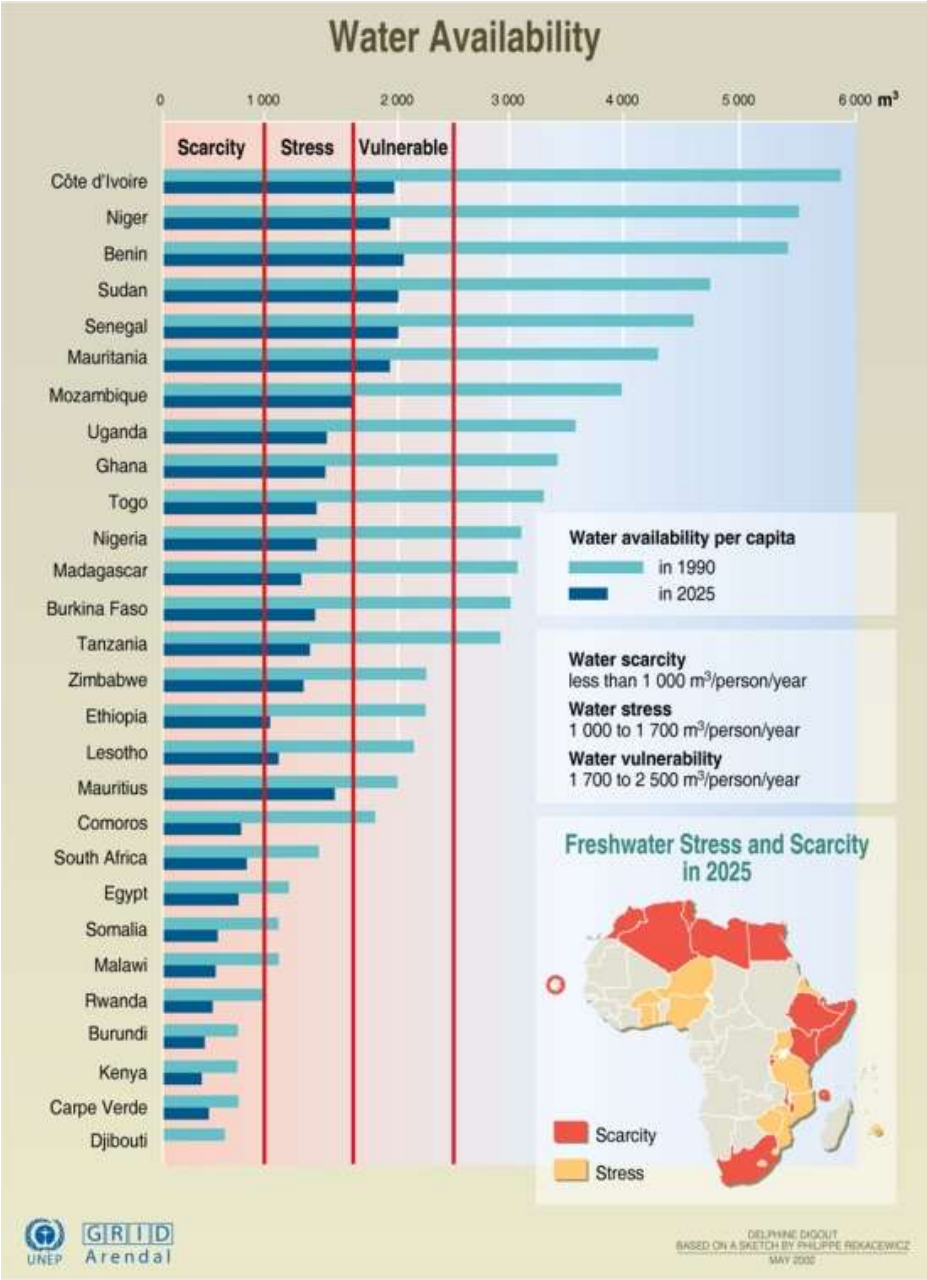
In the discussion of the effects of and vulnerability to climate change, there are a number of concepts that need to be clarified.

- **Impact**: The consequence(s) of exposure to a change or stress on a system.

- **Resilience and vulnerability**: Resilience and vulnerability are two ends of the spectrum describing the ability of a system to absorb perturbations or stresses without changes in its fundamental structure and function that would drive the system into a different state (or extinction). A system that is well able to absorb change is a resilient system, while a system that is poorly able to absorb change is vulnerable. The most appropriate response to climate change is to increase the resilience of human and natural systems where possible.

- **Adaptive capacity**: The potential of a system to reduce impacts from stresses or perturbations; not necessarily the actual adaptive actions taken in response.

- **Risk**: The probability and significance of harm attendant on exposure to a perturbation or stress



Source: United Nations Economic Commission for Africa (UNECA), Addis Abeba ; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

Figure 7: Water availability in Africa (Source UNECA 2000)

3. METHODOLOGY

The need for risk assessments as a mechanism to support water sector decision-making is increasingly being recognized as a central component of adaptation to climate change. Many alternate approaches and methodologies for undertaking such assessments now exist, and a general consensus is emerging over the utility of these methods for identifying future risks and vulnerabilities and developing adaptation strategies.

In order to determine the key freshwater risk areas in Africa in this study, a framework assessment was developed based on four key assessment elements: hydrological, socio-economic, institutional and climate change. The first three categories look at the current status while the climate change assessment looks at the future climate change prediction and impacts. Regional specialists in each of five regions were appointed to compile the necessary information for the framework assessment. This information collection was conducted at a desk top level, through the sifting of existing information.

The information provided through the framework assessment was examined through the lens of the sectoral vulnerabilities as described in section 3.2. On the basis of this layering of information, a set of thematic risks were identified. These thematic risks are described in section 3.3. An analysis of the hydrological, institutional and socio-economic status and the climate change predictions, enabled the identification of key thematic risks for each of the basin clusters. The results of this process were tested in a workshop held in Pretoria from the 4th – 6th November 2009, attended by a range of specialists from across the continent. Arising from this process, those areas in Africa most vulnerable to the impacts of climate change have been identified, as described in section 9.

The water resources status was assessed on the basis of per capita water availability, general water quality and the level of water stress. The socio-economic status reflects average per capita income and the development status of the country largely as reflected in the UN human development indices. The institutional capacity broadly reflects the existence and capacity of transboundary water management institutions, the level of infrastructure development, the national water resources management capacity including the existence of appropriate policy and legislation, and the financial and human resources capacity to implement the policy and legislation. The climate change column reflects the predicted severity of climate change impacts in terms of rainfall and temperature changes and their impact on the hydrology of the region. A qualitative assessment of these four parameters was done to generate the final column describing the level of risk in the region to the impacts of climate change. Thus, the risk is seen as being higher where the institutional capacity to adapt is low and where levels of poverty are already high. Risk is, therefore, not just a measure of the physical impacts of climate change, but a measure of the ability of the society to adapt to and withstand that change.

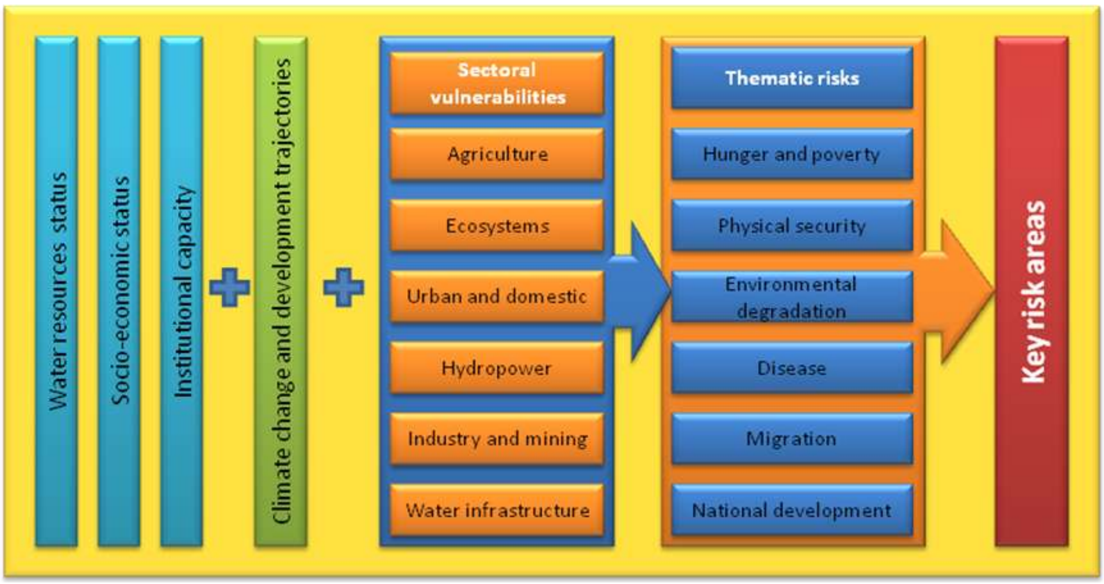


Figure 8: Methodology applied to determine key freshwater risk areas in Africa

3.1. REGIONS AND CLUSTERS

In order to generate effective information within the project constraints, rather than attempting to analyse climate change vulnerability individually in each of the transboundary basins and aquifers in Africa, these basins and aquifers were grouped into 15 clusters according to broad similarities in hydrological, climatic and socio-economic characteristics and geographical location. This grouping was tested against specialist knowledge in each of the five regions to ensure the validity of the approach. These fifteen clusters, grouped into five regions, are outlined in figure 7 below, and can be described as follows:

Northern Region:

- Cluster 1: Transboundary basins and associated aquifers in North Africa.
- Cluster 6: The Nile River Basin
- Cluster 15: The aquifers of inland North Africa.

Western Region

- Cluster 2: Coastal rivers of West Africa from the Senegal to the Little Scarcies
- Cluster 3: Coastal rivers of West Africa from the Moa to the Sassandra
- Cluster 4: The Niger, Volta, and adjacent smaller basins
- Cluster 5: The Lake Chad basin

Eastern Region:

- Cluster 7: The Baraka and Cash rivers in East Africa
- Cluster 8: Transboundary rivers and aquifers in the horn of Africa
- Cluster 9: The river and lake systems of the Rift valley

Central Region:

- Cluster 10: The Congo River Basin
- Cluster 11: The coastal rivers west of the Congo River Basin

Southern Region:

- Cluster 12: The Zambezi River Basin
- Cluster 13: Transboundary river basins in the eastern part of Southern Africa, including the Ruvuma, Limpopo and Incomaputo

- Cluster 14: The transboundary basins and aquifers of western Southern Africa from the Kunene to the Orange-Senqu.

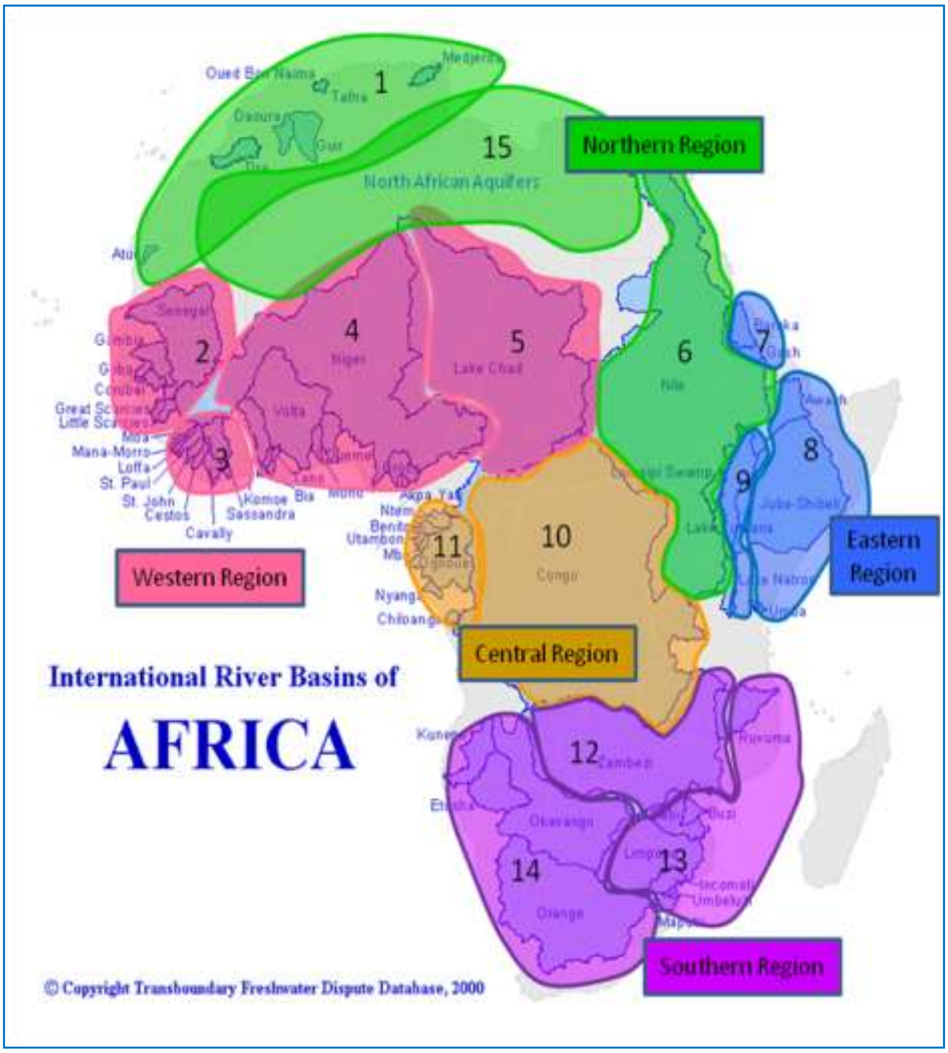


Figure 9: Map of clusters and regions of transboundary basins and aquifers used in this study

3.2. SECTORAL VULNERABILITIES

Sectoral sensitivity to climate change, viewed through a water lens, is a useful point of departure in considering potential risks and vulnerabilities. This section provides a high-level description of key sectoral sensitivities. These sectoral sensitivities have been outlined in more detailed reviews of the impacts of climate change on particular sectors elsewhere in the climate change literature, and such reviews add substance to this brief overview.

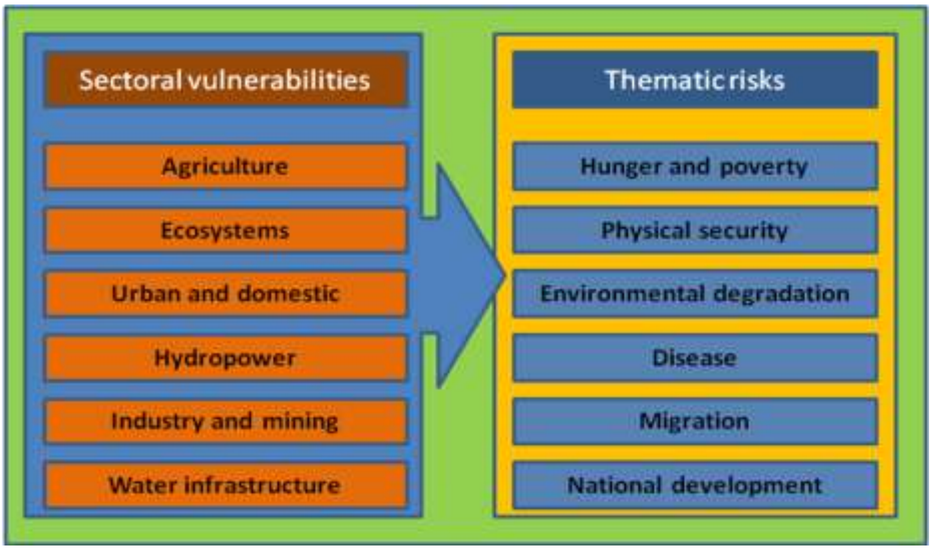


Figure 10: Diagram of Sectoral vulnerabilities and Thematic risks defined in this study

- **Agriculture**

Agriculture is sensitive to climate through the effects on rainfall, temperature and CO_2. Effects of rainfall are relatively obvious, as they drive rain-fed agricultural production and result in the run-off (and recharge) that provides for irrigation water. For rain-fed crops, the nature of the rainfall events and of the rainy season is at least as important as overall annual rainfall, with high intensity events often resulting in extensive runoff and physical damage to crops (particularly where hail is involved). In addition, prolonged dry spells between rainfall events can have profound effects on agricultural production, particularly during the crop emergence phase. Similarly, late or unseasonal rains may spoil crops or increase the disease burden.

A number of countries in Africa already face semi-arid conditions that make agriculture challenging, and climate change will be likely to reduce the length of growing season as well as force large regions of marginal agriculture out of production. Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected. This would adversely affect food security in the continent. (IPCC AR4 2007)

The temperature effects on agriculture are primarily through changed productivity and increased crop water demand. Some crops require cold conditions to flower or seed, and increased temperatures can reduce productivity in these cases. In many cases, a small rise in temperature will increase crop productivity, while too high a temperature rise will impact negatively on growth. Increased temperature also affects disease, typically increasing the disease burden.

A number of the African NAPAs identify the agricultural sector as one of the key areas of climate change vulnerability in Africa.

- **Ecosystems**

The environment is sensitive to both the amount of rainfall (and the associated quantity and timing of run-off) and to temperature effects. Ecosystems have evolved over time to function within a particular temperature range. Temperatures moving significantly outside this range may have major impacts on particular species or on whole ecosystems. Low flows coupled with high temperatures can place significant stress on freshwater ecosystems, while storm events can result in physical damage and change the morphological characteristics of the river beds (and wetlands), in some cases resulting in dramatic changes in the system. Surface temperature effects in lakes can increase stratification and reduce turn-over, dramatically changing the nutrient balance and associated ecosystems. Snowmelt effects, although rare in Africa, can dramatically change the spring and early summer run-off in snow-fed rivers, as snowfall decreases and snowmelt in the spring is accelerated (e.g. rivers on the slopes of Mount Kilimanjaro). Small temperature increases can dramatically affect the proliferation of invasive alien plants and eutrophication responses in freshwater lakes and rivers.

- **Urban and domestic**

The urban-domestic environment is most dramatically affected by temperature, with increasing water demand driven by higher temperatures, although urban water use remains a relatively small proportion of overall water use in Africa. In addition, local flooding effects following increased rainfall and storms can have dramatic local impacts, undermining quality of life, resulting in increased water ponding and disease risks, and potentially reducing economic activity where disruptions of services and economic activities are experienced. Urban sanitation systems can also be disrupted by flooding, with potentially severe health effects. Water supply may also be affected through potentially reduced run-off / yield in a freshwater system receiving less rainfall input, or through damage to water supply infrastructure following storms. Pressure on urban systems will also be increased by sea level rise in coastal cities, with the potential for exacerbating flood events and causing saline intrusion into urban groundwater systems. Of particular concern is that Africa already has an extremely high proportion of urban communities living in informal settlements (around 70%), and people in informal settlements are most vulnerable to floods, disease and service delivery failure, including access to water services.

- **Hydropower**

Hydropower production is fundamentally affected by the yield of the system where impoundment infrastructure has been constructed, or run-off where production is "run-of-river". Reductions in yield and / or runoff because of reduced annual rainfall can have dramatic effects on hydropower production and the return on hydropower investment. Finally, climate change may result in proliferation of invasive aquatic weeds (particularly water hyacinth) that can cause physical damage to and block hydropower turbines, resulting in increased maintenance costs and a marked reduction in power production.

Hydropower is identified in a number of NAPAs as being a key area of climate change-related vulnerability.

- **Industry and mining**

The effect of climate change on industry and mining is primarily through temperature related changes in demand, and through adaptations in infrastructure and safety investments that may be required following increased risk of infrastructure damage, pollution incidents, and safety incidents associated with extreme events. A further possible impact is through the reduction in available water for production, and in available assimilative capacity within the resource for effluent discharge, resulting in the need for technological and operational shifts. Such changes impose a financial cost and affect profit margins and hence the investment decisions of the industrial and mining sectors.

The tourism industry's vulnerability to climate change is primarily through the effects on the environment, and the changes in the environment that drive the viability and productivity of the tourism sector. Physical damage to tourism infrastructure and reduced utility through uncomfortable climatic conditions are fringe effects that are possible in some (limited) locations but are unlikely to manifest widely.

- **Water infrastructure**

Although not specifically being a sectoral vulnerability, water infrastructure is included here as it is directly at risk through climate change. Increased storm and flood events put water infrastructure (be it major storage infrastructure, small or medium storage or irrigation infrastructure and water services and sanitation infrastructure) at risk. Increased sediment loads from increased rainfall on degraded land also pose a threat to storage and to treatment effectiveness. Reduced rainfall, on the other hand, can reduce the yield of a system, thereby reducing potential revenue from the sale of water, the potential to cover the costs of capital and operation and maintenance expenditure, and the reliability of water that can be provided in multiyear cycles.

3.3. THEMATIC RISKS

The sectoral vulnerabilities described in the previous section contribute to a range of risks to human security, either at the individual, household or national level. These risks are described in this section under five broad headings, which describe the risks within a particular thematic group. These thematic risks are used in the following sections to tell qualitative stories of the climate-water risks in key areas across the continent. Each of these thematic risk groups is briefly described below.

HUNGER AND POVERTY

African nations have, on the whole, high levels of hunger and poverty, particularly, but not only, in the rural areas. Those already living in poverty are extremely vulnerable to negative impacts arising from climate change.

Rural communities, as a result of high levels of poverty, distance from the services provided in urban areas, and high dependence on natural systems and rain-fed agriculture for their livelihoods, are the most vulnerable to the impacts of climate change. This is compounded by the fact that communities or households with limited resources struggle to recover from disasters and similar negative impact events. Poor households headed by women struggle the most to recover from disasters.

Rural communities dependent on dryland agriculture are extremely vulnerable to climate change. Rain-fed agriculture (commercial or small-scale) will become more marginal in many areas, with significant consequences for food security and rural livelihoods. Limited temperature increases may, to a certain extent, increase crop productivity in some areas, but will also increase crop water needs through increased evapotranspiration.

Around the great lakes in Africa, rural communities are dependent on freshwater fisheries for protein sources and for income. However, in many of these areas there is the potential for a decline in fisheries productivity due to changing aquatic temperature, water quality and/or hydrological regimes, with potentially severe consequences for local livelihoods and economies.

Poor women in Africa will, and do, bear the greatest burden from the changing climate.

Where industrial or economic growth is negatively impacted by floods, interrupted hydropower production, or water shortages, increased unemployment, or a failure to reduce unemployment through economic growth, may increase the number of people in urban and peri-urban areas living in poverty and facing food insecurity. A recent study revealed that urban workers in developing countries will be particularly vulnerable to increased food prices as a result of climate change, and may be driven into poverty as a result.

Finally, rural domestic and stock water use of shallow wells may be jeopardised by falling groundwater tables associated with decreased aquifer recharge and increasing temperature, with consequences for increased poverty and hunger in rural and peri-urban areas.

Increasing poverty and hunger are likely to exacerbate gender inequalities, with the worst impacts being borne by women- and child-headed households.

PHYSICAL SECURITY

Climate change will affect people's physical security through flooding in smaller unregulated river tributaries due to changing hydrograph peaks (flash floods) caused by increasing rainfall (storm) event intensity, frequency and/or duration, or, at the basin scale, inundation of flood plains due to increased frequency of large cyclonic events resulting in significant quantities of water routing through the system, both causing loss of life and destruction of infrastructure and property. Floods also contribute to the loss of housing and the displacement of people.

ENVIRONMENTAL DEGRADATION

A large number of environmental goods and services provided by water systems are under threat from climate change. Aquatic ecosystem health and functioning may deteriorate due to changing quantity and timing of rainfall, on top of increasing development impacts on water resources. Equally, the direct use of natural resources by local communities may be increased by climate change related impacts on other livelihood resources such as agriculture, fisheries, and woodlands. This may have consequences for biodiversity and local conservation tourism (terrestrial ecosystems).

DISEASE

In many regions, climate change will increase the areas vulnerable to water-related diseases such as malaria. This is of particular significance for poor and marginalized communities who suffer from poor health and lack of access to good medical care.

Human health, already compromised by a range of factors, could be further negatively impacted by climate change and climate variability, e.g., malaria in southern Africa and the East African highlands (IPCC AR4 2007)

The high prevalence of HIV/AIDS in sub-Saharan Africa makes people in this region particularly vulnerable to the disease related impacts of climate change. Households coping with HIV/AIDS are generally already under stress from dealing with ill family members, or the loss of breadwinners and parents. The number of child headed households is on the increase in sub-Saharan Africa. The increased poverty and malnutrition experienced by many AIDS affected households increases vulnerability to infection.

More frequent outbreaks of malaria, across a wider range, as a result of changing temperature and rainfall patterns pose a lethal hazard to those with AIDS. The level of other diseases such as leishmaniasis, a parasitic disease transmitted by the bite of sand flies, may also be affected by climate change, hitting those with compromised immune systems the hardest.

MIGRATION

In some areas, the impacts of climate change and the resulting competition over scarce resources will result in people leaving areas that have been particularly badly affected, to look for land or jobs in other areas. Already Africa has experienced significant internal migration or displacement as a result of political conflict and natural disasters. According to the UN Office for the Coordination of Humanitarian Affairs, Africa reported 104 natural disasters in 2008, of which 99 percent were climate-related. These disasters affected 16.7 million people. As rain-fed agriculture decreases due to climate change, the number of internally displaced people will increase significantly. This will result in increased pressure on other rural areas, or, more especially, increased migration into urban areas. It is also likely, in this process, to deepen social inequities and the vulnerability of women and children in particular.

The issue of increased migration to urban areas as a result of climate change impacts in rural areas will increase stress on urban water supply systems, and the need to provide safe drinking water and sanitation to urban and peri-urban populations, and increase the number of people living in informal settlements.

NATIONAL DEVELOPMENT

All the above issues contribute to hampering national development. However, there are other factors that will have significant impacts on potential national development as well. Climate change may have significant impacts on hydropower generation assurance or security because of changes in the quantity and timing of water availability for dams or run-of-river schemes, with consequences for national and regional energy security and economic growth and stability.

Bulk industrial, mining and thermal power generation requirements are also under threat in some areas, as a result of decreasing water availability due to climate change and decreasing water quality due to unmanaged development impacts.

Commercial irrigation also faces threats from significant changes to hydrological regimes. Irrigated agriculture (commercial or small-scale) demand for water (from surface or ground water sources) is likely to increase with increasing temperature and decreasing rainfall, or as farmers shift from dryland farming to irrigation where rainfall becomes inadequate. This will result in increased pressure on water resources or, conversely, on food security at local and national scales.

In urban areas, urban domestic and industrial requirements which are likely to increase as a result of population and economic growth, may be jeopardised by decreasing assurance of supply from surface or groundwater sources, and/or coastal salt water intrusion, with the social and economic consequences of constrained supply of quality water.

REGIONAL ASSESSMENTS

This section sets out the hydrological, institutional, socio-economic and climate change assessments for the five regions of Africa as described in section 3.1. Arising from this assessment, key risk areas for the region or particular areas in the region are drawn out.

Some common issues pertain across large parts of the region, such as high levels of poverty and underdevelopment, poor institutional capacity and governance systems, limited access to finance, and low levels of human capacity for water resources management and development. These factors combine to set a fragile base from which to manage the impacts of climate change, resulting in high levels of risk to large numbers of people across most of the continent.

4. NORTHERN REGION

The northern region under discussion here is composed of a number of small transboundary basins to the north west between Morocco, Algeria and Tunisia as well as the large Nile basin to the north east. This largely dry region also encompasses a number of transboundary aquifers that are important water resources for rural and vulnerable communities as well as supporting agriculture across the region.

While the Nile basin extends into eastern Africa, it is discussed under the northern region. However, because the complex nature of this basin which straddles both countries and climate zones, it is dealt with as a separate case study within the northern region section.

4.1. OVERALL SCENARIO: NORTH TO NORTH WEST AFRICA

WATER RESOURCES STATUS

This region is one of the most water-scarce regions of the world. It lies in the arid to semi-arid climatic zones, where typically dry conditions prevail. Due to the diverse climatic influences across the cluster the climate is extremely variable. Maritime climatic conditions impact on the coastal regions from the west (Atlantic Ocean) and from the north (Mediterranean Sea) whilst from the south there are Saharan climatic impacts. As a result rainfall ranges from 50 mm/annum in the south to as high as 1000 mm/annum along the coast.

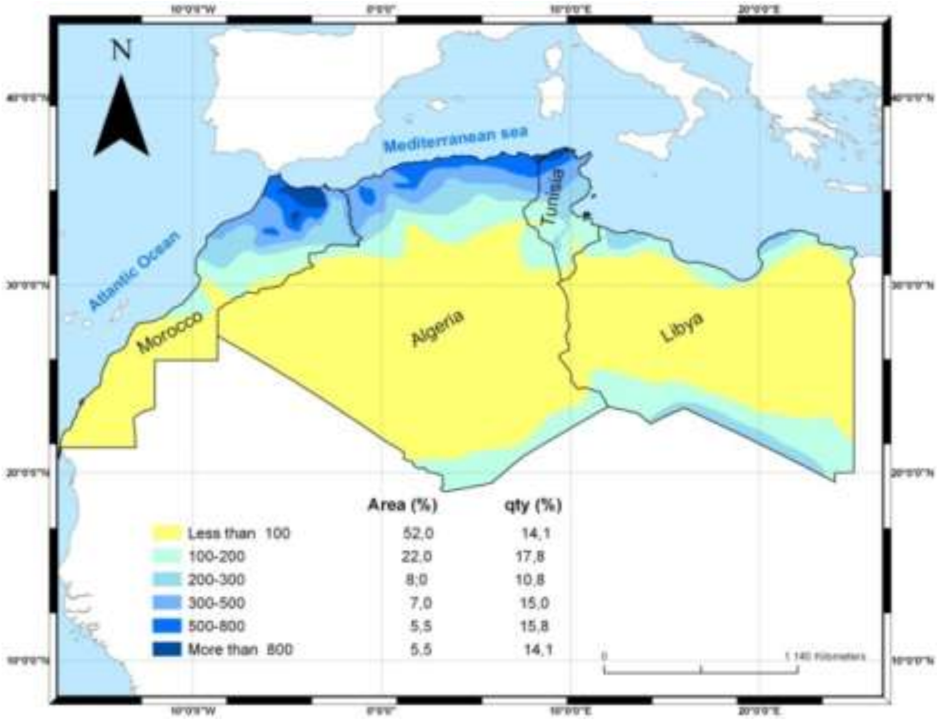


Figure 8: Rainfall (mm/a) in the Maghreb countries of Algeria, Morocco and Tunisia.

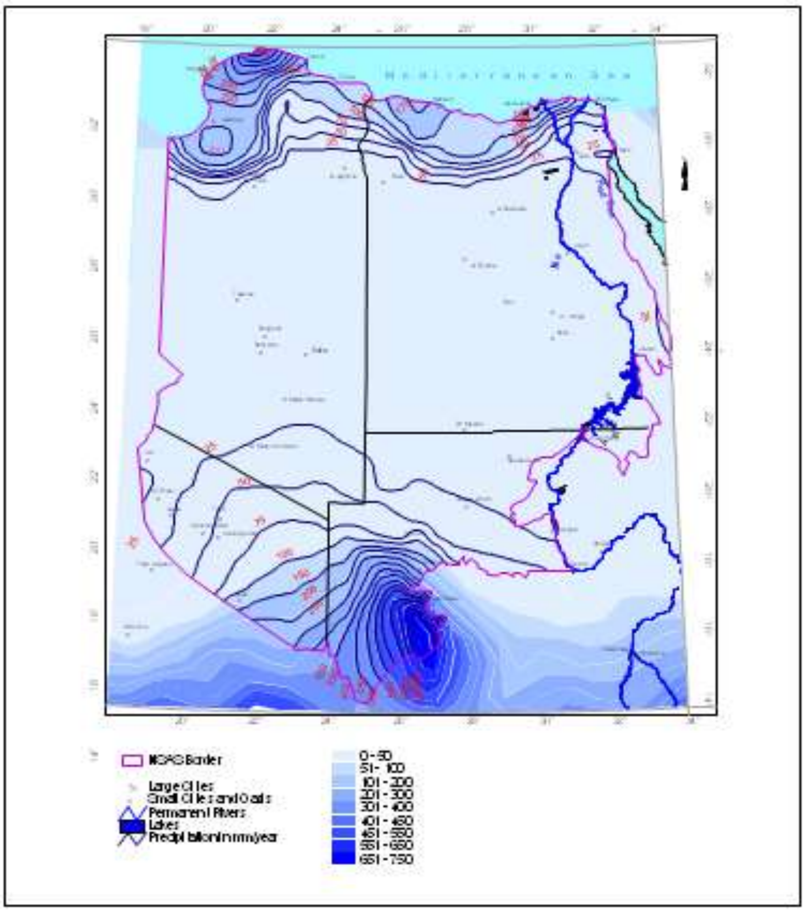


Figure 9: Rainfall across the area of the Nubian Sandstone aquifer (ArcAtlas, ESRI, 1998)

The distribution of rain over the year is very irregular and there is considerable inter-year variability, so that the region has repeatedly experienced extreme climatic events (drought and floods) that pose a continuous risk to North Africa's people and their livelihoods, and national economies. Since the rainfall occurs mostly as short and heavy storms, generally between autumn and winter, flood events contribute extensively to the water fluxes of the rivers. With such events erosion is of serious concern.

Transboundary basins in this cluster are variable in size and complexity. A number are small basins with low population densities. However, because of the high aridity and recurrent droughts, most basins in this cluster are facing severe water stress.

Table 2: List of transboundary basins in the northern region with riparian states, population and area (Data drawn from the Transboundary Dispute Database, Oregon State University)

Name	Countries	Area (km^2)	Population
Atui	Mauritania, Western Sahara	31,709	3,730
Daoura	Algeria, Morocco	34,451	623,394
Dra	Algeria, Morocco	96,249	1,417,175
Guir	Algeria, Morocco	78,843	418,589
Medjerda	Algeria, Tunisia	23,149	2,991,624
Tafna	Algeria, Morocco	9,430	1,618,212

Groundwater plays an important role in the overall water resource framework for this cluster and is used extensively. Many of these aquifers are transboundary in nature and present some complexities in terms of resource management.

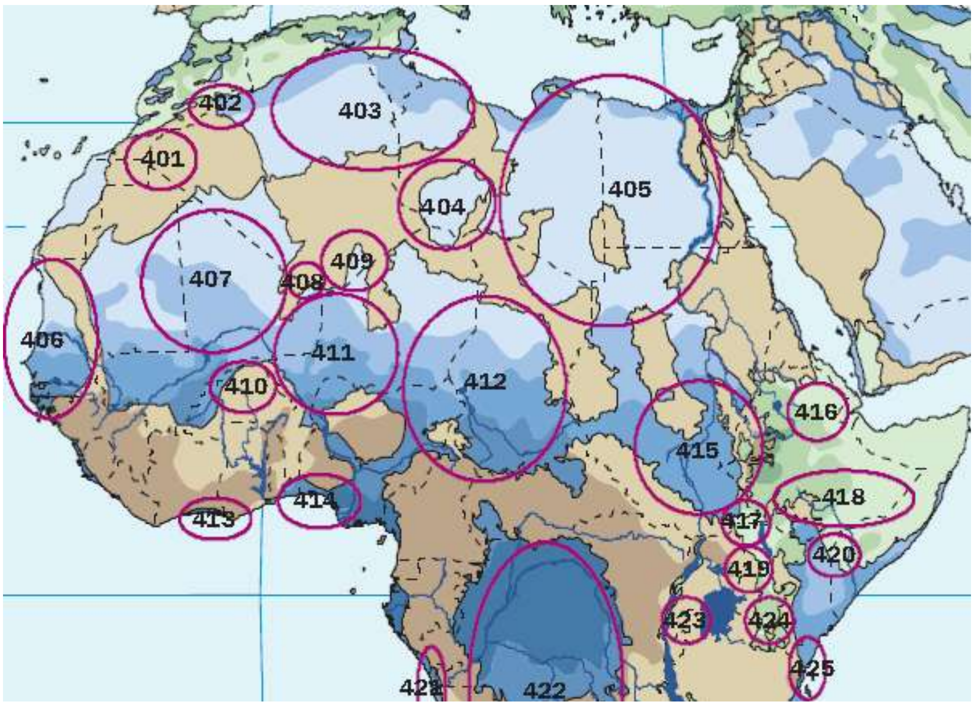


Figure 10: Transboundary groundwater aquifers (from UNESCO ISARM programme, 2009)

The transboundary aquifers for this cluster are tabulated below.

Number	Name	Countries

401	Tindouf Aquifer	Algeria- Morocco
402	Errachidia Aquifer	Algeria- Morocco
403	North West Sahara Aquifer System	Algeria- Libya-Tunisia
404	Moutzouk-Djado Basin	Chad-Libya-Niger
405	Nubian Sandstone Aquifer	Chad-Egypt-Libya-Sudan
407	Touderi Basin	Algeria-Mali-Mauritania

Figure 11: Transboundary aquifers in North Africa

While there are instances where these aquifers are being mined to support urban and industrial developments, these resources mainly play a critical role in supporting rural and nomadic peoples, and irrigated agriculture through wadis, oases and shallow wells. The Nubian Sandstone aquifer is largely non-renewable in nature as are a number of others. Availability and dependency on groundwater vary across the region.

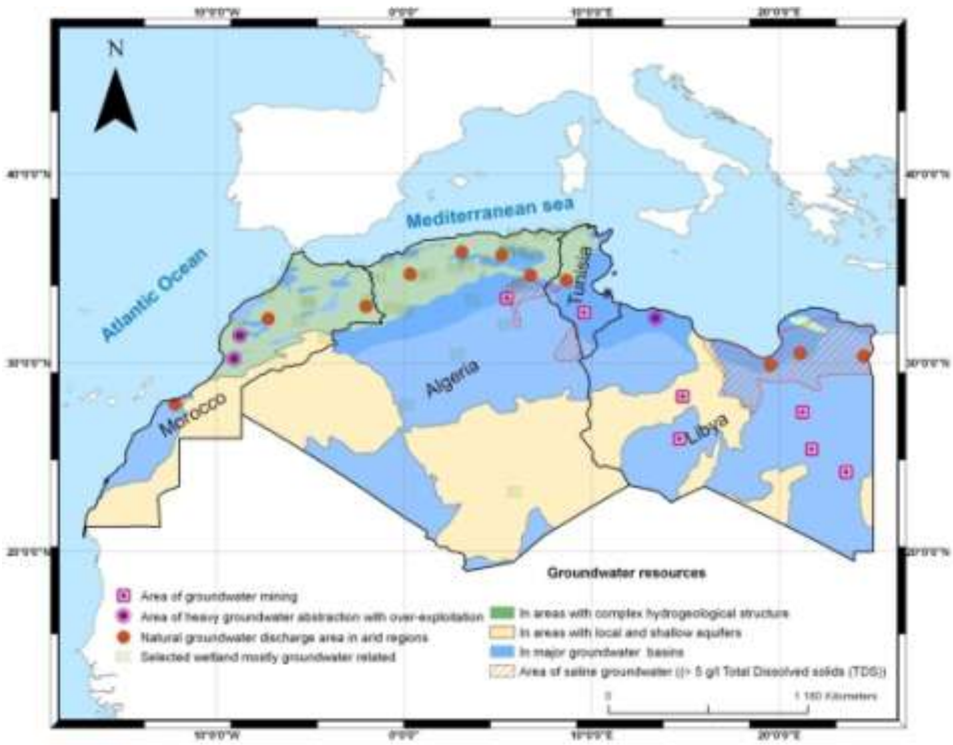


Figure 11: Groundwater resources in the Maghreb sub-region

SOCIO-ECONOMIC STATUS AND DEVELOPMENT TRAJECTORY

This cluster has typically very low human development indices. The economies are very dependent on water and agriculture, and this lack of diversification brings its own economic vulnerability. Rural communities face poverty and health challenges related, amongst other things, to water. This leaves these communities very vulnerable to droughts and floods. Due to these pressures, some nodes across the cluster are experiencing increased urbanization.

In the wetter Medjerda basin there is a significant dependency on rain-fed agriculture, but the rest of the region relies heavily on irrigated agriculture which constitutes over 80% of water use across the cluster. In a number of the countries, agriculture makes up a significant part of the GDP, although industry and tourism are increasingly adding to national GDP. Domestic use appears to make up about % of water use, while industry uses some 7%.

While agriculture is dominant across the cluster, and probably will be into the near future, there are likely to be gradual changes as members of rural communities in water stressed basins migrate towards urban areas. There appears already to be some concern over the quantity and quality of water required to support tourism, and with increased urbanization and growth across the cluster there will be further pressure to meet the requirements for reliable water supply.

In the Maghreb sub-region, deterioration of water resources is taking place due to increases in salinity and nutrient loads from irrigation and the domestic and industrial sectors. In some countries urban wastewater treatment is inadequate or non-existent. In arid areas which are highly dependent on underground aquifers for drinking water supplies, groundwater pollution is a particular concern.

Aquatic ecosystems are already facing serious risks from development pressures such as eutrophication, and pollution from domestic and industrial effluents and chemical spills. As a result, reduction in fish populations, habitat destruction, and loss of biodiversity are already being experienced.

In terms of large hydropower development, Algeria, Libya and Tunisia are poorly developed while Morocco has some installed capacity. Some reports indicate that the large hydropower potential of North Africa is almost exhausted and that the future focus should be on small hydropower development. However, it does appear that Tunisia has hydropower opportunities that will be exploited in future, although the extreme hydrology represents a significant challenge, especially to smaller schemes.

INSTITUTIONAL CAPACITY

In this region policy, legislation and planning are largely focused on meeting supply requirements, with a limited management perspective. It has been recognized across many of the countries that policy and legislative shifts are required, and some have been made, but lack of political commitment, long term vision and financial resources to support such shifts has held back the much needed reforms.

As with many countries across the continent, the countries in this region have had challenges in ensuring co-operation between government departments to support integrated water resource management. The focus of past water management was largely on providing water services and sanitation. The Moroccan authorities have recognized the need to shift policy and approaches and have, in response, developed a National Water Plan. Algeria, in 2005, promulgated a new water law focused on sustainability. In Tunisia, an action plan has been developed which prioritises water demand management, integrated water resource management, the development of non-conventional water resources and the protection of water resources.

Infrastructure has been developed across the cluster through a mix of large and small dams, water transfer schemes and networks of boreholes. However, infrastructure development has not been as significant in the transboundary basins, leaving these basins vulnerable to climate change. The siltation of dams is of particular concern across this cluster, not only diminishing basin yield, but also impacting on hydropower potential.

Generally, water conservation across the cluster is poor and the monitoring that underpins effective water resource management requires improvement. This is exacerbated in the transboundary context where there are mismatches in approaches and the quality of such systems.

This cluster is typified by complex governmental and agency arrangements that are often fragmented, with limited coordination and large inefficiencies. The capacities of many of these institutions appear stretched and in need of long term capacity building support. Morocco has established nine river basin agencies to manage water resources, supported by an inter-ministerial water commission that was established in 2001. However, these agencies are not fully operational because of human resource challenges and financial constraints. Algeria has also established five basin agencies to manage their 19 watersheds. A National Water Council has been established to coordinate and regulate these bodies, but capacity challenges are also significant. Tunisia, in the face of capacity constraints and the frequency of droughts, has focused on acquiring relevant experience in water management under shortage conditions.

This situation is further exacerbated by poor cost recovery and generally insufficient allocation of funds by government. The disparities between countries in the transboundary situation exacerbate this situation. Most of these basins have no transboundary agreements and no shared watercourse institutions to facilitate cooperative approaches.

CLIMATE CHANGE

Historical climate data in the region indicate that during the 20th century, temperatures increased by more than 1°C, with a pronounced trend in the past 30 years. The data also show increasing drought frequency from one event every 10 years in the beginning of the 20th century, to five or six events every 10 years currently. Floods, though generally more localized than droughts, are being experienced more frequently now than ever before in the region. In the last few years, North African countries, especially Algeria, Morocco and Tunisia, have experienced torrential flash floods sparked by heavy rains, resulting in loss of lives and significant damage to infrastructure.

It is estimated that, by 2030, temperatures will be 1 - 1,5 ^{0} C higher, with longer term scenarios predicting significantly warmer conditions and associated increases in evapotranspiration. At the same time, rainfall is predicted to decrease by 10-20%. For the "Saharan" region (18N, 20E to 30N, 65E) predictions are that by 2080 there will be an increase in temperature by 3.6^{o}C and a decrease in rainfall of 6%. A 10% reduction in rainfall would result in a 25-39% reduction in perennial drainage.

Rainfall events are expected to be more intense and less frequent, which will see reduced infiltration and lower aquifer recharge. This could have serious impacts on the wadis and oases scattered across this region. Coastal aquifers could face increased threat of saline intrusion.

The analysis of all climate models and SRES scenarios shows a likely increase in the number of people who could experience water stress by 2055 in northern Africa (Figure 12).

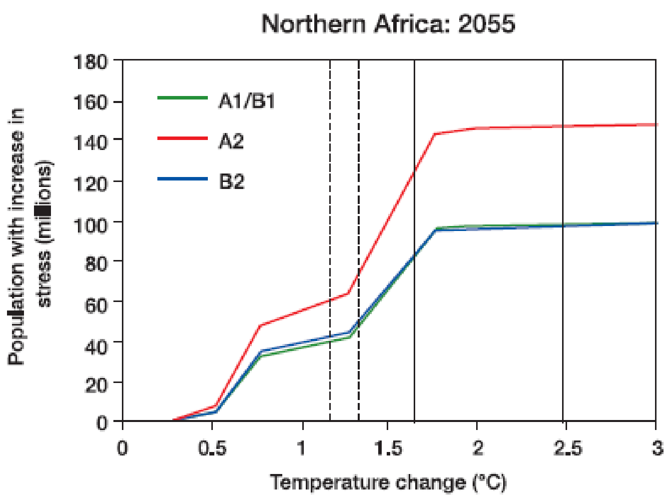


Figure 12: Number of people (millions) with an increase in water stress (Arnell, 2006). Scenarios are all derived from HadCM3 and the red, green and blue lines relate to different population projections.

4.2. KEY RISK AREAS

The overlay of future climate change scenarios over the current development, hydrological and institutional challenges of the cluster result in a number of key risk areas being identified.

HUNGER & POVERTY:

Some 80% of water use is for agriculture across this region, and agriculture provides an important contribution in terms of jobs and food security. There is an intention to expand agriculture as there are general food security concerns. However, there is substantial agreement that these regions will become increasingly warmer and drier, putting irrigated agricultural under stress and re-emphasising the need to develop infrastructure to improve assurance of supply. Some rain-fed agriculture exists in the more coastal and Montane areas, and climate change will result in shortened growing periods. This may require storage in order to move to irrigation, but in many instances these more marginal agricultural activities may well disappear as a result of climate change.

The transboundary basins of Daoura, Dra and Guir are at severe risk. Very much dominated by agriculture, these basins have large populations facing severe water stress. Crop yields will decrease with increased temperatures, increased water stress and shortened length of growing periods. With little adaptive capacity via institutional structures and infrastructural capacity these basins require urgent adaptation support.

Under significantly warmer and drier conditions, the need for rural communities to shift to more urban environments will become more urgent. Many communities are dependent on groundwater aquifers as well as systems of wadis, oases and pans that provide water for both domestic uses and to support livestock and food gardens. Shallow groundwater tables have already by 0.4 m/year in recent years, and deeper groundwater tables by as much as 0.7m/year. This makes communities dependent on groundwater extremely vulnerable – a scenario that is exacerbated by the climate change predictions. Over recent years, there has been significant urbanization and this is likely to increase as a result of climate change.

Decreasing agricultural production may result in increased food prices in urban areas with the potential to push workers in these areas into poverty.

PHYSICAL SECURITY:

The region is likely to see more extreme events, including floods. Although the flooding has been a part of the water resources history, it is likely that these will become more frequent and severe, with associated impacts on infrastructure, human security and economic development. As the most densely populated areas of the region, the Medjerda and Tafna are at risk in this regard.

ENVIRONMENTAL DEGRADATION:

Reduced runoff will result in decreased aquifer recharge and have serious impacts on the various oases dotted across the region. As a result of the impact on certain endemic fish species there will be a knock-on impact upon migratory bird species.

Increased levels of water stress will result in degradation of aquatic ecological integrity in transboundary systems. Within the wadis, oases and pans, very unique flora and fauna exist. These areas are at risk from lower rainfall and groundwater recharge.

MIGRATION:

This region has already seen a progressive migration of rural communities towards urban areas which is likely to be exacerbated by climate change impacts. The more arid transboundary basins are most at risk in this regard, despite the fact that some of these have fairly low population densities. Basins at particularly risk include the Atui, Daoura, Dra and Guir.

NATIONAL DEVELOPMENT:

The increased variability in climate will influence the assurance of supply that is needed to successfully generate hydropower. This will be exacerbated by the increased possibility of siltation. This is of concern specifically in the Mejerda where both Algeria and Tunisia would like to develop hydropower capacities.

Morocco has already developed some hydropower and there is a move to create more, even if only at small scheme level. Algeria and Tunisia are expecting to develop further hydropower capacity, but future climate conditions will see infrequent and even extreme rainfall events which do not support hydropower development. It is estimated that Morocco's hydropower schemes have in recent years only produced some 50% of expected production due to recurrent droughts. Increased silt loads from more extreme events will also diminish infrastructure capacity.

Water quality is also of concern. Deteriorating water quality will arise due to poor waste water treatment and runoff from agricultural lands under more intense rainfall conditions. Localised urban pollution is of major concern because of its impact upon tourism as a key growth sector for the region.

SUMMARY RISK ASSESSMENT

While a number of risks have been identified in this region, the region is buffered by relatively good levels of institutional capacity and a relatively good socio-economic base. These features enable the countries and communities of this region, on the whole, to be able to adapt to and manage the severe impacts of climate change.

4.3. OVERALL STATUS: NILE BASIN

WATER RESOURCES STATUS

The Nile and its tributaries flow though ten countries: the White Nile flows though Uganda, Sudan, and Egypt, the Blue Nile flows through Ethiopia, while Kenya, Tanzania, Democratic Republic of Congo (DRC), Rwanda, and Burundi all have tributaries which flow into the Nile or into Lake Victoria Nyanes. The Nile is the longest river in the world (6695 km), but in relative terms it does not carry very much water, the average discharge being only 84 billion cubic meters annually. This low runoff is in large part due to the majority of Nile flow originating from a relatively small fraction of the basin. The extreme length, modest discharge and high water demand and population growth increases the potential for water stress.

The two primary runoff producing regions in the Nile Basin are the lake plateau of equatorial East Africa and the Ethiopian plateau. Some 86% of the average annual discharge originates in Ethiopia, consisting of the Blue Nile (some 59%) and two further tributaries. While the White Nile contributes 14%, it loses nearly 50 percent of its original discharge in the Sudd swamplands of southern Sudan.

Figure 13: Map of the Nile Basin (Source: Nile Basin Initiative)

Importantly for the Nile basin, the Inter Tropical Convergence Zone brings wetter climates to the upper basin in the Ethiopian highlands, the cluster of countries in the region of Lake Victoria and southern Sudan. As a result, annual rainfall is relatively high along the northern coast, decreases southwards, and then increases again in the upper reaches of the basin to the south. Annual rainfall in the basin ranges from less than 25 mm/a in the hyper arid regions to as high as 1600mm/a in the more tropical regions.

SOCIO-ECONOMIC STATUS AND DEVELOPMENT TRAJECTORY

While the upstream countries can depend upon a more diverse suite of water resources, for the downstream country of Egypt, the Nile River is the only renewable water resource available to sustain irrigated agriculture and drinking water supplies. The primary water uses in the basin are water supply (agricultural, industrial, and urban) and energy generation. At present, Egypt and Sudan represent nearly all of the consumptive use in the basin with 18.5 and 55.5 billion cubic meters per year, respectively.

Agricultural water use is the most important use of water in all the Nile basin countries. On average 85% of the water is utilized for agricultural purposes. In Egypt and Sudan the amount of water used for irrigation is almost as much as the total annual renewable water resources. The irrigation potential of the other countries is extensive and they are interested in exploiting this potential (FAO 1997; Mohamoda 2003). Agriculture contributes 35-50% to the overall GDP of the Nile Basin countries and provides employment to 60-90% of the population. Only Egypt has a smaller agricultural sector, contributing 17% to the country's GDP and providing employment to about 30% of the population.

The Nile River is also an important source of hydropower generation. Several dams have been constructed for this purpose, most significantly within in Egypt and Sudan, as well as the Owen Falls on Lake Victoria. It is clear that hydropower will play an increasing role in water management into the future, and whilst other countries consider this option, Ethiopia is most notably considering this as a development future.

The Nile River is a vital waterway for the transportation of people and goods. The river and its tributaries are partially and seasonally navigable. River steamers still provide the only means of transport facilities especially in Sudan south of latitude 15º N during the flood season, when road transport is usually not possibl e. Most of the towns in Egypt and Sudan are situated on or near riverbanks.

Groundwater resources within the Nile River Basin are highly variable, both in terms of their recharge and their extent. In the north of the basin, the main aquifers are the Nile Valley System and the Nubian Sandstone Aquifer System. The Nubian Sandstone Aquifer is fossil, i.e. non-renewable. The Umm Rawaba Formation is an important aquifer system in the Sudan which supports many people, livestock and vegetation. This aquifer, which occupies 20% of the country's area, has a storage capacity estimated at about 4 000 km^3 and an annual recharge rate estimated at around 600 km^3.

Groundwater is used increasingly to irrigate during the dry season, and in the most arid zones groundwater can be the only supply source for all types of farm activities. Groundwater resources are under pressure from increased water demand because of rapid population growth and surface pollution. Unsustainable quantities of water are being extracted in many areas, seriously diminishing the reservoirs.

SOCIO-ECONOMIC STATUS

The Nile Basin is one of the poorest regions of the world. With the exception of Egypt and Kenya, the remaining eight basin countries are classified as least-developed countries by the United Nations, making their populations particularly vulnerable to famine, disease and the impacts of climate change. Nearly 100 million people within these basin countries live on less than a dollar a day. Burundi and the DR Congo are among the world's poorest countries, with per capita incomes in the range of US$100-200 per year, whereas Egypt is ranked as a middle-income country with a per capita income of US$1,580 in 2007.

More than 70% of the population depends directly or indirectly on farming for their incomes and livelihoods. Water scarcity is therefore a major challenge for the already closed basin. Besides widespread poverty and inequality, the region also faces humanitarian crises, including the HIV/AIDS pandemic, violent interstate and internal conflicts, and severe waterborne diseases and malaria.

INSTITUTIONAL CAPACITY

There are a number of treaties and agreements on the use and water allocations of the Nile, but none of these are agreed to by all of the river basin states. Due to the fact that these countries have a long history of disputes over water allocation, political tensions have often escalated to threats against other member states. Egypt and Sudan hold absolute rights to use 100 percent of the river's water under agreements reached in 1929 between Egypt and Britain and in 1959 between Egypt and Sudan, while the upstream countries are seeking to negotiate a new Nile waters agreement. Since Egypt must consent to other nations' use of the Nile's water, most of the other basin countries have not developed projects that use it extensively. Not surprisingly, over the years other basin countries have contested the validity of these treaties and demanded their revocation to make way for a more equitable system of management.

In February 1999, the "Nile Basin Initiative" (NBI) was launched. The Initiative is a partnership initiated and led by the 10 riparian states of the Nile River through the Council of Ministers of Water Affairs of the Nile Basin states (Nile Council of Ministers, or NILE-COM). The NBI seeks to develop the river in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security. The NBI started with a participatory process of dialogue among the riparian countries that resulted in their agreeing on a shared vision to "achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources". It provides an institutional mechanism, a shared vision, and a set of agreed policy guidelines which define the following as the primary objectives of the NBI:

To develop the Nile Basin water resources in a sustainable and equitable way to ensure prosperity, security, and peace for all its peoples

- To ensure efficient water management and the optimal use of the resources
- To ensure cooperation and joint action between the riparian countries, seeking win-win gains
- To target poverty eradication and promote economic integration
- To ensure that the program results in a move from planning to action.

In July 2008 the Nile Basin Council of Ministers endorsed a concept note for the development of a project to address climate change impacts and adaptation in the Nile basin and gave the go ahead to the Nile Basin Initiative Secretariat (Nile-SEC) for full project proposal development and the mobilization of funds for the project. The objective of the initiative is to jointly assess vulnerability and address climate change related impacts and risks through appropriate alternatives and adaptation actions.

CLIMATE CHANGE

The climate of the Nile basin varies considerably over both space and time, resulting in fluctuations in river flows and the levels of lakes in the basin. The levels of Lake Victoria and runoff in the Ethiopian highlands are, in fact, quite sensitive to variations in rainfall. Increased temperatures raises the possibility of increased evapotranspiration, particularly given the arid climate of the lower parts of the river, which might imply reduction in stream-flows, and increased water demand. On the other hand, increased precipitation in the Ethiopian highlands, may give rise to increased stream-flow downstream to the Nile's waters in Egypt.

The results of 21 climate models published in the IPCC Fourth Assessment Report show that, by 2080, warmer conditions can be expected, with the model mean showing an increase of 3.2°C and all models showing an increase of between 1.8 and 4.3°C. Nearly all models project wetter conditions in a range of between 3% reduction in precipitation, up to a 25 % increase.

In addition to changes in mean climate conditions, climate change is expected to cause changes in climate variability, in particular in the frequency and severity of extreme climate events, such as floods and droughts. However projections of changes in extreme events for the tropics remain uncertain. Variability in the climate in East Africa is driven largely by the behaviour of the El Nino/Southern Oscillation (ENSO) and circulation patterns in the Indian Ocean, but climate models do not show clear tendencies in the future behaviour of these large-scale drivers.

Climate change may have significant impacts on the lakes in the basin, resulting in reductions in fish populations on which a large number of communities depend for protein and income.

4.4. KEY RISK AREAS: NILE BASIN

The size and complexity of the Nile Basin dictates an array of vulnerabilities that also vary from country to country, including:

- Egypt: Long-term water security given the rapidly rising demand for water with a growing population; sea level rise and groundwater risks in the delta which is the main agricultural region and where the bulk of the population live.
- Ethiopia: Food security.
- Sudan: The impacts of extreme events and to some degree, food security.
- Lake Victoria basin: The impacts of extreme events and impacts of variability on hydropower generation and livelihoods, and reductions in fish populations in the lake.

Out of the size and complexity of the Nile Basin, a number of emerging risk narratives emerge.

HUNGER AND POVERTY:

Whilst this is of a general concern across the region, due to the high levels of water stress, there is high risk in Ethiopia, Sudan and the upper basin around Lake Victoria. Rural populations dependent on rain-fed agriculture are most at risk because of reduced crop production. Already high levels of poverty and under-development in the region put these communities particularly at risk.

PHYSICAL SECURITY:

The nature of climate futures for the region will see more extreme events, particularly floods. This is of real concern within the mid-basin areas of Sudan. This is exacerbated by densely populated areas and weak and fragmented institutional a capacity.

NATIONAL DEVELOPMENT:

Within this region the issue of the impact of climate change on national development has a number of dimensions. Firstly, Egypt, as the downstream state with limited renewable resources, relies significantly on the Nile for water security. However, there is in effect sufficient water, and it will take significant development in the upper basin to place Egypt at serious risk. Secondly, the ability across the region to develop the full hydropower potential will be placed at risk by extreme events and lack of assured supply. Thirdly, the discord within the basin as a whole, between the various member states, will continue to weaken progressive and sustainable solutions for the basin. This will over time have an impact upon broader socio-economic imperatives and national development agendas. The delta in Egypt is particularly at risk, particularly from sea level rise. Since this is the key agricultural area of Egypt and houses more than half of the Egyptian population, this is a particular concern.

SUMMARY RISK ASSESSMENT

The weak institutional arrangements and high level poverty of in most of the Nile Basin countries are of concern and limit the possible adaptive responses. While the Nile Basin Initiative has resulted in the development of a project to look at adaptive responses to climate change in the basin, implementation of adaptive responses will remain a challenge except in Egypt which has relatively higher institutional capacity and per capita GDP, resulting in higher levels of resilience to climate change impacts. The area most at risk is the Nile delta, where sea level rise and potential flooding put million of people and Egypt's prime agricultural areas at risk.

5. EASTERN REGION

In Cluster 7, the Gash-Megreb River is shared by Eritrea, Sudan and Ethiopia and the Barka (or Baraka) is shared by Sudan and Eritrea. Both flow north out of the Eritrean/Ethiopian Highlands, the Barka discharging to the Red Sea in Sudan. The Gash is considered in some literature to be an extension of the Nile basin, although others show the termination of the Gash as an internal basin north of Kassala in Sudan. The Setit/Tekeze River is also shared between Ethiopia, Eritrea and Sudan, though it is considered to be part of the Nile Cluster.

Transboundary water bodies in the Horn of Africa include a number of aquifers: Merti Aquifer/Daua Basin Ogaden-Juba; Coastal Sedimentary plains; Kilimanjaro Aquifer; Awash Valley Aquifer and the river basins of the Juba-Shebeli shared across Kenya, Ethiopia and flowing into Somalia, and the Umba River flowing from Tanzania into Kenya. In the rift valley the Lake Turkana - Omo Basin system is shared by Kenya, Ethiopia and Uganda.

5.1. OVERALL SCENARIO

WATER RESOURCES STATUS

The greater horn area (cluster 8) is characterised by arid to semi-arid climates in the east and north to more temperate and tropical conditions in the highlands of Ethiopia, Kenya and Tanzania (see figure 12). Temperatures are generally high and rainfall, whilst quite variable, is often orographically influenced. Mean annual rainfall ranges from 220 mm/yr in the drier areas in the north east to above 1000 mm/yr and as much as 2000 mm/yr in pockets of Ethiopia, Tanzania and Kenya. Rainfall is highly variable both spatially and temporally with high inter-seasonal and inter-annual variation, through typical wet seasons. In parts the climate is dominated by the monsoonal system and can be considered equatorial, with large variations in the distribution of rains as one moves away from the coast.

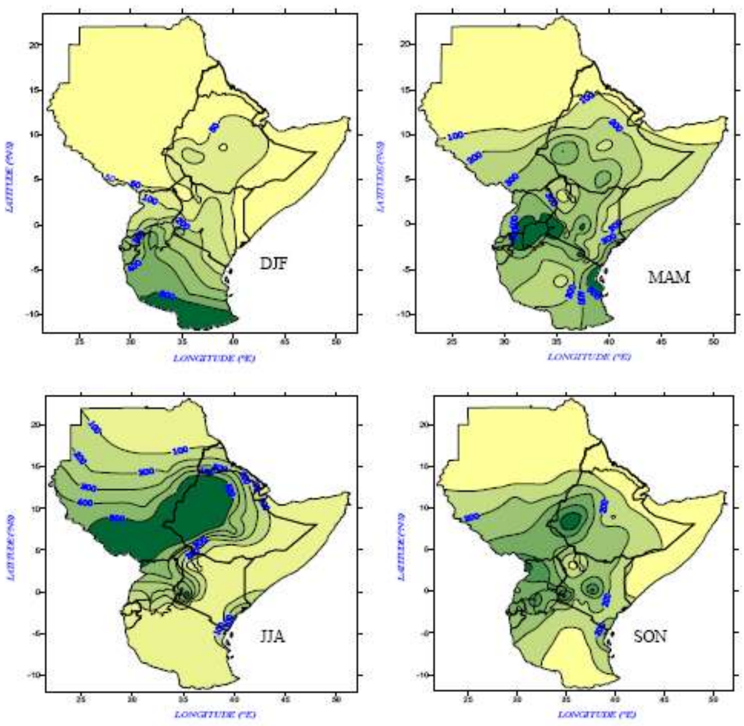


Figure 12: Distribution of seasonal rainfall across greater horn area

Severe drought occurs periodically throughout this cluster. Eastern and western Ethiopia and western Kenya are the areas most frequently affected by severe drought, with a greater than 40% annual probability of moderate to severe drought during the rainy seasons. Rainfall is erratic and can occur in intense tropical storms which contribute to frequent severe flood events. The Shebeli River sees severe floods on average once a year and the Juba, Awash, and Tana Rivers every two years. The densely populated areas along these rivers in Ethiopia, Kenya and Somalia face the highest flood risk within the Horn of Africa.

The lower elevations of the Turkana basin have a very dry, subtropical desert climate, with tropical and temperate zones at higher altitudes to the north and south. Water resources in the basin are very unevenly distributed both temporally and spatially. Lake Turkana receives run-off and sediment from a diverse geographical area with the Omo River providing about 90% of inflow. The seasonal Turkwel and Kerio rivers contribute most of the remaining fluvial input. Other streams, direct rainfall and groundwater flow are considered insignificant in the lake's water budget.

Cluster 7 (the Baraka and Gash basins) is characterised by an arid climate, with high temperatures, low but high intensity rainfall and excessive evaporation rates. Topographically, the region can be subdivided into two zones: the mountains to the east and the major plains located to the west and north. The Gash and Barka Rivers flows northwards into Sudan's major agriculturally important floodplains. Most of the basins are open shrub-land with the exception of areas close to the rivers, where there is still some riverine forest in spite of the region's rapid deforestation.

The headwaters of the rivers (altitude 300–1000m) receive tropical and relatively abundant summer rains, from June to September. From November to March there is no rain. Rainfall is usually high intensity and short duration, causing rapid runoff, flash floods and problems of topsoil loss. Average monthly temperatures in Gash-Barka range between 25 to 34ºC, with maximum temperatures of up to 50°C in the lowland areas. The Gash and Barka rivers are seasonal and flow usually only from August to November.

By 2020, Eritrea will be considered water scarce based on projected increases in population. The only year-round source of fresh water available to the populations is groundwater, which is of critical importance for domestic supply and supplementary irrigation. Groundwater can be tapped across the country but not in the quantities and quality needed. Available information on hydrogeology is limited. Kenya and Djibouti currently face water scarcity and by 2030 all countries in the cluster will face scarcity, with Kenya and Somalia facing severe scarcity.

SOCIO-ECONOMIC STATUS AND DEVELOPMENT TRAJECTORY

The overall economic performance of East Africa depends on the agricultural sector which is heavily dependent on water resource availability and management. There is a large dependence on subsistence agriculture, which employs as much as 70 – 80% of the population in some areas. It is estimated that 85% of Sudan's rural population lives on less than US$1 per day. Overall, some 20 million people were living in extreme poverty in 2002 (IFAD, 2008). Although endowed with rich natural resources, Sudan remains comparatively underdeveloped, primarily as a result of protracted civil strife and poor economic management.

The Horn region is typified by widespread poverty and relatively low levels of economic and social development. While GDP growth shows positive trends in Ethiopia and Tanzania, largely through emergent sectors such as mining and export agriculture, it masks continued hardship amongst the majority of the region's population. There is continued reliance on rain-fed small-holder agriculture and livestock keeping, or livelihood strategies heavily reliant on access to water related natural resources such as fishing. At the same time, with some of the largest population growth rates anywhere in Africa, the region is undergoing rapid rural-urban migration. Domestic water supply needs, power generation and the food security needs exerted by growing urban centres will drive increasing demand

Surface water provides the majority of bulk water needs for irrigation, with groundwater rarely used because of pumping and infrastructure costs. Most irrigation is through surface or spate irrigation by small-holder farmers, though large scale commercial farming with high water demands and more advanced irrigation technology is expanding across the region. Agro-pastoralist and nomadic pastoralist systems exist mainly in the lowlands and escarpment zones. Agro-pastoralists derive their livelihoods from cattle, sheep and goats, while nomadic pastoralists often keep camels as well.

There is further potential for irrigation development and a strong policy push in this direction. In Eritrea, for example, the potential of spate irrigation is estimated to be in the order of 90 000 ha, but the area equipped for spate irrigation covers only 17 490 ha. In the Ethiopian parts of this region around 10.5% of the economical irrigation potential has been developed.

In Cluster 9, the Turkana-Marsabit region bordering Lake Turkana to the west and east is classified as one of the poorest regions in Kenya. Investment and employment are extremely low. The mainstay of the economy is fishing and subsistence farming, mainly sorghum, maize and millet. Fishing is largely done for subsistence although there have been unsuccessful attempts to introduce commercial fish farming. The rest of the economy in this area comprises livestock rearing, especially goats and zebu cattle.

Water-related diseases include malaria, onchocerciasis, leishmaniasis, and diarrhoeal diseases, which typically result from contaminated drinking water or food, and which afflict a significant proportion of children and adults throughout Kenya and Ethiopia. Guinea worm is endemic in the Lake Turkana Basin and other water related diseases such as intestinal worms, schistosomiasis, trachoma, and skin diseases are common. Malaria is alleged to be a growing public health problem in Ethiopia with perennial transmission taking place near bodies of water, swamps and irrigation projects.

Domestic water supplies throughout the Cluster are provided almost exclusively by groundwater, primarily shallow wells. Access to improved water supplies and sanitation are generally low and the region suffers high incidences of water born disease. For example, in Marsabit District in Kenya, only 5.7% (1700 of 30 000) households have access to potable water and the average distance to the nearest water point is 25km, where as in Turkana these figures are 28% and 10km respectively Only 10% of the population of rural Ethiopia has access to improved water points.

In the Turkana basin the hydro-electric power generating potential of the Omo-Gibe basin is being developed by Ethiopia. Two operational hydropower dams, the Gibe I and Gibe II are in place and a third, Gibe III, is under construction. The Turkwel River in Kenya is also used for hydropower generation, with the Turkwel Gorge Dam. Currently there is no hydro-power production on the Gash and Barka Rivers, although three potential hydropower sites have been identified for development by Eritrea.

Lake Turkana’s water’s are too alkaline to support irrigation and domestic use, but the lake is an internationally important ecosystem and archaeological site and was recognised as a UNESCO World Heritage Site in 1997. Fishing takes place both in the Omo River and in the Lake with the sustainable yield of traditionally exploited fish from the off shore areas of the Lake estimated at 15 000 to 30 000 tonnes per year. There are around 60 000 subsistence fishermen along the western shore of the Lake and fishing remains a very important livelihood and food security strategy in the basin.

INSTITUTIONAL CAPACITY

From an institutional perspective there has been a significant shift to introduce improved water policy and legislation. Ethiopia, Tanzania and Kenya have each seen reforms of water resource policy, legislation and planning frameworks over the past ten years which explicitly aim to move them towards Integrated Water Resource Management. With donor support, legislation and policy have been reformed and capacity building initiatives are ongoing. Eritrea has rewritten both policy and legislation, but it appears that this has not been finalized. Sudan focuses its management of water resources largely on agricultural water use and such endeavours as the Sudan Comprehensive National Strategy for the Agricultural Sector.

In the absence of a formal central government, Somalia has no effective legislation, implementation, strategy or policy on water resource management although the Somali authorities recognise the rehabilitation of flood control and irrigation infrastructure on the Juba and Shibeli rivers as a priority for the country's development. Water resource management is a localized affair, based on clan ownership of land and water territories.

The level of infrastructure development across the region varies considerably. Currently there are about 187 dams with a capacity of over 50 000 m3 each. About 42% are for domestic use and irrigation, 40% for domestic use only, 13% for irrigation, and 5% are not used. The total capacity reaches 94 million m^3. Sudan has a considerable network of irrigation canals that is maintained by the Ministry of Irrigation and Water Resources (MIWR) up to the minor off-takes. The Ministry of Finance and National Economy provides the MIWR with the annual budgets for operation and maintenance. Somalia and Djibouti have no large dam storage capacity. In Somalia, flood control, irrigation infrastructure and off stream storage have collapsed, leading to poor drainage, salinization and water logging. In Kenya and Tanzania, there are no major storage infrastructure installations on shared water bodies, although the Kitivo Irrigation scheme on the Umba includes small dams and was developed with FAO support in the 1990's and still irrigates several hundred hectares at the base of the Usambara Mountains upstream of the Kenyan border.

In Ethiopia, on the Wabi Shibeli and Genale Dawa which drain 33% of the countries South East Mountains, flow is regulated at Melka Wakana by a 153 MW hydropower station. There are two other dams on the Shibelli and together these control 50% of the discharge. There is a new hydropower development at Gode. Aside from the hydro-electric installations, water management infrastructure is minimal.

Ethiopia, Kenya and Tanzania have all been in receipt of donor support to strengthen their water resource management capacity, but capacity and coordination between institutions which share responsibility for water management is still very weak in many parts of the region. Although both financial, technical and personnel resources to deal with the difficult water resource management challenges facing the Barka and Gash Basins are very limited, recent gains have been made. In particular, the Gash basin is now receiving support from UNESCO through its HELP initiative. It is likely however that institutional water resource management capacity will remain limited for some time, which will hamper the ability to exploit opportunities for transboundary cooperation and adaptation to climate change.

In Eritrea, revised policy and legislation are yet to be finalised. There is no formal system of permits or licenses, and traditional customs prevail. In principle, water is a public property controlled by the government, but there are no clear rules for allocation, or regional or national plans. Because of the lack of effective water law, activities in the water sector are still uncoordinated.

Institutional capacity in cluster 7 is limited and is likely to remain limited for some time, undermining opportunities for transboundary co-operation and adaptation to climate change.

While canal committees and water user associations do exist in Somalia and work well on small irrigation schemes, institutional capacity for water resource management is almost non-existent, although the Somalia Aid Coordinating Body has a remit for sharing information and developing strategy.

CLIMATE CHANGE

Against a backdrop of existing high levels of variability, climate change will alter the timing, distribution and quantity of water resources across the region. Although there are few regionally downscaled models, the IPCC Fourth Assessment Report provides a comprehensive review of climate model projections for this region. The climate models show a consistent response in both mean annual and seasonal temperature change in the region, projecting warmer conditions of +3.2°C for East Africa by the 2080s. There is also much consistency amongst models in projecting wetter conditions in East Africa, by +7%.

There is some uncertainty as to how climate change will influence extreme events in the tropics. The climate drivers for inter-annual and decadal rainfall variability in East Africa are the El Nino Southern Oscillation events and Indian Ocean dynamics, and models do not show clear tendencies for them. However it is likely that the number of extremely dry and extremely wet years will increase.

Table 3: Changes in mean temperature and precipitation between present day and 2080s for East Africa. Multi-model means and model range shown, based on Christensen et al. (2007). (From Goulden et al. 2009)

	Temperature:		**Precipitation**:	
	Annual (inter-model range)	Seasonal *	Annual (inter-model range)	Seasonal *
East Africa (12°S, 22°E to 18°N, 52°E)	+3.2°C (+1.8 to +4.3°C)	Warming in all seasons: +3.1°C (DJF, SON) to +3.4°C (JJA)	Increase of 7% (–3 to +25%)	Increase in all seasons: 4% (JJA) to 13% (DJF)

* DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON: September, October, November.

There appears to be significant agreement that temperature will increase and that the region will generally get wetter. However, with the shifts in seasonality, related to the movement of the ITCZ, there will be differences between the northern and southern parts of this region such that in the south it can be expected that during summer rainfall will increase, while in the north, with the shift in the ITCZ, the rainfall will increase later in the year towards winter. The degree of wetting is not clear but, as with other regions, it is likely that heavier storm events can be expected, and increased extremely wet and dry years.

5.2. KEY RISK AREAS

Considering the climate change forecasts for the region, a number of climate-development risks emerge.

HUNGER AND POVERTY

This region is densely populated and has large rural communities reliant on fishing, small community gardens and livestock. Due to the levels of water stress that currently exist and lack of institutional support from government, these communities are already vulnerable. Increased variability in rainfall events will serve to exacerbate that situation. Wetter conditions could increase erosion and the water-logging and increased salinisation of crop-lands, reducing crop productivity and increasing poverty and hunger. It will be difficult for poor communities to harness the additional water without the necessary infrastructure to capture and channel it. There is an opportunity that can be exploited in terms of assisting communities to develop such infrastructure on a local basis, where this is appropriate, such as through rain water harvesting.

Decreasing agricultural production may result in increased food prices in urban areas with the potential to push workers in these areas into poverty.

PHYSICAL SECURITY

With more extreme events, in an area already typified by climate variability and flooding, future flood events in areas such as the Juba Shibeli, which is very densely populated, present a very real risk to human security and property. Coastal centres could also be impacted upon by both floods and sea level rise.

DISEASE

Wetter conditions may increase the levels and spread of water-related disease both in humans and livestock placing vulnerable communities at further risk.

NATIONAL DEVELOPMENT

The high levels of conflict between countries such as Ethiopia and Eritrea, or internally, such as in Somalia, prevent governments from establishing meaningful institutional support mechanisms for managing transboundary basins and climate change challenges. This creates considerable instability within the region and limits national development potential.

There are significant opportunities to develop hydropower across the region, and a few countries have developed, and are planning to investigate further, these opportunities. However, the climate uncertainties place these at risk where these schemes need consistent supply. This region is also woefully short of infrastructure to help mitigate extreme floods and drought, placing economic development at the mercy of annual rainfall which will increase in variability as a result of climate change.

SUMMARY RISK ASSESSMENT

The underdeveloped water resources of the region, poor institutional and governance capacity, and poor socio-economic status of the populations, mean that the countries of the eastern region are at considerable risk from the impacts of climate change, coming as it does, on top of the existing development challenges.

6. WESTERN REGION

6.1. OVERALL SCENARIO

Four clusters of transboundary basins/aquifers were identified in the western region: the coastal rivers from the Senegal to the Little Scarcies; the coastal rivers from the Moa to the Sassandra; the Niger, Volta, and adjacent smaller basins; and the Lake Chad basin. These clusters are highlighted in figure 13 below. The major transboundary aquifers, found in clusters 2, 4 and 5, are shown in figure 14. There are no major transboundary aquifers in the Moa to Sassandra cluster.

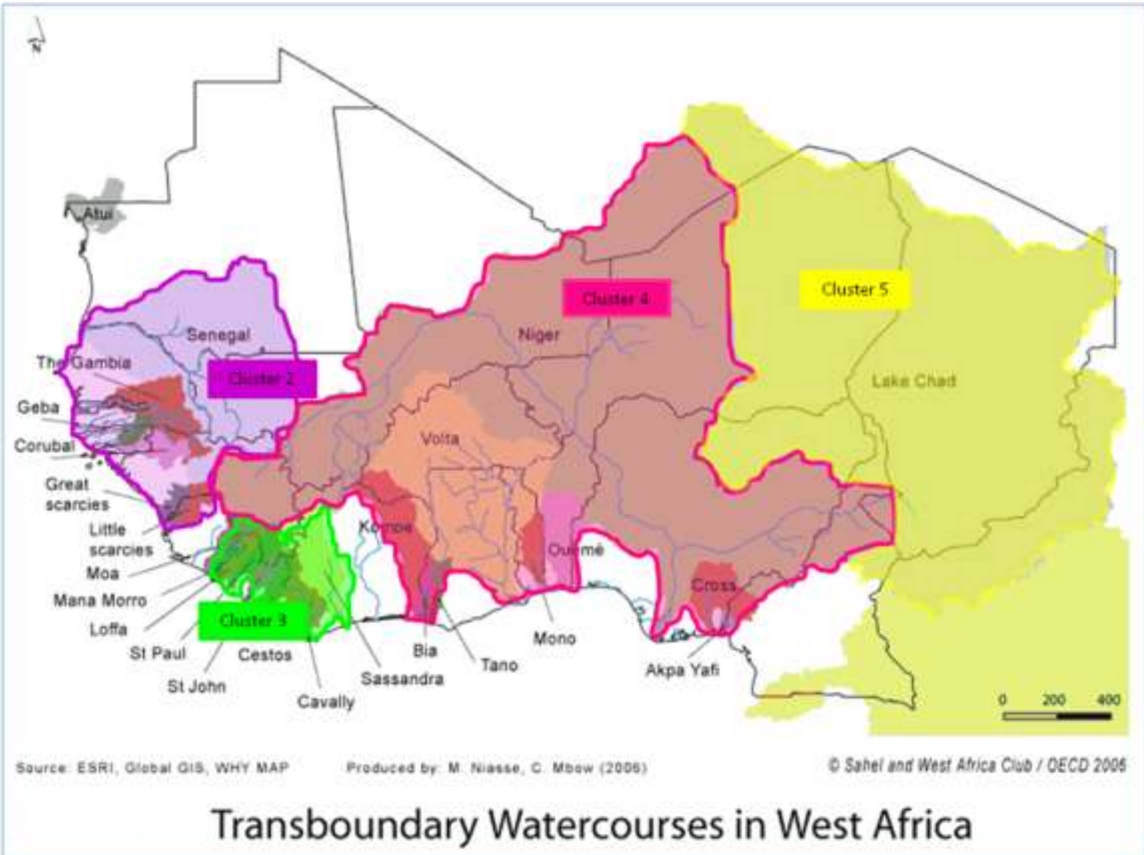


Figure 13: Outline of clusters in western region

WATER RESOURCES STATUS

The hydrology of this region is characterised by two key elements. The first is decreasing rainfall from south to north, as indicated in figure 15. While the southern swathe of the western region receives average annual rainfall well above the world average, the northern swathe falls into the Sahel region, with rainfall of below 500 mm per annum, decreasing further north to below 200 mm per annum. These areas can be considered arid, as opposed to the humid southern band.

The second key hydrological phenomenon affecting the region is the West African Monsoon (WAM) effect. This effect is the result of a seasonal shift in the Intertropical Convergence Zone, and the large seasonal temperature differences between the land and the ocean. As a result, summer sees winds from the ocean bringing heavy rains to west Africa. The WAM provides most of the rain in the Sahel and Sudan[1] regions of west Africa. Along the coastal region of cluster three, rainfall ranges between 3,500 mm and 4,000 mm per annum.

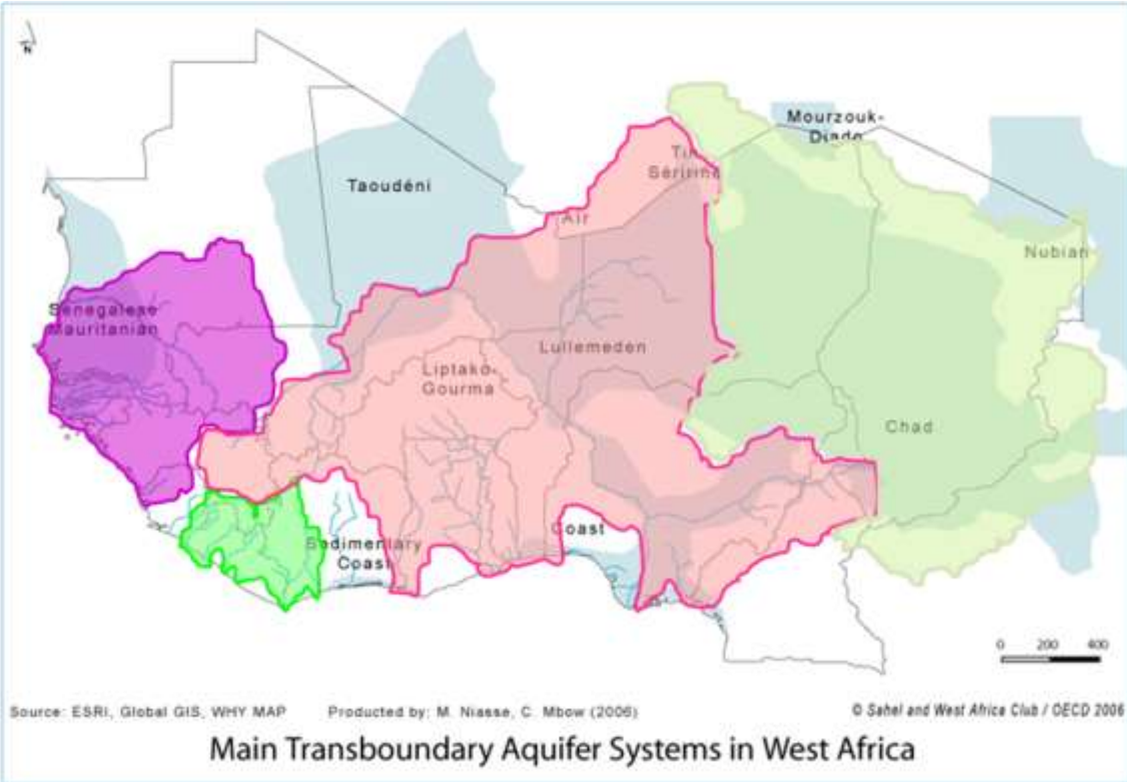


Figure 14: Main transboundary aquifer systems in West Africa per cluster

The eastern Senegal basin, Mauritania and Mali are largely arid. The Canary Islands and Cape Verde experience low, erratic rainfall, while large parts of Senegal, the Gambia, Guinea and Guinea Bissau are fairly humid. A large portion of the Cluster falls in the Sahel region. Most rivers in the region have been dammed for irrigation and energy production, leaving downstream countries vulnerable to upstream withdrawals. The coastal areas of Gambia, Mauritania and Senegal have substantial groundwater aquifers, but there is a lack of precise data about yield capacity, depth, thickness and the degree of contamination. There is, however, clear evidence of declining base flow in most groundwater systems in the Cluster because of a dry period of over 30 years, over-abstraction for irrigation, and low recharge rates. Water quality is compromised by rising levels of pollution from sewage and industrial effluents, agricultural run-off, sedimentation due to poor farming techniques, sand storms (wind erosion), and waste disposal. There is a particular problem with groundwater contamination around urban areas. Eutrophication, chemical pollution and suspended solids form major water quality problems.

The river basins of Cluster 2 contain a great number of ecological sites of national and regional interest. In the Senegal Basin, the National Park of the Birds of Djoudj is one of the 830 sites of the cultural and natural inheritance of the world. The basin also has two Reserves of Biosphere, the Reserve of the Loop of Baoulé and the Transboundary Reserve of the Senegal Delta (between Senegal and Mauritania). There are 5 Ramsar sites in the Delta.

[1] The Sudan region is not to be confused with the country of Sudan. The Sudan region lies to the south of the Sahel, and receives slightly more rainfall.

Cluster 3 includes the Mao, Mana-Morro, Loffa, St. Paul, St. John, Cestos, Cavally and Sassandra rivers, in Guinea, Sierra Leone, Liberia and Côte d'Ivoire. The Cluster is humid in the south and central parts, with a humid-dry Sudano climatic type in the extreme northern part. From October to March the weather is generally dry, while the rainy season falls between April and September. Along the coast of the cluster the annual rainfall is between 3,500 mm and 4,000 mm, while annual rainfall only falls below 2,000 mm inland in the extreme east of Guinea, near the border with Mali. Temperatures are consistently high around the year on the coast and, during the dry season, rise even higher inland. There is variability of river flows, as a result of the temporal and spatial variations in precipitation, urbanisation, agriculture and agro-industrial development, although few of the rivers in the cluster have been modified by major dams.

This area experiences wide spread flooding of agricultural land and river bank settlements with the destruction of properties and crops. Pollution is a major concern, including microbiological pollution and eutrophication, and chemical pollution in basins affected by mining activities, tanneries and metal treatment industries. There is a proliferation of invasive aquatic species

The Niger/Volta area experiences very variable rainfall, both spatially and temporally, resulting in seasonal water availability, floods (particularly in the coastal area) and droughts (particularly in the Sahel). Some areas in the cluster are well endowed with water while others face water scarcity. By 2015, one-third of the countries in the cluster will experience either water stress or water scarcity (Togo, Burkino Faso and Nigeria, with Ghana coming very close to water stress). There is a high degree of vulnerability arising from the natural variability and the increase in demand from a rapidly growing population. Urban waste, particularly from inland port communities and urban settlements located near the banks of the rivers and reservoirs, is a major cause of water pollution. The surface waters of this cluster are shared throughout each of the eight basins, making the degradation of water quality a transboundary problem.

This cluster contains three major types of aquifers. In the arid and semi-arid zones, large and deep sedimentary aquifers are often present, mostly as fossil aquifers. In the humid and sub-humid regions, the groundwater is dominated by Precambrian crystalline and large sedimentary formations.

In the Lake Chad Basin, mean annual rainfall varies from 255-560 mm, and most of the Basin faces acute water stress. Chad and Niger are amongst the 10 most water impoverished countries in the world. Cameroon and the Central Africa Republic are the principal sources of rainfall water in the basin, and the bulk of the inflow into the Lake is contributed by the Logone/Chari Rivers. The amount of water flowing into Lake Chad from the Chari River has decreased by 75% over the last 40 years, and the lake has decreased in size by 90% since the 1960s because of a combination of human water use such as inefficient damming and irrigation methods, and shifting climate patterns. There is a proposed plan to divert the Ubangi River into Lake Chad to resolve the reduction in water in the lake, but there is a shortage of capital for implementation.

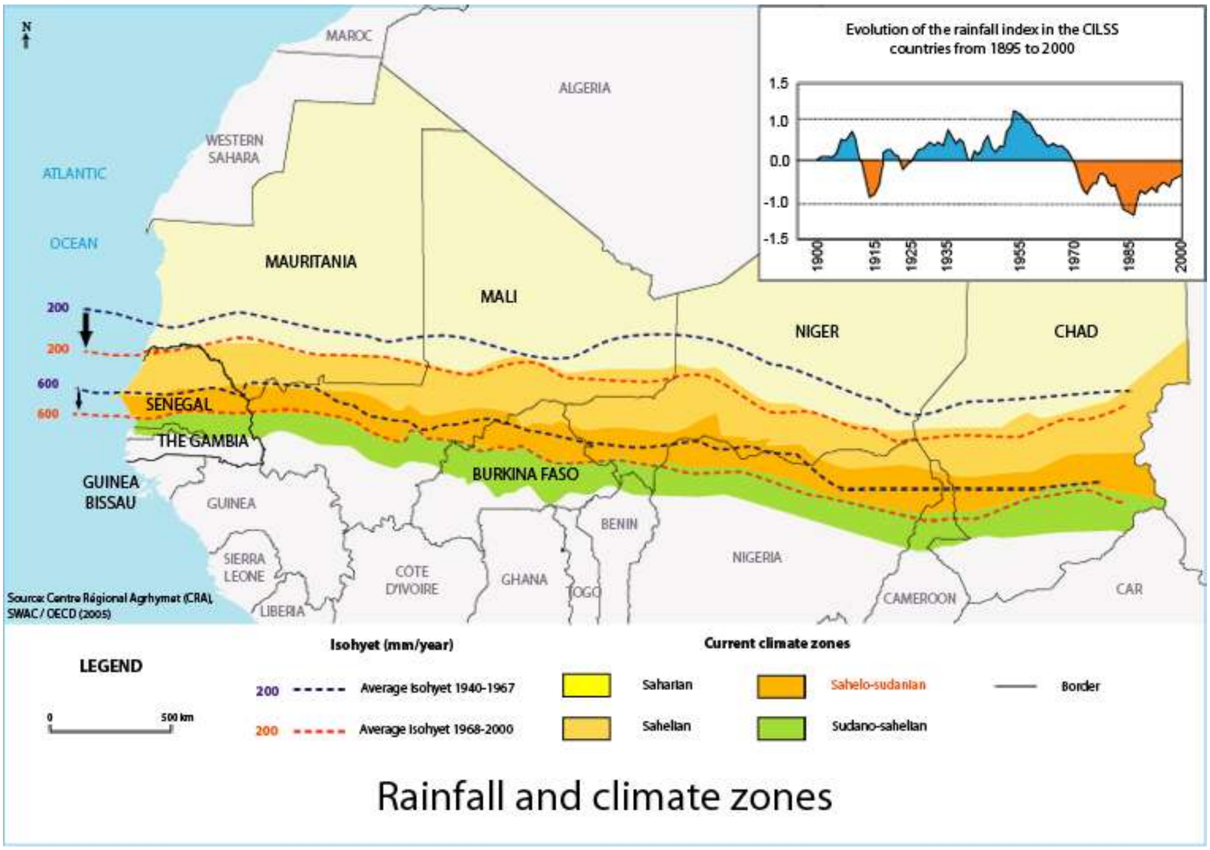


Figure 15: Rainfall and climate zones of west Africa, showing the southern movement of rainfall since 1968 (source CRA, SWAC/OECD 2005)

There are four major aquifers in the Lake Chad basin, but two of them do not produce water suitable for irrigation. The Quaternary phreatic aquifer contains about 150 billion cubic meters of water suitable for domestic consumption. There is little information on the important continental Hamadien aquifer. These aquifers are recharged by infiltration from tributaries of the lake.

There is relatively little industrial or mining activity (except in Chad) and the impact on water supplies appears to be minimal, although effluent discharges in the upstream parts of the Basin (particularly in Kano, Nigeria) from tanneries and textile production have led to localised fish kills. It is likely that untreated domestic wastes are also being discharged into the rivers of the Basin, with negative effects on water quality. Water contamination and reduced stream flows have caused the proliferation of weeds that have encroached into reservoirs and clogged channels on the Hadejia River. These infestations have provided a preferred nesting ground of the avian pest *Quelea quelea* resulting in regular loss of grain crops to large flocks of *quelea*. Freshwater shortage has impacted heavily on the cluster's economic activities including fisheries, agriculture, animal husbandry, fuel wood provision and wetland economic services. There has been consequential food insecurity in the basin.

SOCIO-ECONOMIC STATUS AND DEVELOPMENT TRAJECTORY

Some of the poorest countries in the world fall into this region. The human poverty index of the United Nations for 2006 reveals that 50.9% of people in Guinea, 51.2% in Sierra Leone, 40.5% in Cote D'Ivoire and 40.5% in Liberia live on less than $1.25 US dollars a day. Poverty is worst in the rural areas.

The Gambia, Guinea, Guinea-Bissau, Mali, Mauritania, Senegal and Sierra-Leone, rank among the poorest countries in the world. Infant mortality in these countries is around 73 per 1000 live births. All of the riparian countries face energy shortages and growing water constraints. 70% of the population is dependent on shared waters. The countries do not have sufficient financial resources to finance the needed water resources development activities that would make more water available for use. A growing population is putting increased pressure on the land.

Water is used for agriculture, hydro-electric power, tourism (especially in the Gambia), industry, and domestic water for both rural and urban areas. There is a reasonable level of fishing in the Gambia and Senegal basins. Nearly 80% of the water in the region is used by the agriculture sector for irrigation. There is vast unused irrigable land in Cluster 2, and the agricultural sector is expected to grow. Urban water use (currently <10%) especially for industrial activities and the tourism sector is also expected to grow substantially.

Cluster 3 is also a region with high levels of poverty and inequality. However, it is experiencing some growth under the recent political stability. Guinea, Liberia and Sierra Leone are the countries with the highest prevalence of violent conflict and political instability. Food poverty and insecurity is widespread. Most households do not have access to an adequate food supply due to low domestic production levels and abysmally low incomes. In 2005, agriculture represented about 50 percent of GDP and employed about 60 percent of the total economically active population, mostly in small-scale, peasant production. 40% of the population is below 15 years, and the unemployment rate is very high.

Cluster 4 is also characterised by political instability and high levels of poverty. All the countries in the cluster except Ghana are amongst the thirty countries with the lowest human development index in the world. The area is densely populated, with strong population growth and a large proportion of the population under 15. There is poor water supply and sanitation coverage, particularly in the rural areas, resulting in high levels of waterborne and water-related diseases such as guinea-worm, cholera, typhoid, and bilharzia. As a result of rural poverty, there is migration from the rural to urban areas in search of improved livelihoods.

The economy is dominated by rain-fed agriculture, mainly at the subsistence level. Inland navigation provides essential transport for people and goods. The cluster’s rural economy depends heavily upon natural resources, but the environment is under severe stress, threatening rural livelihoods and increasing the rural population’s social and economic vulnerability. Hydropower is a key water use, with many dams built for this purpose. There is huge untapped irrigation potential and the need to construct new irrigation infrastructure and to maintain existing infrastructure.

37 million people reside in the Lake Chad basin, which is also marked by political instability and conflict. The basin countries are among the poorest in the world and are characterized by extremely slow and variable economic growth. Poverty is particularly acute in the countries in the south of the Basin. Illiteracy is a major hindrance to development, with Niger having the lowest literacy rates in the world. Access to safe drinking water in the Basin is very limited. In West Darfur, over 50 % of water is obtained from dug wells with bucket collection. All over the Cluster women have to travel great distances to gather water. Cholera outbreaks are common.

The principal economic activity in Cluster 5 is agriculture, which is the biggest water user and provides about 60% of total employment. Livestock, fishing and general trade account for just under 30% of employment. There is some mining and oil exploration activity. The many large irrigation projects are located predominantly in the Komadugu-Yobe Basin where the total water requirements for all the planned projects are estimated to be 2.6 times the available water resources. The recently developed master plan for the basin proposes to concentrate future developments on small-scale projects, many based on pumping of shallow groundwater in the floodplain. Very little water is used for industry. Water demands in the Lake Chad drainage basin are expected to increase, as the population increases, becomes more dependent on irrigation agriculture, and the standards of living of the increasingly urbanized inhabitants improve. The leading demands are expected to come from irrigated agriculture and agro-industrial development, environmental flows, water for downstream fishers and recession farmers, and domestic water use. The Cluster is already experiencing some conflict between fishermen and pastoralists, and between fisherman and farmers.

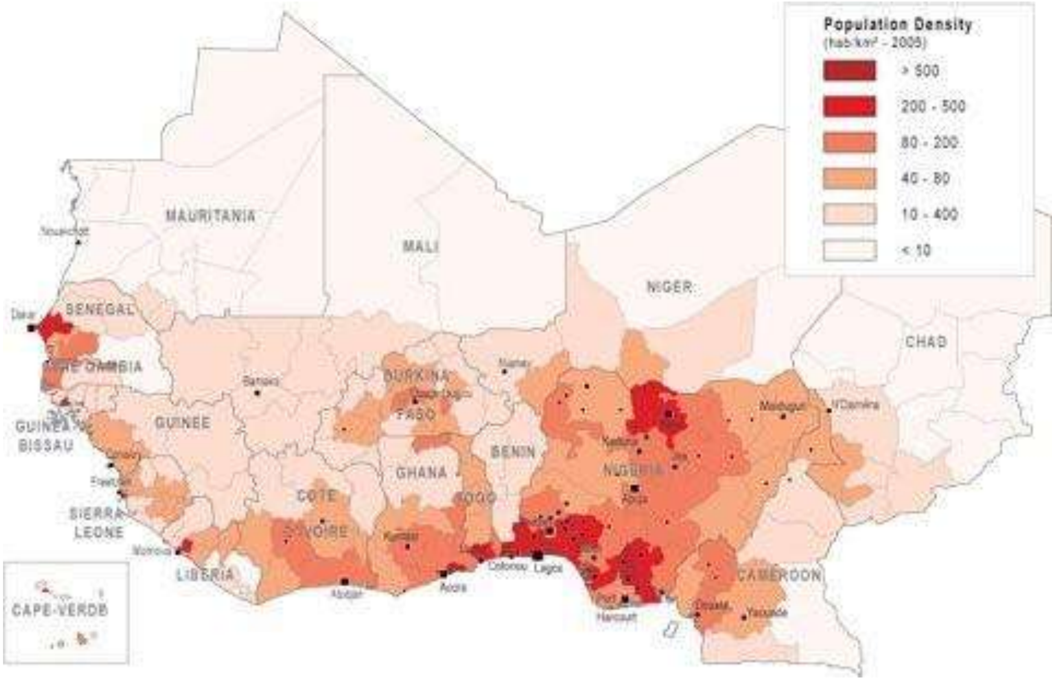


Figure 16: Population density in West Africa (FAO)

INSTITUTIONAL CAPACITY

This region has seen a high degree of political instability in recent decades, which has harmed both infrastructure and institutional capacity in many of the countries. The countries in cluster 3, for example, were ravaged by civil wars in the 1990s, and this political instability may underlie the lack of international water agreements in this region.

Similarly, most of the countries of the Lake Chad Basin have experienced considerable political instability and a history of domestic and international conflict since the 1960s, with only Cameroon having had a stable government during this period. Armed clashes and rebel activity on islands in the Lake have persisted since the 1970s and are associated with civil wars in the Republic of Chad and Nigerian fishermen following the receding lake. A multi-national 'Joint Patrol' was created in response to these outbreaks and has been monitoring the Lake to prevent further violence.

In Cluster 2, IWRM-compliant water policies and programmes have been established in about a third of the countries, but effective water administrations are yet to be put in place. Only the OMVS (in the Senegal river basin) has developed a water charter that applies to all riparian countries. Water resources conflict resolution mechanisms are still poor in most of the countries, and individual countries do not have sufficient capacity to manage water resources effectively. There are some structures and processes in place to deal with climate change impacts in transboundary basins. However, lack of technical know-how and competent human resources coupled with the extremely poor financial status, as well as poverty and the prevalence of disease exacerbated by poor design and management of some prominent dams undermines the effectiveness of these structures and processes in combating climate change issues.

In Cluster 3, the socio-economic challenges include the political instability affecting many of the countries and the difficulty in mobilizing funds for effective water resources development and management. There are no international agreements in place. There is, as with all the clusters in this region, an absence of regional or national standards/guidelines for monitoring water quality and quantity. There are poor water resources conflict resolution mechanisms (particularly in international basins) in most of the countries. The Mano River Union is the only basin management body in place. There is insufficient sufficient capacity at the national level to manage water resources effectively, and the countries can't afford to finance the development and management of their water resources in a sustainable manner. Landmark water resources initiatives and developments have been supported by international donors or through credit facilities from the international agencies. There have been several attempts by individual countries to address the climate change impacts on water resources, especially through the protection of ecologically fragile environments and wetlands, but there are no processes in place to deal with climate change impacts on water resources at the transboundary basin management level. There is a lack of technical capacity to design, build, maintain and operate large water facilities and distribution systems.

Cluster 4 has a weak institutional framework for international basin management, although at the national level most of the countries have water policies, have developed their water management and development strategies, and enacted water law and regulation based on the principles of IWRM which emphasizes equity, efficient and environmental sustainability. However, there is a lack of skilled people to implement the legislation effectively. The Niger Basin Authority involves all riparian states while the Volta Basin Authority only applies to two riparian states.

Although an international basin organisation is in place in the Lake Chad Basin and is supported internationally, there is limited data and extremely weak capacity for implementation. Water-demand management is ineffective and little attention is paid to adapting production methods to natural resource limitations. There are some bilateral agreements in place, but there is no implemented water allocation law between the Chari-Logone and Lake Chad sub-system's riparian states, to enable the equitable use, conservation and sustainable development of the water resources. The equitable use of groundwater supplies is a further gap in national law and the Fort Lamy Convention. An additional legal weakness in the Fort-Lamy Convention is that there is no requirement for prior agreement from member States to proceed with development. The Lake Chad Basin Commission has no power to enforce the agreements made between the riparian countries, so they are often not complied with. There are conflicting policies between ministries in terms of aiming to reduce poverty by increasing economic growth and improving food self-sufficiency through the utilisation of irrigated rice cultivation while also intending to conserve wildlife through the creation of national parks.

CLIMATE CHANGE SCENARIOS

A great deal of uncertainty remains with regard to the impacts of climate change in the western region in relation to rainfall, although there is general agreement that temperature will rise across the region. The model projections of rainfall over West Africa are inconsistent, or weak, with some simulations suggesting that the region will become drier, and others predicting increases in rainfall over the 21st century. More needs to be done to apply appropriate regional scale models to aid the prediction of climate change in the coming decades in this region.

However, in general, climate change scenarios predict reduced rainfall and increases in evaporation in most parts of the region. More specifically, an increase in the rate of desertification is predicted for the Sahelian zone in the long run (2070-2100), although there may be some wetting of this area prior to 2070. Countries in the coastal zone are expected to experience more intense rainfall and increase in runoff. Temperatures are certain to rise across the whole region, which will increase evapotranspiration and crop water requirements.

In the short to medium term, the Sahel zone will experience an increase in rainfall for June, July and August. The significant increases in the rainfall of June will tend to bring that month more effectively into the planting season. The savannah and Sahel areas of cluster 4 will probably experience less rainfall, which coupled with the temperature increases, will reduce soil moisture availability.

In cluster 2, some climate change scenarios predict reduced rainfall and increased evaporation in the Sudano-sahelian zones. However, recent modeling studies suggest that climate change may make the rainfall regime more robust and droughts less frequent and persistent. These models suggest that climate change may result in a strengthening of West African Monsoon (WAM) and the penetration of rainfall and vegetation further north, leading to a “greening” of many parts of the Senegal, Gambia, Great and the Little Scarcies. However, due to changes in run-off, ground water recharge is expected to reduce drastically by 2030. The intensification of the West African Monsoon (WAM) is likely to result in more frequent flash flooding, and agricultural expansion into marginal areas with resultant increases in vulnerability to climate variability.

The climatic future of Cluster 3 is also uncertain. A “worst case” scenario could be based on the following assumptions: increases in mean surface temperature of up to 0.5^0C per decade, with increased evapotranspiration and crop water requirements; increased rainfall variability and intensity resulting in increases in continental runoff and sediment transport, but less predictability in the timing of rainfall; and increased environmental degradation through flooding and erosion.

If the model of increased intense rainfall in Cluster 3 is correct, the coastal zone will experience increased runoff. Combined with the existing high rate of deforestation and ecosystem degradation, this could have serious consequences on soil erosion, agricultural production and food self-sufficiency. The high degree of water interdependence of the countries of this Cluster is conducive to tension and even conflicts among states over water resources. Potential conflict areas include the Mao and Mano, the Cestos and the Cavally. Other consequences of climate change and variability are devastating floods, the proliferation of floating weeds along watercourses, and the deterioration of water quality. Significant areas of mangroves and coastal wetlands will disappear as a result of sea-level rise, affecting the local economy, disturbing the migration cycle of millions of birds, and increasing the salinization of soils, ground water and surface water in coastal regions.

In Cluster 4, most climate change scenarios predict an average of 10 to 20% decrease in rainfall for the 2025 horizon, and a decrease in flow and recharge of ground water tables in the arid and semi-arid countries of the region. In general, river flow is expected to decrease by between 5 and 34%, depending on the time horizon and the country. An increased runoff coefficient is expected because of degradation of the vegetative cover and the soil, resulting in a fall in the ground water level and a reduction in the number and size of ponds and watering points. Major droughts and recent floods of unusual magnitude in the Sahel and in other zones of the cluster have prompted many specialists to expect exacerbated climate extremes. Flows during low seasonal water levels could drop in many areas because of lower groundwater levels and greater evaporation.

There is a lack of localized models for cluster 5. However, the Lake Chad basin has been experiencing a significant decline in rainfall since the early 1960s. While there has been some increase recently, there is uncertainty with regard to the trends. It would appear, however, that the rainfall has already moved south. Increased temperatures are likely, resulting in an increased number of very hot days which will impact on water use and crop productivity. The change in climate and temperature is expected to increase the spread of malaria in the cluster.

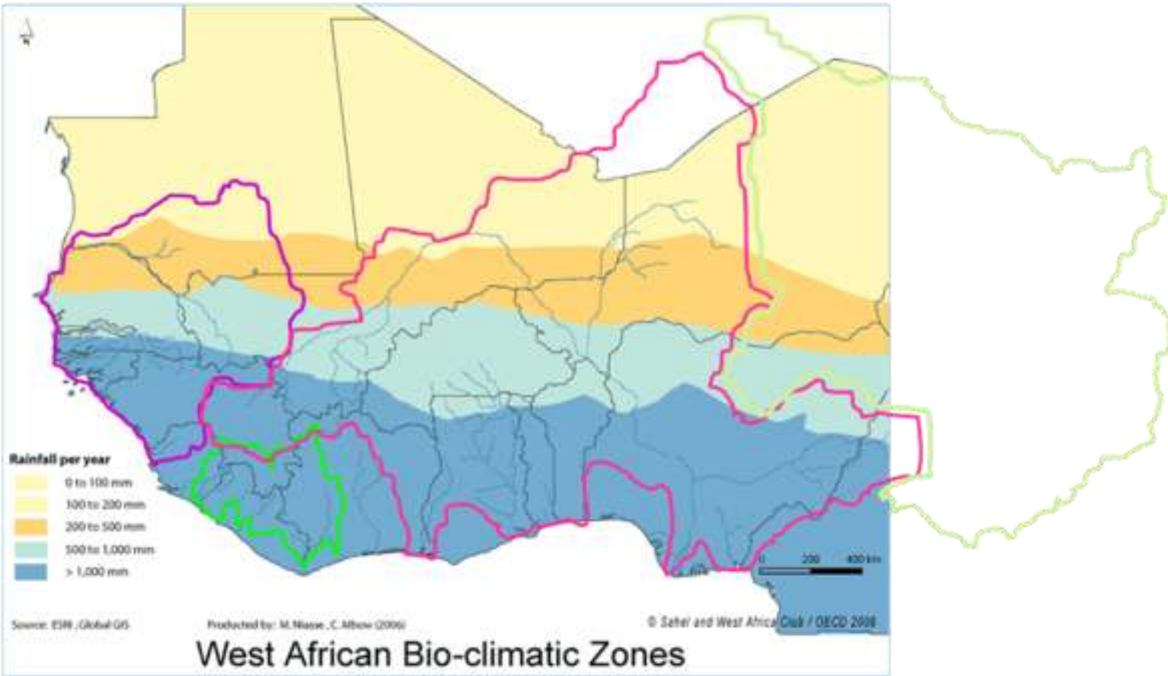


Figure 17: Map indicating rainfall regions across the western region

6.1. KEY RISK AREAS

The key climate change vulnerabilities for this cluster are painted against a high level of uncertainty in the predictions regarding the potential change in rainfall in large parts of the region. The vulnerabilities are, therefore, likely to vary depending on which scenario (wetter or drier) turns out to be correct in these areas.

The key vulnerabilities in the region relate to the climate change impacts on agriculture, hydropower, ecosystems, and the urban and domestic sector. These vulnerabilities in turn lead to a range of risks in the region as outlined below.

POVERTY AND HUNGER

The countries of this region are largely dependent on agriculture, and large portions of the rural population are subsistence farmers. Depending on whether rainfall increases or decreases across the region, climate change may either improve, or negatively impact on, agricultural productivity in rain-fed agriculture in particular. An increase in rainfall with a limited increase in temperature may make agriculture more productive, although a more extensive increase in temperature will negatively impact on agricultural productivity.

In the coastal countries, increased rainfall is may have negative impacts on agriculture through increased flooding, erosion and damage to crops, particularly if the increase comes in stronger storms. In the rest of the region, decreased rainfall and increased temperatures will also have negative impacts. The damage to agricultural productivity and household food production arising from climate change will increase poverty and hunger, on the back of already high levels of poverty.

Under a drying scenario the Sahel is particularly at risk, as is the Lake Chad basin. Other areas at risk include the coastal areas, and the Volta and Niger basins.

ENVIRONMENTAL DEGRADATION

The reduction of continental wetlands (Niger River Inland Delta, floodplain of the Senegal River Valley, Lake Chad) combined with a decline in the rate of river flow will lead to the modification of the ecological niches and life cycles of fish in particular. Human population growth, unsustainable resource use and development, and desertification are already leading to drastic declines in the productivity of the Niger's fisheries. Deforestation and farming of fragile soils are leading to sedimentation of river channels. Drought and reduced water availability have forced rural communities, such as farmers and cattle herders, to migrate south to more humid conditions increasing pressure on the remaining floodplains and wetlands. With this migration, traditional resources management has given way to unsustainable survival modes leading to declining biodiversity and productivity of natural habitats. A circular relationship between poverty and environmental degradation characterizes the region. This combination of increased human pressure and drought then exacerbates desertification and the levels of poverty and hunger.

PHYSICAL SECURITY

The combination of increased flood risks and sea level rise puts the residents of coastal cities particularly at risk. Loss of mangroves which protect the coastline from storm surges, and coastal erosion will add to these risks. The number of people at risk may be exacerbated by migration from rural areas where crop production has been reduced as a result of climate change. The coastal cities in clusters 2 and 3 are particularly at risk in this regard.

DISEASE

Niger and Togo anticipate the resurgence of malaria, and an upsurge in epidemics of meningitis and measles as well as respiratory diseases. Increased urbanization with limited services, and increased flooding in urban areas could result in increased disease burdens in these areas.

MIGRATION

Migration from rural to urban areas is likely to be enhanced by the drop in agricultural productivity in many areas. Where this migration is to coastal cities which will experience sea-level rise and increased flood risks, an increased number of people will be put at risk of disease, hunger, poverty and physical harm.

NATIONAL DEVELOPMENT

Hydroelectric power generation could be affected in countries such as Ghana, Côte d'Ivoire, Togo and Benin. Interrupted, unreliable, or limited electricity supply can directly impact on the development trajectories of countries, limiting economic growth potential.

In a number of countries, negative impacts on agriculture will also impact on the national development picture. However, in some of the countries, the presence of oil may alleviate the dependence and pressure on agriculture in due course.

SUMMARY RISK ASSESSMENT

The coastal areas of the western region are extremely vulnerable to a combination of sea level rise, storm surges and flooding from more intense rainfall events. These impacts, combined with high levels of population growth and increased migration to urban areas will put millions of people at risk in the coastal areas. The population at risk is estimated to be around 100 million by 2050.

In the Sahel region, the initial changes may be beneficial, bringing increased rain during the growing season, but this will change in the longer term to a drier scenario, which is likely to result in significant impacts on these communities which are dependent on rain-fed agriculture. The result will be increased poverty and hunger, and increased migration to already stressed urban areas.

7. CENTRAL REGION

The central cluster is composed of the Congo Basin (primarily), and the Sanaga and Ogooue coastal rivers to the west of the Congo. The Congo River basin falls primarily into the Democratic Republic of Congo (DRC), but includes Tanzania (and Lake Tanganyika), Burundi and Rwanda in the east, the Central African Republic (CAR), Cameroon and the Peoples Republic of Congo in the north, and Angola and Zambia in the south. Although the Ogooue River originates in the Congo, the basin is almost entirely within Gabon. Similarly, the Sanaga River basin is almost entirely within Cameroon, with minor parts of the basin in Nigeria and the CAR.

Whilst facing profound development and natural resource challenges, these basins are richly endowed with water resources and as a whole are not as vulnerable to changing climate as some neighbouring basins in the south and north. Nevertheless, pockets of significant vulnerability exist.

7.1. OVERALL SCENARIO

WATER RESOURCES STATUS

The climate of the Sanaga and Ogooue River basins is almost exclusively a humid, equatorial climate, with rainfall in excess of 2000mm in much of the basins. The Congo River basin is similarly dominated by an equatorial climate, although, given the size of the basin, climatic variation does exist. The basin receives around 1600 mm rainfall per annum, with some parts receiving in excess of 2000 mm.

The Congo River has an MAR of approximately 1 267 billion m^3, while the MAR of the Sanaga and Ogooue Rivers are 65 billion m^3 and 148 billion m^3 respectively. Available water resources per capita are high, well in excess of the benchmark that denotes the beginning of water stress (1700 m^3 / person / year). The unit run-off demonstrates the extensive rainfall that enters the rivers as run-off, reflecting the high rainfall regime and associated soil moisture and run-off relationships of central Africa.

Table 4: Comparison of the central cluster rivers with the Zambezi, Nile and Limpopo Rivers

RIVER	LENGTH km	BASIN AREA km^2	DISCHARGE Million m^3/year	UNIT RUNOFF mm
Ogooué	1200	224 000	148 000	661
Sanaga	920	140 000	65 000	471
Congo	4700	3 800 000	1 260 000	330
Zambezi	2650	1 400 000	94 000	67
Nile	6650	3 400 000	89 000	26
Limpopo	1750	415 000	5 500	13

Only a small portion of the available water resources are utilized in all three basins. Most of the water is used for agriculture, although most of the agriculture is rain-fed. Hydropower and navigation are important non-consumptive uses of water in the Congo basin in particular, and mining in the Southern Congo is having significant local water quality (sediment) effects. The Ogooue River is almost exclusively within a protected area, with its water resources allocated almost entirely to environmental requirements. Domestic water use is through a combination of surface and groundwater, with shallow wells extensively used in the rural areas and surface water abstraction for domestic consumption in those urban centres where infrastructure is still operational.

SOCIO-ECONOMIC STATUS

The three basins in this cluster encompass socio-economically depressed regions, with very high levels of poverty and low human development indices. While Gabon is the country with the highest human development index in sub-Saharan Africa, much of the Ogooue basin is deeply rural with relatively low levels of development. Population densities are generally low, with the Ogooue River basin the lowest at 4 people / km^2, while the Congo and Sanaga River basins are slightly higher at 20 people / km^2 and 71 people / km^2 respectively. Pockets of relatively high population density exist within the Sanaga River basin, with over 200 people / km^2 in both the northeast and the agro-industrialised southeast. Livelihood activities centre on subsistence agriculture, fishing and natural resource harvesting, with some pockets of economic activity in mining or urban centres. Many of the urban centres are located on the river banks, largely because the rivers are the primary means of transportation.

The predominant economic activities in the basins are extractive – mining, logging and fishing, with little beneficiation of the extracted resources. The Ogooue River basin falls almost entirely within national parks, with the economic activity here centred on tourism and resource protection. Hydropower production and potential in the Congo and Sanaga River basins (and the Ogooue) is high, with both basins generating most of the national power and with sufficient potential to provide a large amount of power to other countries.

Penetration of services is very poor, with very limited social services in the rural areas and failing services in most of the urban centres. Infrastructure is similarly limited, with navigation along waterways the predominant means of transportation of people and goods. The state of existing infrastructure is in many cases extremely poor, owing to decades of civil conflict and low investment in repairs and maintenance.

INSTITUTIONAL CAPACITY

Institutional capacity in the three basins is weak. Water resources management centers on the management of water infrastructure – primarily hydropower but also water supply and sanitation infrastructure for urban centers. Given the abundant water resources in all three basins, water sharing agreements and complex water management strategies are not an immediate priority for member states. Nevertheless, the International Commission for the Congo-Oubangui-Sangha Basin, (CICOS) was created in 1999 by Cameroon, CAR, DRC and the Republic of Congo, to improve cooperation ties amongst the member states and to promote improved water management to enhance development and alleviate poverty. The success of this institution has been mixed, with limited resources and relatively low levels of commitment to date. Whilst the capacity in Gabon is relatively good, limited capacity needs exist within the Ogooue River basin, given its remoteness and protected area status.

Development scenarios for the Sanaga and Congo River basins focus on the extractive industries and hydropower potential. Although much natural wealth exists within both these basins, the low levels of institutional capacity, limited infrastructure investments and potential for civil conflict undermine the probability of high growth scenarios and extensive social development. Urban migration coupled with poor service provision supports the growth of large informal peri-urban settlements with extreme levels of poverty and severe hardship. Unregulated and unfettered resource extraction will likely result in unacceptable environmental and social impacts, with the loss of great expanses of tropical rainforest imposing a global impact through lost carbon sequestration capacity and lost biodiversity. Development scenarios in the Ogooue are more positive, with the strong economic and institutional structure of the Gabonese state likely to maintain and enforce the protected status of the basin, and the rapid expansion of ecotourism investment in the basin bearing dividends for the state. It is however not clear that these benefits will filter to the local, rural level although improved rural services and reduced poverty are likely in a strong Gabonese state.

CLIMATE CHANGE

Climate change projections for the three basins are uncertain, with consensus on increased mean annual and mean seasonal temperature but lack of consensus on the direction or magnitude of rainfall change. Intensity of events is likely to increase, consistent with the increased energy of the atmospheric systems driving the regional climate. Accordingly, local floods are likely following high intensity thunderstorm events, and an overall increase in flooding in the basin is possible given the projections for increased rainfall contained in some climate models.

Temperature effects on freshwater ecosystems are also anticipated, particularly in Lake Tanganyika.

7.2. KEY RISK AREAS

Water resources are abundant in the Central Cluster and currently massively underutilized. Flooding is a natural phenomenon, with various strategies currently employed to adapt (and benefit from) seasonal flooding. Moreover, given the marked rainfall in the cluster, slight changes in mean annual rainfall (increase or decrease) are unlikely to have profound effects to the system that is already adapted to very large amounts of water. Accordingly, other than increased flood risks, the central cluster is probably not as highly at risk to climate change to some of the other clusters explored in this report.

That does not imply that there are no potential risks or hotspots in the central cluster. Three important risk areas can be identified:

1. Physical security in urban areas, particularly informal peri-urban settlements in low-lying riverine environments;
2. Hunger and poverty related to Lake Tanganyika fisheries and fish dependent communities; and
3. Invasive alien vegetation, particularly water hyacinth.

PHYSICAL SECURITY

Given the weak institutional environment in much of the cluster, and the low levels of services and infrastructure, urban areas and particularly peri-urban informal settlements are at risk to flooding. Specific examples include the large cities of Kinshasa, Brazzaville and Kisangani, and particularly the informal areas surrounding the formal cities, and some of the smaller towns and urban centers on the margins of the river-courses. Rural villages on the river banks are in some cases better adapted to these flooding conditions, as they are often more advantageously placed (higher lying ground) and have systems and practices adapted to periodic / seasonal flooding.

The impacts of such flooding include loss of life, damage to infrastructure (homes and social infrastructure), isolation and inability to move to more favourable environments, disease-effects and reduced quality of life.

Flooding can occur either through heavy local rainfall that results in local flooding and ponding, or through increased run-off and flooding of the river, with bank-flow exceeded and extensive flooding of surrounding low-lying areas.

The primary drivers of the flooding risk are two-fold:

- Climate - heavy intensity local events or increase overall rainfall and river flooding; and
- Low levels of development and/ or institutional capacity, resulting in lack of drainage, poor location of settlements in low-lying areas / depressions, limited early warning systems and forecasting and limited disaster response capacity.

ENVIRONMENTAL DEGRADATION

Lake Tanganyika is the second largest freshwater lake in the world, and the second deepest. The lake covers 32,900 km², with a shoreline of 1,828 km, a mean depth of 570 metres and a maximum depth of 1,470 metres, and is estimated to hold 18,900 km³ of water. The depth and tropical location of the lake prevent turnover of water masses, with the surface water much warmer than the depths maintaining stratification year round. As a result, the lower depths of the lake contain fossil water and are anoxic.

The lake holds over 400 species of fish, of which 250 species are cichlid fish living along the shoreline. 98% of the cichlids are endemic to the lake and many species are prized within the aquarium trade. However, the largest biomass of fish is in the pelagic zone with two species of Tanganyika sardine (Capenta) and four species of predatory lates (related to the Nile Perch).

It is globally recognized as a hotspot of biodiversity, endemism and represents significant tourism potential. In addition, the lake shore and surrounds is relatively heavily populated, with the lake's pelagic fishery the dominant source of livelihood. Over 100,000 people are directly involved in this industry, operating from over 800 sites around the lake. This industry currently provides 25–40% of the animal protein supply for the populations of the basin countries, demonstrating the marked footprint and significance of the Tanganyikan fishery. Accordingly, fish exports, both for consumption and into the aquarium fish trade, earns important income for the local economy.

It has been recently demonstrated that the regional warming patterns since the beginning of the twentieth century have resulted in a rise in surface-water temperature that has increased the stability of the water column. Conjunctively, a regional decrease in wind velocity has contributed to reduced mixing, decreasing deep-water nutrient upwelling and entrainment into surface waters. These effects have resulted in a marked reduction in productivity of the pelagic fishery – roughly a 30% decrease in fish yields. These climate change effects are anticipated to intensify under future increased temperatures, with further profound effects on the pelagic fishery, local income and regional protein supplies.

Freshwater invasive aliens are common in the three river systems under investigation. The most significant of these is arguably the water hyacinth. Higher temperatures may have significant effects on the proliferation of invasive alien species (particularly water hyacinth), both on Lake Tanganyika and within the river systems of the Congo, Sanaga and Ogooue rivers. While these effects may be systemic, it is most likely that proliferation will be a local response. Besides the biodiversity and ecological impacts of such proliferation, effects on hydropower may be experienced, particularly where extensive proliferation clogs turbines.

Similarly, temperature increases may drive localized eutrophication where waste from human settlements enters the water bodies. However, these effects are likely rapidly assimilated within the vast water bodies and highly productive biological systems of the cluster.

SUMMARY RISK ASSESSMENT

The central region is less at risk from the impacts of climate change than many of the other regions. The key challenge is that increased rainfall may result in increased flood events. Loss of fish stocks and biodiversity in Lake Tangyanika is also a concern. Of major concern, however, is that the Congo River, in particular, provides a source of vast amounts of water, and vast hydropower potential, which can benefit neighbouring states and the continent in general, particularly under a regional integration scenario. The protection of this region is therefore critical as one of the major water and energy producing regions of the continent. The protection of the central African forests is also critical as a climate change mitigation measure with opportunities to access carbon credits as a means to support protection of the forests and development for local communities.

8. SOUTHERN REGION

8.1. OVERALL SCENARIO

WATER RESOURCES STATUS

Figure 18 below describes the climatic zones of the African continent according to the Van Koppen classification system. As shown, southern Africa progressively becomes arid to the west, with most of the coastal zone being described as desert. The central region of southern Africa falls into the dry steppe zone with climatic conditions similar to that of adjacent desert zones. Here, conditions are semi arid and hot with very high temperatures. Slight rainfall may occur when the edges of the ITCZ reach the zone. Moving north towards the equator and east towards the Indian Ocean, the climate becomes that of the savannah which is sometimes referred to as tropical wet-and-dry. This region experiences dry winters and wet summers with most of this falling in the months between October and April.

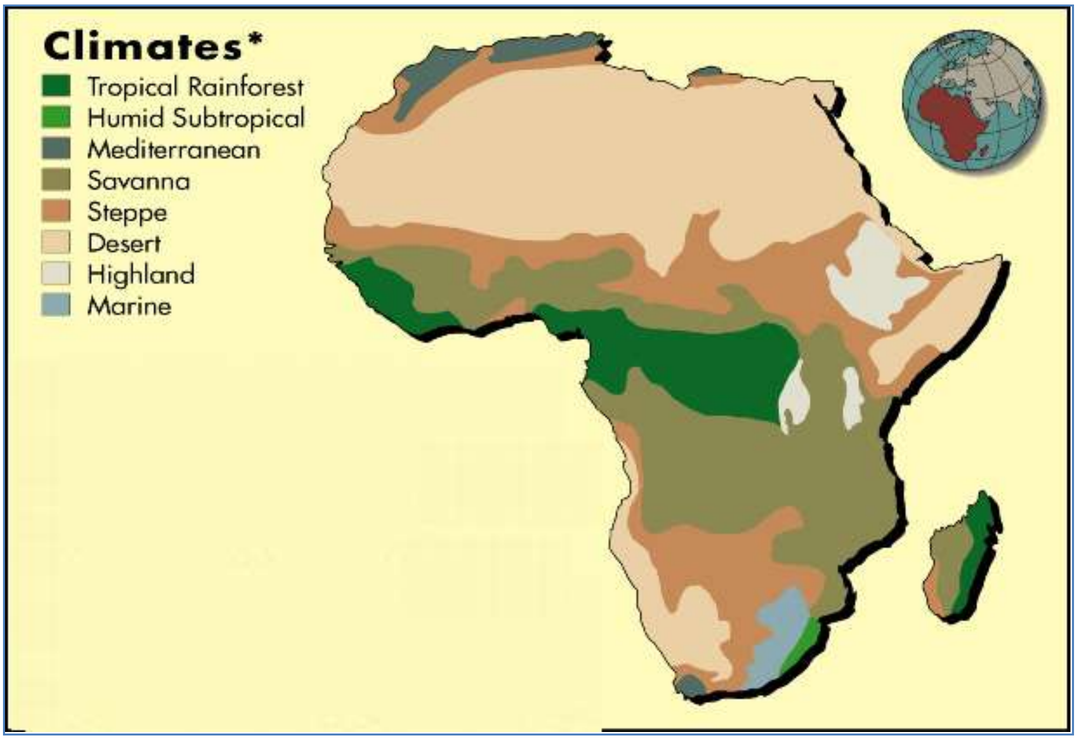


Figure 18: Climatic zones across Africa. Based on Van Koppen Classification. Source: The Pennsylvania State University

To the south-east the coastal climate varies from marine to humid-subtropical. This is due to the influence of the warm Mozambique current of the Indian Ocean. At the coast, the humid sub-tropical climate results in year-round rainfall, with the heaviest rain in the summer months.

Table 5 below lists the transboundary basins in the Southern African region, their size, and countries in which the basins fall.

Table 5: Transboundary basins in Southern Africa, size and riparian countries Source: Transboundary Freshwater Dispute Database. 2000

Basin Name	Total area of basin km^2	Country name
Cuvelai/Etosha	167,400	Namibia, Angola
Incomati	46,700	South Africa, Mozambique, Swaziland
Kunene	110,000	Angola, Namibia
Limpopo	414,800	South Africa, Mozambique, Botswana, Zimbabwe
Maputo	30,700	South Africa, Mozambique, Swaziland
Okavango	706,900	Botswana, Namibia, Angola, Zimbabwe
Orange	945,500	South Africa, Botswana, Namibia, Lesotho
Ruvuma	151,700	Mozambique, Tanzania, Malawi
Save	115,700	Zimbabwe, Mozambique
Umbeluzi	10,900	South Africa, Mozambique, Swaziland
Zambezi	1,385,300	Zambia, Angola, Zimbabwe, Mozambique, Malawi, Tanzania, Botswana, Namibia, DRC
Pungwe	32. 500	Zimbabwe, Mozambique
Buzi	31, 000	Zimbabwe, Mozambique

Water resources in the Southern African Development Community or SADC region are generally considered to be in short supply due to low and variable seasonal rainfall and the high evaporation potential prevalent across most of the region. Many parts of region also lack the infrastructure to adequately deal with these challenges with severe consequences for people living in the region. The region is also characterized, as shown in Table 6 above, by large rivers which are shared between two or more countries which emphasizes the need for co-operation between the basin states.

As with the climate, the hydrological regime of Southern Africa is variable. In the eastern part of the region, precipitation is largely driven by the Indian Ocean, while to the west the Benguela Current of the Atlantic Ocean predominates. Most rainfall takes place in the summer months between October and April.

The figure below are based on the World Meteorological Organisation's baseline period for present climate conditions (1961-1990) and indicates the Mean Annual Precipitation (MAP; left) and potential evaporation for the region. Inter-annual variability measured by the coefficient of variation of rainfall CV (%) in the Southern African region is high, ranging from about 15% in the region of Zambia to approximately 20-30% over most of Botswana and Zimbabwe.

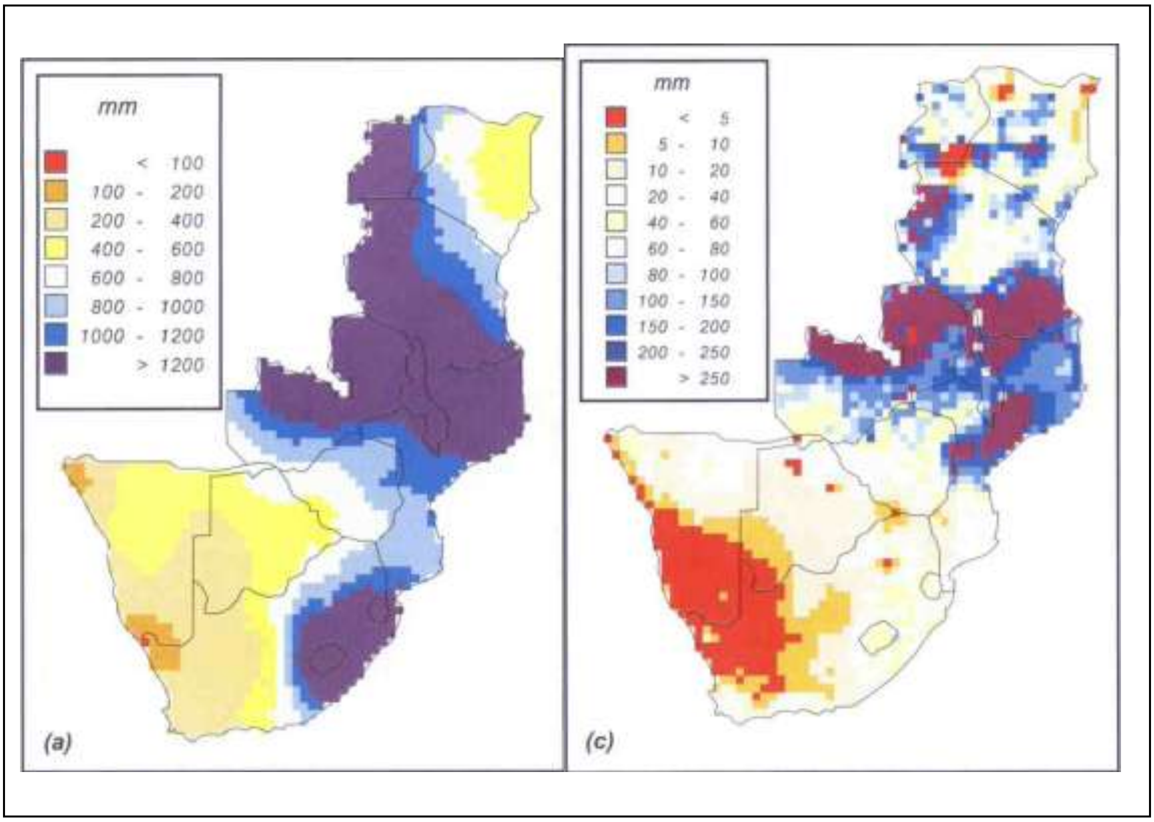


Figure 19: Precipitation and runoff in southern and eastern Africa. Right hand figure represents precipitation under present conditions; Left hand figure represents runoff under present conditions. Source: Schulze, Meigh and Horan

As shown, precipitation in the region varies considerably and increases eastwards. Mean annual precipitation is in excess of 800mm per annum across most of the region. Exceptions are the southern parts of Zimbabwe where the MAP is between 600 and 800 mm and the west part of the region where MAP decreases significantly to less than 200 mm per annum. Runoff patterns, represented in the left-hand figure, indicate a high amount of runoff, in excess of 1000 mm per annum in the north

SOCIO-ECONOMIC STATUS

The SADC region is characterised by disparate inter-country and within country conditions. At an inter-country level, population densities vary with Malawi, Lesotho and Swaziland being the most densely populated of the SADC countries while Zambia, Botswana and Namibia are the least densely populated. South Africa dominates the region in terms of economic performance and together with Botswana and Angola have the highest Gross Domestic Product. Lesotho, Swaziland and Malawi have the GDP. It is also worth noting that Mozambique is currently the fastest growing economy in the region, but off a very low base. The water resources implications are that this growth will need to be matched by the appropriate levels of water resources development.

There are also disparities in wealth particularly between rural and urban populations. The Save, northern Cunene, upper Cubango and Okavango River basins have pockets of high rural populations most of whom are very poor and highly dependent on groundwater sources.

In rural communities, the predominant activities involve (rain-fed) subsistence agriculture and livestock farming. Away from rural areas, irrigation farming, mining, industrial operations, forestry, tourism and eco-tourism, and game farming are the dominant economic activities. The main population centres in the region are the Gauteng region of South Africa in the Orange-Senqu River basin, the nodes of Blantyre, Bulawayo, Harare and Lusaka in the Zambezi River basin as well as the Cuvelai and Kavango regions of the Okavango.

Population growth in these areas is significant and will continue to be with profound implications for water demand, supply and pollution.

Generally speaking, water resources in Southern Africa are extensively utilized by several competing uses. Irrigation agriculture accounts for most of the region's water use (figure 19) while a significant amount of water is lost to evaporation through reservoirs. As shown, demands across all sectors are expected to increase into the future as irrigated agriculture, industry and urban populations expand.

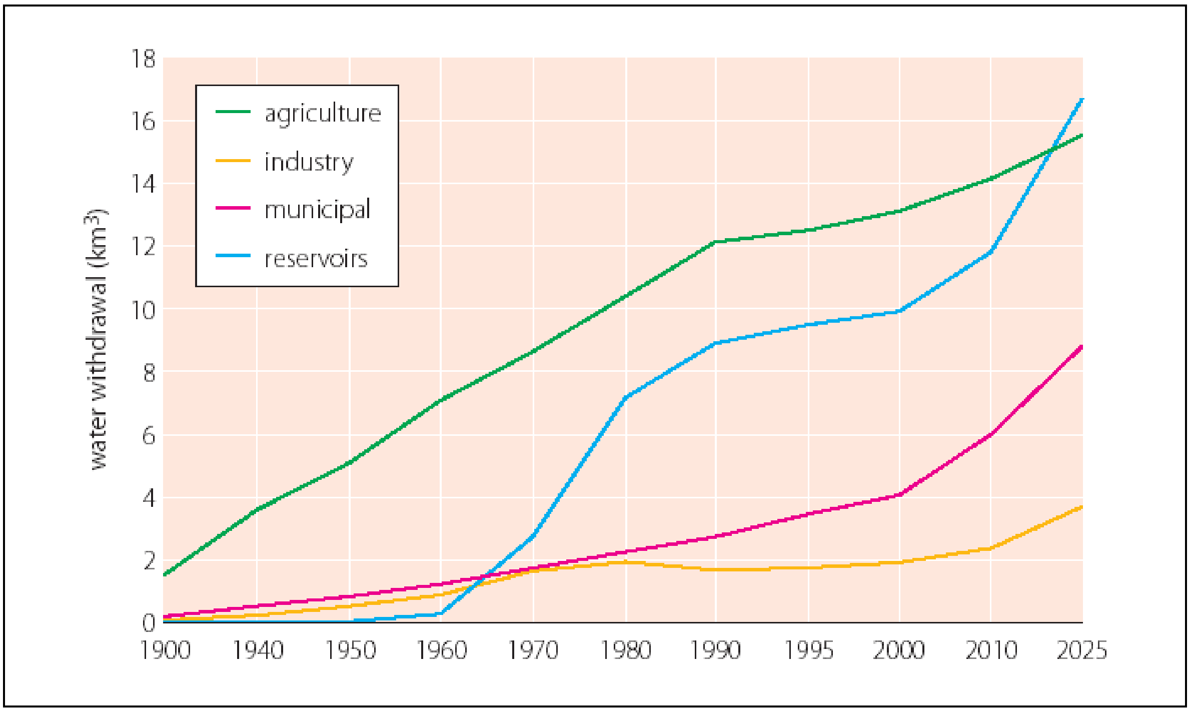


Figure 20: Current and predicted future water use by sector in Southern Africa. Source: UNEP Africa Environmental Outlook

In the Limpopo River basin where surface water is the main source of water for most of the economic activities, South Africa accounts for most of the river's water use and is the region's largest irrigator. The same basin is almost fully developed in the Zimbabwean portion with very little rainfall contributing to the main stem. There are currently plans in place to expand irrigation. Although the Incomati basin is fairly small, it is located in a region with significant development pressure and, consequently, its resources are extensively exploited. Most of the basin's water resources are used in irrigation and forestry and there are plans by South Africa to expand irrigation in this basin.

Water use in the Maputo river basin is estimated at 1198Mm^3/a. Agriculture accounts for approximately 86% of water use while industry and power generation account for the remaining 14%. The potential for groundwater development is generally considered good. Water resources in the upper Pungwe river basin in Zimbabwe are extensively utilised. This part of the basin is densely populated and substantially developed in terms of agriculture and tourism. Forest plantations and irrigation agriculture account for most of the water consumed in this part of the basin. It is also anticipated that water consumption will increase in future.

According to assessments conducted for the Zambezi basin's IWRM strategy, only 20% of the basin's total runoff is currently in use. Much of the basin's agricultural and hydropower potential is yet to be exploited.

The SADC Regional Strategic Water Infrastructure Development Programme (RSWIDP) identifies priority development initiatives earmarked for the region. It is effectively these developments that will drive the growth in water demand and use shown in Figure 20 above.

INSTITUTIONAL CAPACITY

In most of the Southern African states the responsibility to control, supply, and manage water resources is held by the national department of water affairs. While institutional and legislative frameworks exist, regulations for the holistic development and management of the region's water resources are still lacking. In addition, while Southern African countries are moving towards an increasingly integrated approach to water resources management and decentralised water resources management, capacity, both financial and human, has been identified as a key constraint.

A number of institutions have been established in the various transboundary river basins in Southern Africa, as well a range of transboundary agreements. In this regard, Southern Africa is relatively advanced. However, there are still significant challenges in managing and financing water resources management at the national level.

All the Southern African states are signatories to the SADC Revised Protocol on Shared Watercourse Systems which was revised in 2000 in order to align it with the provisions of the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses. The SADC protocol outlines principles which guide the development, use and protection of international watercourses. These include, inter alia, balancing development with conservation, developing national systems which are complementary and compatible, and encouraging the equitable sharing of water courses.

CLIMATE CHANGE

The general trend of predictions indicates increased aridity in the western parts of Southern Africa, with the eastern part of the continent receiving substantially more rain. Temperature is expected to rise across the region.

Downscaled forecasts indicate that most of Southern Africa will get drier although there are pockets which will become slightly wetter, notably eastern Zambia, most of Tanzania and northern Malawi. Western Southern Africa is predicted to become significantly drier, with a decrease in runoff of over 30%. The area of the Save is predicted to become moderately drier while the Buzi will become significantly drier. In the case of the latter, the MAP is predicted to decrease by more than 30%. Most of the Limpopo is expected to become slightly drier with the exception of a small pocket along the border of South Africa and Botswana which is expected to become slightly wetter. The Incomati, Maputo and Umbeluzi River Basins follow the same trend and are predicted to become slightly drier. Most of the Rovuma River Basin however is expected to become slightly wetter with a predicted increase in MAP by between 0-15%.

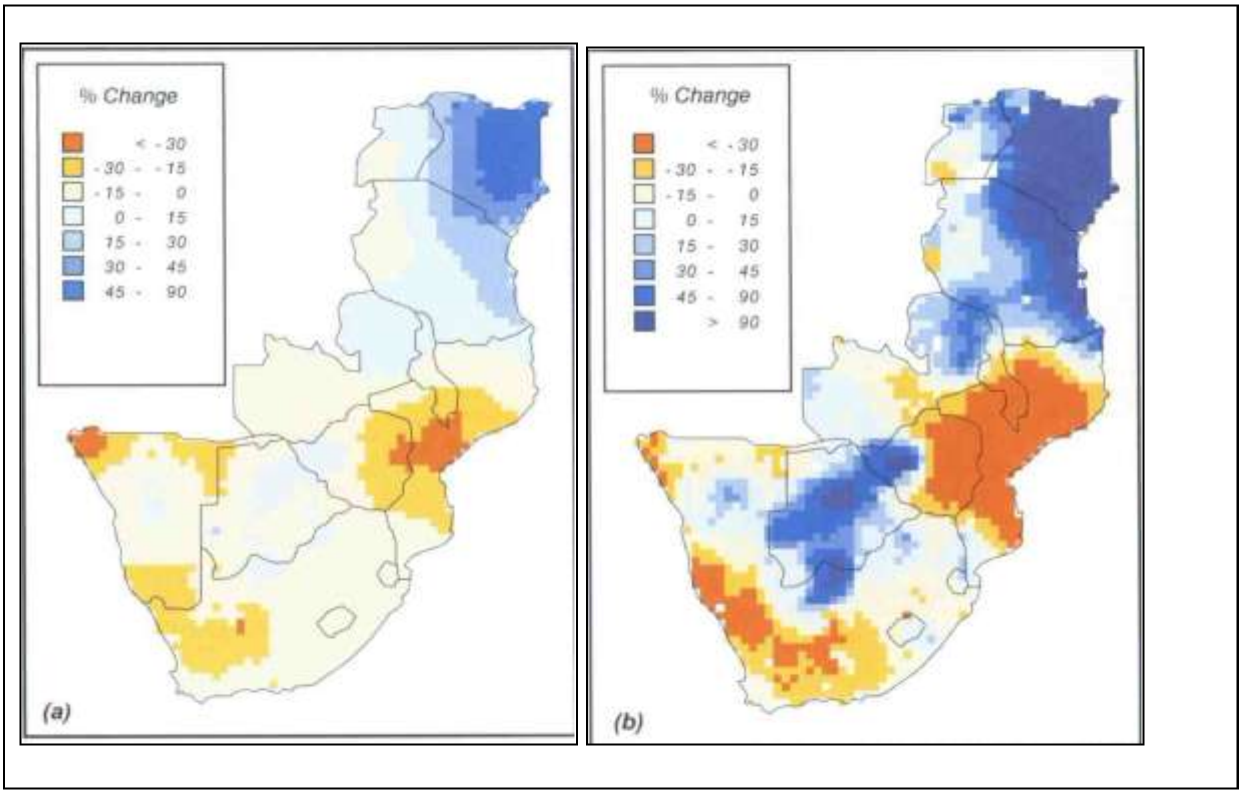


Figure 21: Predicted rainfall and runoff changes for southern and eastern Africa. (Right hand figure represents predicted change in annual precipitation for the year 2050; Left hand figure represents predicted change in runoff for the year 2050). Source: Schulze et al.

However parts of the Okavango River basin in Botswana may experience significant wetting while Namibia will generally become drier. According to predictions, the highlands of the Kunene and Okavango, within Angola maybe become wetter. In the Orange River basin, predictions are that the eastern basin will become wetter, although only marginally so (by approximately 15%).

What remains unknown, particularly for the coastal plains of Mozambique is the influence of cyclonic weather patterns on water resources and flood risk. Therefore while predictions show that most of the inland area of Southern Africa will become drier it is unclear whether cyclonic activity and therefore, flooding, will become more intense or more frequent. For this reason, the coastal regions and flood plains of Mozambique are flagged as potential hotspots.

A further uncertainty relates to the interrelationship between the inter-annual variability of rainfall and future climate change. As it is, Southern Africa experiences significant year-on-year variability in rainfall which not only poses challenges for infrastructure planning and management but has consequences particularly for rural populations which are dependent on subsistence agriculture. The uncertainties in rainfall coupled with climate change compound the problem. Any inter- and intra-seasonal variations may actually disguise variations attributable to climate change.

8.2. KEY RISK AREAS

HUNGER AND POVERTY

The area covered by the Limpopo, Pungwe and Buzi River basins in the central zone of Southern Africa is predicted to become significantly drier and is flagged as a key risk area. This coincides with a part of the sub-continent where water resources are already heavily utilized, with plans afoot for further development. In addition, while the area of the Save River basin is only predicted to become moderately drier, it supports a large rural population which will be particularly vulnerable to any change in climate given their reliance on groundwater resources and subsistence agriculture.

ENVIRONMENTAL DEGRADATION

The Middle Zambezi is of concern as a drying scenario would significantly alter the environment, which depends on a certain amount of rainfall to maintain its current form. However, there is a lack of agreement in predictions concerning the Zambezi's future climate. This in itself should be highlighted as a concern for policy makers. That said, the Kafue catchment is flagged as being at risk for several reasons. A drying scenario, which has been predicted by some authors, will negatively affect the Kafue sub-basin as the wetlands and flood plains require a certain amount of wetting both from flooding and rainfall to sustain their functioning.

The environmental impacts from climate change are significant and will play out at key sites such as the Orange River mouth where the ability to implement current and future Ecological Flow Requirements will be seriously eroded.

NATIONAL DEVELOPMENT

While future hydropower schemes might be useful, their net value may be reduced by climate change due to lower river flow as a result of reduced rainfall and increased evapotranspiration. Planned developments in Angola and Namibia should be flagged as areas under risk due to challenges in meeting assurance of supply and increased pressure on the resource. This will place stress upon both rural communities that have a very direct relationship with the environment, as well as key environmental sites such as Etosha Pan and the Okavango Delta and the Makgadikgadi Pans.

In the Orange-Senqu River basin development is expected to increase, particularly in Gauteng in South Africa. A drying scenario for this region will see already heavily utilized resources becoming extremely stressed. In addition, expansive areas of irrigated agriculture may become unviable under drying scenarios which will necessitate major shifts in water use patterns. .

SUMMARY RISK ASSESSMENT

Two key risk areas emerge in this region – the east coast areas, which are vulnerable to increased flooding from storm and cyclone events, and the central/eastern semi-arid areas where increased temperatures and drying will exacerbate poverty and hunger amongst already vulnerable communities.

9. ASSESSMENT OF REGIONS MOST AT RISK

Africa has been recognised by the International Panel on Climate Change as being the continent that is the most vulnerable to climate change. There is, therefore, an imperative for all African governments to manage the freshwater impacts of climate change.

There are, however, three key areas in the continent that, because of the extent of the impact, the size of the population that will be affected, the vulnerability of the affected population and the lack of adaptive institutional capacity to manage the impacts, have been identified as being particularly at risk. There is also one area that has been identified as holding potential opportunities, but which is under threat, not from climate change, but from development and human impact, and which requires protection.

Before outlining these regions and the particular risks that they face, it is important to reiterate that adapting to climate change is a development issue. Africa's land and water resources are already under stress, and population growth and economic development with associated improvements in standards of living, will, without climate change, significantly impact on these resources. Equally, one of the biggest challenges in Africa today is the issue of poverty. People living in poverty are far more susceptible to the impacts of climate change than those with access to and ownership of more resources. Development is needed to eradicate poverty on the African continent. At the same time, eradication of poverty will provide the best form of defence for currently poor communities against climate change.

Underpinning all of this is the need for good governance, for transparent and effective institutions, and for political commitment to pro-poor development through the effective use of water and other resources. Equally important is that African governments make the necessary financial commitments either through national budgets, or through accessed financing, to support this development scenario.

The section below outlines the regions in Africa that have been identified in this study as being most at risk from the impacts of climate change. These areas are indicated on the map in figure 22.

9.1. REGIONS MOST AT RISK

COASTAL AREAS

The coastal areas of West Africa (from Senegal to Nigeria), of eastern and southern Africa (from Mozambique to Tanzania) and the Nile delta, are at risk from flooding, sea level rise, storm surges (except the Nile delta), and saline intrusion into surface and groundwater. Currently over 70 million people are at risk in these areas, and the population of the coastal region of West Africa is estimated grow to around 100 million by 2050 because of population growth and migration from increasingly arid inland areas. In the coastal areas of West Africa, institutional capacity is extremely limited, resulting from impoverished societies and decades of conflict. Combined with the extremely high population increase expected in this region, this makes this the most vulnerable of the coastal regions. While 40 million people currently reside in the Nile delta, and are also at risk from sea level rise and flooding, the institutional capacity in Egypt is significantly higher than that of West Africa, allowing for greater adaptation capacity. The east coast of Africa, while also very poor in terms of institutional capacity and per capita income, has a lower population exposed to risk than the projected population in West Africa. However, the high levels of HIV/AIDS in these parts of sub-Saharan Africa mean that these populations are already weakened and vulnerable.

GREAT LAKES

The great lakes of the Rift Valley (Lakes Victoria, Turkana, Tanganyika, and Malawi) and Lake Chad are extremely vulnerable to climate change. Around 50 million people are currently dependent on these lakes, most of which are already experiencing a reduction in fish stocks, decreasing water quality, and reduced water levels. Temperature changes are predicted to result in lower wind intensity which will, in turn, reduce turnover in the lakes. This raises the possibility of the collapse of fisheries, massive loss in biodiversity, increased eutrophication and decreased water quality. The impact of these lakes in terms of contribution to protein consumption in rural communities, and international trade through export of tropical fish, is significant, and a collapse of the lake systems will have massive impacts on local and national well being.

THE SEMI-ARID REGIONS

In the semi-arid regions of the Sahel, central and eastern Southern Africa, and the Horn of Africa, large rural and peri-urban communities are largely dependent on rain-fed agriculture, and bio-mass derived energy. Their water supplies are often insecure and may be dependent on local rivers or groundwater. Increased climatic variability in these regions, combined with more intense droughts and floods, increased temperatures and lower rainfall overall, will put these communities hugely at risk. In southern Africa the vulnerability of these communities to climate change is exacerbated by extremely high rates of HIV/AIDS.

PROTECTING KEY WATER SOURCES

On a more positive note, there is a need and an opportunity in protecting the critical water sources of central, west and eastern Africa, (the Congo forests, the Fauta Djallon mountain areas in west Africa and the Ethiopian highlands). These areas are at risk from deforestation and poor land-use management, resulting in decreased effectiveness of these areas as critical catchment areas. Protection of these areas is important in protecting the quantity and quality of water, while also contributing to climate change mitigation through the conservation and restoration of critical forest areas, and protecting biodiversity. There is a particular opportunity to access carbon credits to assist in the restoration and sustainable development of these areas, while protecting their watershed functioning at the same time.

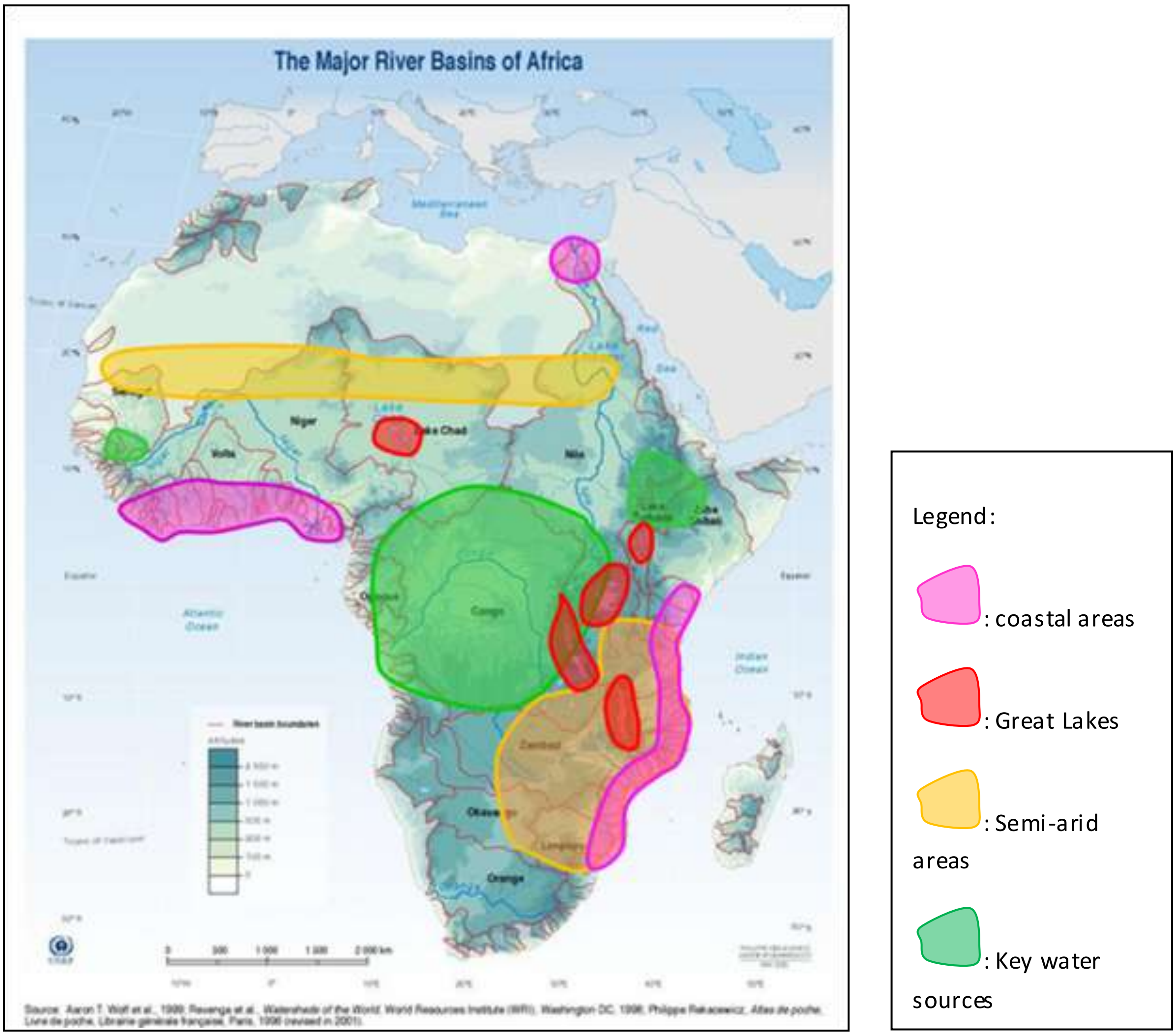


Figure 22: Map of areas most at risk from climate change, and key water sources requiring protection

10. OVERVIEW OF KEY RESPONSE STRATEGIES

While it is important to recognize many of the weaknesses across the continent that may complicate effective responses to climate change, such as poor institutional capacity, high levels of poverty, poor data, and limited modeling of climate change impacts at the local scale, it is equally important that immediate action is taken to improve the resilience of communities and societies to the impacts of climate change.

The following section describes some key actions that could be taken in response to the key risks identified in this report. This is by no means a comprehensive list, but offers some critical intervention points that should be addressed.

The actions that are provided here are actions that lie within the field of water management. However, some of the most successful responses to the water-related impacts of climate change and the building of resilience may lie outside the water sector, such as social grants for affected communities. It is, therefore, important for integrated adaptive approaches to be developed, not approaches limited only to the water sector.

10.1. DO GOOD WATER MANAGEMENT

The first point of intervention that is critical in addressing the key water related vulnerabilities to climate change in Africa, is to improve water management across the continent, particularly in the most vulnerable areas. There is no magic bullet that will help to address the impacts of climate change, and any response must be built on a foundation of solid and effective water management. A key issue is to ensure that water management plans are aligned with national development and poverty reduction strategies and that implementation of these strategies is driven hard to address the current development and poverty challenges.

A second issue is to improve the ability to manage the current challenges of climate variability. This will significantly improve the ability to manage the longer term impacts of climate change. Such measures include:

- ensuring that appropriate legislation (and agreements at the transboundary level) is in place,
- ensuring the institutional capacity to manage water effectively (both water resources and water services),
- developing sufficient skilled and experience staff to manage water effectively,
- ensuring sufficient financial resources to develop, operate and maintain the necessary water infrastructure to respond to climate change, and
- ensuring appropriate information is available, which requires effective monitoring and data collection. The latter is particularly important to be able to monitor climate trends.

Where human and financial resources are limited, as they are in many parts of Africa, it is important to identify and focus on managing the most vulnerable areas and the most critical issues, rather than attempting to spread limited resources over too large an area or too many issues.

It is also critical that water resources management is practiced in the context of the large number of transboundary basins that are vulnerable to the impacts of climate change. This will require improved relations between riparian countries, the sharing of information, and joint processes to address critical areas.

A number of areas that constitute good water management and that are critical in the face of climate change, are highlighted below.

10.2. INVESTMENT IN INFRASTRUCTURE AND TECHNOLOGY

There are a number of areas in which investment in infrastructure is necessary to support development and thereby to build resilience to the impacts of climate change. These infrastructural responses will be appropriate in different areas depending on the vulnerabilities and challenges of those areas. Key to the building of infrastructure, however, is the understanding that infrastructure is required primarily to support development, and through that process, if designed and managed correctly, to increase the capacity to adapt to climate change. It is also important to recognize that infrastructure refers not only to large dams and Interbasin transfers, but to small scale infrastructure as well, such as wells and pumps, rainwater harvesting infrastructure, and small scale irrigation systems.

In many areas climate change is likely to bring increased likelihoods of floods, and increased flood intensity. A number of management actions are required to enhance flood management, including the development of early warning systems and the rehabilitation of degraded catchments. However, the development of flood attenuation infrastructure may be appropriate in some areas, while the protection of infrastructure against floods is also critical. In flood conditions, water services (water and sanitation) infrastructure may be damaged, leaving communities vulnerable to poor quality water or lack of drinking water, and lack of functioning sanitation facilities. The flood-proofing of water supply and sanitation infrastructure should be considered in vulnerable areas.

The other side of the coin is that some areas will see decreasing rainfall and increased droughts. In most of Africa, water storage is, in any event, insufficient to disconnect economic growth from rainfall. Even if climate change were not a reality, Africa requires increased storage (both large dams and small storage facilities) in order to overcome the impacts of frequent droughts in both rural and urban areas. With the potential for climate change to extend the period of drought and to increase the intensity of drought, the need to invest in increased storage becomes all the more important. In this regard, finding the financial resources for the development of infrastructure remains a critical challenge and one where African governments and international financing agencies all have a role to play.

At the farm level, increased investment in and access to information about appropriate irrigation technology, including drip irrigation and rain water harvesting, is required to improve water use and productivity in the face of climate change. In many areas, a shift from rain-fed agriculture to irrigated agriculture may be necessary to protect rural livelihoods and food security.

Investment in natural infrastructure, such as investment in protecting and rehabilitating aquifers and wetlands can also contribute significantly to building resilience to climate change.

Recognising the disproportionate burden that poor women will bear arising from climate change, it is critical that investment in infrastructure and technology is flexible enough to reflect women's priorities and needs and that women are actively involved in decisions relating to infrastructure development. Other technological developments designed to increase resilience to climate change should also take into account the specific needs and requirements of women.

10.3. DISASTER PREPAREDNESS

It is clear that, in many parts of Africa, climate change is likely to bring more frequent and more intense water-related disasters, in a continent already prone to floods and droughts. Disaster preparedness, including well developed early warning systems, and post-disaster intervention plans, are a critical part of the resilience of a society to climate change.

Women are particularly at risk from natural disasters, for a number of reasons, including their lack of savings, property or land to buy new shelter after a disaster. As a result, women are more likely to be put in crowded shelters than men, and face the possibility of rape and physical abuse in such circumstances. Women are also physically less able to escape from floods, for example, either due to the nature of their clothing, or their already weakened state in a context of food shortages. Cultural practices may also prevent women from seeking healthcare. Women in countries with high gender disparities are most vulnerable. As a result, it is critical that disaster plans are specifically gender-sensitive and address the particular needs of women.

10.4. FLEXIBLE / ADAPTIVE DEVELOPMENT PLANNING

Of key importance in managing the water-related impacts of climate change in Africa is the need to ensure alignment between national development objectives and water availability. Because of the difficulty of predicting climate change impacts on water with any accuracy at this point, the challenge is to ensure that a flexible approach is taken to planning which allows adaptation to a changing climate over the years. This requires access to relevant and updated climate change information for the key water-related development planning departments, (e.g. agriculture, mining, power generation, municipalities), and also requires strong alignment and cooperation between water departments and departments responsible for development planning.

Given the vulnerability of poor women in particular to climate change, development plans and climate change response plans should proactively address the issue of gender and the protection and support of women and girl children in particular.

10.5. FLEXIBLE AND CLEAR ALLOCATION SYSTEMS

Water allocation takes place at a number of levels. In the basins and aquifers under consideration in this report, the first level of allocation is between riparian states. While there are a number of transboundary agreements in place in transboundary basins in Africa, there are also a large number of basins in which there are no agreements in place. Even where agreements are in place, some are lacking effective dispute resolution mechanisms, and many lack effective institutional capacity at the national or transboundary level for effective implementation and optimal sharing of water resources and the benefits derived from water resources. In basins facing water stress as a result of climate change it is important that effective transboundary water allocation systems are put in place, supported by good, shared data on the status of the basin.

At the sub-basin or local level, a range of water allocation systems operate in Africa, with parallel formal and customary systems in many countries. It is important that these systems are sufficiently flexible to enable adjustments in allocation to manage climate variability and climate change in support of national development objectives. It is also important, however, bearing in mind the limited institutional capacity in Africa, that these systems are sufficiently simple to be effectively implemented and managed within the capacity constraints.

10.6. RESPONSIVE INSTITUTIONS

Climate change in Africa will result in significant changes in the demand for and availability of water. As has been seen in the earlier part of this report, institutional capacity to manage this change is limited in most parts of the continent. Institutional capacity must be built, including ensuring that appropriate legislation and policy is in place, that a sufficient infrastructure platform is in place for storage and flood attenuation, and ensuring appropriate technical and managerial capacity is in place. The latter requires appointing and training people able to manage adaptively and in the face of uncertainty. This is a different mode of water management from the traditional approach, and requires the encouragement of innovation and creative responses to change.

It is also critical that stakeholders are involved in the water resources management process so that there is full support for the approaches to be taken and so that the exchange of information between stakeholders and authorities enables quick response to situations and optimal adaptive responses at both ends.

However, the key challenge in developing responsive institutions lies in building the adaptive capacity of such institutions. An effective response to climate change will not be based on the ability to accurately predict the changing climate and its water-related impacts, but rather on the ability to respond to change, to enable innovation at all levels, and to create flexible and responsive water management systems.

10.7. IMPROVED SCIENCE AND INFORMATION

The approaches mentioned above are dependent on improved science and information sharing across vulnerable transboundary basins and aquifers in particular. One of the challenges in terms of managing climate change in Africa is the lack of models predicting climate change at the local level. It is critical that the capacity to model climate change is enhanced in Africa so that management options can be based on scientifically sound information. This will require increased investment in the science of climate change and in understanding the impacts in Africa, and there may be a role for an African centre of excellence in this regard.

A critical aspect of improved information is the ability to define the current state, to identify emerging trends, to anticipate the possible future path and the resulting vulnerabilities and risks. This requires an appropriate monitoring system, which can deliver the necessary information at the appropriate scale. This monitoring system should extend beyond simply monitoring climate trends, to also monitoring the status of the resource to detect emerging trends and to identify necessary management actions to be put in place.

A critical part of an improved information system is the development of early warning systems for floods, in particular.

That said, however, bearing in mind the limitations in institutional capacity in Africa, a key challenge is to develop monitoring and information systems that are appropriate to the financial and human capacity constraints and can deliver appropriate information without unsustainable resource demands. In this regard, a partnership with stakeholders, and the use of widely accessible technology such as cell phones, can be used to supplement limited government data and information.

It is also critical that information is exchanged widely across the continent, building the understanding of climate change and of adaptation to climate change between countries and within countries

10.8. INVESTMENT IN PEOPLE

Adaptation takes place at a number of levels, from the creation, say, of major storage infrastructure, to the household level, particularly in rural areas and areas where government fails to reach. In this regard, while government might not be able to extend the necessary services to vulnerable populations to protect them from climate change, the provision of information itself can assist communities and households to prepare themselves for the coming changes.

The provision of information and training to rural communities is particularly important because of their high levels of vulnerability and because they are often out of the information loop. Information might include new crops to use, improved cropping or livestock management techniques, and flood warnings.

It is important to realise that access to technology and information is not gender-neutral and that, in most African countries, girls and women have less access to information and communication technology than men, because of social and cultural bias, lack of technological infrastructure in rural areas, lower levels of education especially in the fields of science and technology, and the lack of disposable income to buy technological services.

There is, thus, a particular need to invest in the training and empowerment of women as the ones who protect family health and well-being, and who are key drivers of adaptation in their own right. Gender mainstreaming and understanding the particular vulnerabilities of women should form a key part of all climate change adaptation strategies.

10.9. TRANSBOUNDARY BASIN MANAGEMENT AND REGIONAL INTEGRATION

The building of trust, shared knowledge and a shared vision of the basin across boundaries is very important, particularly in highly vulnerable areas and areas that already lie in conflict zones. While there are a number of transboundary basins in Africa in which international agreements have been concluded, and transboundary institutions put in place, many of these agreements and institutions are weak, and are not necessarily appropriate to cope with the impacts of climate change.

In many areas the solution to the climate change and development challenges will come not only from transboundary co-operation, but from a greater exploitation of regional competitive advantage, seeing development opportunities within the context of a region, rather than a country. Climate change, in this regard, offers a key driver for the expansion of regional integration across the continent.

Regional integration should be seen in a broader context than simply the water sector. There is an opportunity for the development of regional public goods, such as transport infrastructure, markets, power pools, trade arrangements, and food security responses, that can provide substantial benefits in building regional and local resilience to climate change.

10.10. UNDERSTANDING THE ENERGY/WATER NEXUS

A number of African countries are dependent on hydropower, even though the hydropower potential of Africa is still hugely underdeveloped. However, as has been seen in the regional reports, hydropower is under threat in some areas from diminishing stream flow or increased variability in flow. As a result, the 'climate change-proofing' of current infrastructure is an importance measure to protect the energy supply of many African countries, and hence to protect economic and social development potential. At the same time, further hydropower potential is under development, but such development must take place within a clear understanding of the potential impacts of climate change, and in such a manner as to be able to withstand potential climate change impacts.

It is important to ensure both water and energy security in an integrated manner taking into account the likely impacts of climate change. It is particularly important, in the context of the large number of transboundary basins in Africa, for such understanding to take place at the basin level as well as the national level, for joint planning for a water and energy secure future. Energy sources that do not demand water should also be seriously considered.

10.11. HARNESSING GROUNDWATER

Large numbers of people in Africa are dependent on groundwater, and yet the management and knowledge of groundwater is extremely weak. Monitoring of groundwater availability and use, and understanding of groundwater recharge is poor, but is critical to the sustainable use of this resource. Groundwater is a particularly important resource in the face of increasing temperatures, since it is not vulnerable to evaporation in the same way as surface water. As part of the improved use of groundwater, appropriate technology, and artificial recharge should be strongly promoted.

11. CONCLUSION

The IPCC has recognized that Africa is the continent most vulnerable to the impacts of climate change – partly because of the actual climatic changes that are predicted to happen, but significantly because of the high levels of poverty and low levels of institutional capacity across the continent. The challenges of climate change overlay an already fragile human condition on the African continent, with high levels of poverty and hunger, poor service delivery, and, in many places, already stressed water resources. Not only is climate change is adding to the already existing pressures of development on limited water resources, but as the climate change pressures intensify, they do so in the face of growing populations and economies, both of which place greater stress on water resources. The challenge of managing water in Africa over the next decades is thus both a climate change challenge and a development challenge.

With this in mind, an overview has been provided that identifies some of the most vulnerable areas in Africa, and some approaches have been suggested that may help to ameliorate the impacts of climate change. The already vulnerable poor, particularly, but not only, in rural areas, are the people most at risk from the impacts of climate change. Any action which increases the resilience of these communities will assist them to respond more effectively to the impacts of climate change.

In some parts of the continent, a particular challenge remains the sharing of transboundary waters in the context of increasing stress, and high levels of political instability and conflict. And yet, there are areas where transboundary water sharing is working well. A key message is that, across the continent, there are important lessons that can be learned, about appropriate and indigenous approaches to improved water management and climate change adaptation. A key part of responding to the coming change will be the ability to learn from one another, to share information and experiences, and to develop a body of African experience and knowledge about managing the impacts of climate change.

12. APPENDIX A: TABLE OF CURRENT STATUS AND CLIMATE CHANGE RISK FOR 15 TRANSBOUNDARY BASIN AND AQUIFER CLUSTERS IN AFRICA

The following table captures a summary of the assessment of the four key factors used in the risk assessment for each of the 15 identified clusters. The final column captures, in a high level summary, the key risks likely to be facing each of the 15 clusters. The table has been colour coded for easy reference, with the following meaning:

- (red) Critical/very poor status/severe impacts/high risk
- (orange) Poor status/moderate impacts/moderate risk
- (green) Good status/minor impacts/low risk
- (blue) Insufficient/uncertain information

The water resources status is assessed on the basis of per capita water availability, general water quality and the level of water stress. The socio-economic status reflects average per capita income and the development status of the country largely as reflected in the UN human development indices. The institutional capacity broadly reflects the existence and capacity of transboundary water management institutions, the level of infrastructure development, the national water resources management capacity including the existence of appropriate policy and legislation, and the financial and human resources capacity to implement the policy and legislation. The climate change column reflects the predicted severity of climate change impacts in terms of rainfall and temperature changes and their impact on the hydrology of the region. A qualitative assessment of these four parameters was done to generate the final column describing the level of risk in the region to the impacts of climate change. Thus, the risk is seen as being higher where the institutional capacity to adapt is low and where levels of poverty are already high. Risk is, therefore, not just a measure of the physical impacts of climate change, but a measure of the ability of the society to adapt to and withstand that change.

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
Northern Region					
Cluster 1 Transboundary basins and associated aquifers in North Africa	Semi-arid to hyper-arid with limited renewable resources. Groundwater resources use to varying degrees, but often slow recharge or are fossil in nature	Strong reliance on agriculture. Hydropower at various scales being considered. Marginalised communities in rural and water scarce conditions.	Some policy and institutional reforms although capacity is stretched. Infrastructure development in other large basins, but in transboundary settings insufficient.	Generally agreed warmer and drier	Rural communities vulnerable to decreased agricultural yields due to elevated temperature, reduced rainfall and shorter growing seasons. Urban areas vulnerable to impacted water quality. Domestic supplies across the

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
					board are vulnerable and with excessive reliance on groundwater there is a vulnerability to saline intrusion in coastal areas.
Cluster 15 The aquifers of inland North Africa	Hyper arid with exceptionally low rainfall and little to no aquifer recharge, many fossil such Nubian Sandstone Aquifer	Localised and small scale agriculture in many areas. Marginalised and often nomadic communities in rural and water scarce conditions.	Large transboundary aquifers, many being fossil, that require integrated water resource management.	Generally agreed warmer and drier	Impacts upon oases place vulnerabilities upon rural and nomadic communities. Also, an environmental vulnerability to endemic species.
Cluster 6 The Nile River Basin	Hyper-arid in the north to sub-tropical in the south with the majority of water resources being generated the southern basin.	Very mixed socio-economic settings across very large basin. Large urban developments and many marginalized, rural, poor communities. Agriculture a key element of the socio-economic fabric of the basin.	Some policy reforms have taken place. Nile Basin Initiative and Nile Basin Discourse in place, but often fragmented.	Warmer and drier to the north whilst warmer and wetter to the south.	Impacts on agriculture is places vulnerability on national food security in a number of states. Rural communities are especially vulnerable across the basin. Impacts upon assurance of supply makes further hydropower developments and national development trajectories vulnerable.
Western Region					
Cluster 2 Coastal rivers of West Africa from the Senegal to the Little Scarcies	WAM & ITCZ Partly humid, partly arid; large portion in Sahel; substantial coastal aquifers; growing water constraints	A number of the poorest countries in the world are in the basin	OMVS in place in Senegal basin; lack of human and financial resources at national level	Little agreement but recent studies suggest of increased rainfall – may result in increased flash flooding; increased temperature	Rural communities vulnerable to reduced crops because of temperature rise; Urban areas vulnerable to increased flooding Coastal aquifers vulnerable to saline intrusion from sea level rise
Cluster 3 Coastal rivers of West Africa	Humid in south and central parts. Humid-dry Sudan climatic type	High degree of poverty and inequality; some growth after protracted conflict;	Poor institutional capacity largely due to long period of political instability; lack of	Information very uncertain; temperature will increase	Uncertain climate future; vulnerable to more frequent flash floods with impacts on

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
from the Moa to the Sassandra	in extreme north; vulnerable to floods; pollution a concern	widespread food poverty; High dependence on rain-fed agriculture	transboundary agreements and poor conflict mechanisms; lack of human resource capacity		crops and physical security, loss of coastal wetlands and mangroves; possible salinisation of soils and groundwater in coastal areas; reduction in groundwater recharge;
Cluster 4 The Niger, Volta, and adjacent smaller basins	Sub-humid towards south; serious scarcity in Sahelian zone; floods in coastal belt; unpredictable rainfall with high variability; increasing water stress; water quality problems	High degree of poverty, high population growth. Political instability in many countries. High dependence on rain-fed agriculture; high gender imbalance in income;	Poor institutional capacity largely due to long period of political instability; transboundary institutions and agreements in place in key river basins; lack of human resource capacity	Significant temperature increase; reduced rainfall (10 – 25% by 2025); possible increase in rainfall in Sahel zone in June, July, August; increased evaporation; greater drought probabilities; more rainfall variability and unreliability; reduced groundwater recharge and river flow	Rural communities vulnerable to decreased crop productivity; reduction in key wetland areas; reduced flow will impact on hydropower generation; resurgence of malaria in Togo and Niger; upsurge of measles and meningitis expected;
Cluster 5 The Lake Chad basin	Basin is facing acute water stress; lake shrinking rapidly; local pollution issues from industry; water weed invasion in reservoirs and channels which host the Quelea pest;	Political instability and conflict; high levels of food insecurity; poverty particularly marked in southern countries; slow economic growth; some mining and oil exploration but agriculture remains key economic sector;	Poor institutional capacity; limited data and implementation capacity even where transboundary organisation is in place; international agreements weak on allocation and groundwater;	Information very uncertain; temperature will increase; lack of models of climate change for the basin; Rainfall has already shifted south resulting in reduced rainfall in northern area; increasing maximum and minimum temperatures; may be less rainfall in savannah and sahel areas;	Lower crop yields; more frequent floods and droughts and longer runs of wet and dry years;
Eastern Region					
Cluster 7 The Baraka and Cash rivers in East Africa	Arid climate, with high temperatures, high intensity rainfall and strongly seasonal	Large percentage of population dependent on agriculture and livestock. Very high levels of poverty	Some policy and institutional shifts made but general capacity is very low. Donor support now being provided.	Generally agreed warmer conditions and probably wetter although the local	Flooding is a significant concern making rural communities vulnerable through loss of crops,

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
	rainfall. Resources are stressed and groundwater appears to be inadequate to meet supply needs, although data is limited.		Lack of infrastructure of serious concerns especially under wetter scenarios.	distribution is unclear.	security and potential health threats. Continued conflict between two of the States makes these communities even more vulnerable.
Cluster 8 Transboundary rivers and aquifers in the Horn of Africa	Vary significantly from arid and semi-arid in the east and north to more temperate and tropical conditions in the highlands. Climate monsoonal drivers. Area typified by severe drought. Juba-Shibeli extremely flood prone	Widespread poverty and relatively low levels of development. Some GDP growth shows positive trends largely through emergent mining and export agriculture. These mask continued hardship amongst the majority of the region's population.	Significant policy reforms in some countries whilst others have poor governance systems. Infrastructure developed in some areas but generally insufficient to meet needs. Capacity is stretched across the region.	Generally agreed warmer and wetter with the southern areas being influenced by the ITCZ.	More extreme climate conditions makes large rural populations extremely vulnerable to flooding and related health impacts. Food security threats through hotter and drier cycles adds to this vulnerability.
Cluster 9 The river and lake systems of the Rift valley	Semi-arid ranging to tropical and temperate in the Ethiopian Highlands. Water resources in the basin are very unevenly distributed both temporally and spatially	Large populations facing extreme poverty conditions. Health issues of significant concern in this area.	Policy reforms made but institutional capacity is limited. Hydropower infrastructure in place but little else other than many small dams and tanks, of which many are silted up.	Warmer by some 3.5 ^{o}C and wetter by some 7%. More extreme events predicted.	Rural communities extremely vulnerable through impacts of flooding and various water borne diseases. Impacts of increased temperature on lacustrine environment will increase the vulnerability of rural communities through decreased fishery catches (food security)
Central Region					

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
Cluster 10 The Congo River Basin	High rainfall, humid tropical climate, ITCZ, abundant water resources, no water stress	Despite rich natural resources, levels of poverty very high and low HDI (informal urban and rural communities)	Very weak institutions, poor penetration of services into the basin, limited and collapsing infrastructure	Limited agreement, although climate impacts are not anticipated to result in significant water resource impacts. Local effects may be important	Flooding in urban and peri-urban environments (local and river flooding) Alien species invasions (water hyacinth) with effects on hydropower and ecosystems Lake Tanganyika fisheries at risk through temperature increases
Cluster 11 The coastal rivers west of the Congo River Basin	High rainfall, humid tropical climate, ITCZ, abundant water resources, no water stress	Cameroon similar to Congo. Gabon has highest HDI in SSA	Cameroon similar to Congo. Gabon has highest HDI in SSA with reasonably strong institutions and social investments	Limited agreement, although climate impacts are not anticipated to result in significant water resource impacts. Local effects may be important	Urban and peri-urban environments to flooding (local flooding and river flooding) Rivers to alien invasive species (water hyacinth) with effects on hydropower
Southern Region					
Cluster 12 The Zambezi River Basin	Semi-arid, Tropical wet-and-dry	Poor rural communities as well as fast growing urban centres. Hydropower dominates.	Weak legal and institutional frameworks, fragmented centralized management systems	Little agreement – either wetter, or drier. increased temperature	Rural communities vulnerable to reduced crops because of temperature rise which is certain. Hydropower developments could come under threat as planning will be encumbered.
Cluster 13 Transboundary river basins in the eastern part of	Arid to Semi-arid	Poor rural communities as well as fast growing urban centres. Irrigation is expected to increase.	Weak legal and institutional frameworks. Poor coordination between Zimbabwe and Mozambique on some issues	Will become moderately to significantly drier	Rural communities vulnerable to reduced crops because of temperature rise, Coastal communities vulnerable to flooding.

	Water resources status	Socio-economic status	Institutional capacity	Climate change impacts	Risk
Southern Africa, including the Ruvuma, Limpopo and Incomaputo					
Cluster 14 Orange, Okavango, Cunene, Cuvelai	Progressively becomes arid to the west. Most of the coastal zone is described as desert	South Africa dominates to the South. Increased economic growth expected in all major urban centres	Weak legal and institutional frameworks	Parts of the Okavango in Botswana may become wetter while Namibia will generally become drier. The highlands of the Kunene and Okavango, within Angola maybe become wetter. The eastern part of the Orange river basin will become wetter	Rural communities vulnerable to reduced crops because of temperature rise. Development plans will come under threat.

Critical/very poor status/severe impacts/high risk
Poor status/moderate impacts/moderate risk
Good status/minor impacts/low risk
Insufficient/uncertain information

13. GLOSSARY

GCM – General circulation model. There are a number of General Circulation Models (GCM) used by scientists to predict the effects of climate change. Each GCM attempts to simulate or model the changes in climate as a result of changes in various conditions, such as greenhouse gases. GCMs are very complex and consider the effects of a range of factors. These include the reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean and land temperatures, and areas of ice. Since the different models use different assumptions and relationships between the range of factors, they don't always deliver the same results. For this reason, it is important to look at the results of a number of models to see where they generate the same results for an area and where they disagree.

IPCC – Intergovernmental Panel on Climate Change. The IPCC was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 to assess scientific, technical and socio-economic information related to human-induced climate change, the potential impacts of climate change and the options for mitigation and adaptation. The IPCC has completed four assessment reports, developed guidelines for national greenhouse gas inventories, and prepared various special reports and technical papers.

ITCZ – Inter-tropical Convergence Zone. The ITCZ appears as a bank of clouds and thunderstorms around the earth, near the equator. It forms where the trade winds of the northern hemisphere and those of the southern hemisphere converge, and force moisture-laden air upwards, resulting in heavy rain, typically as thunderstorms. These thunderstorms are often short but intense. The ITCZ moves over time, following the sun's zenith point during the year. This variation in location of affects rainfall in both equatorial and countries further from the equator. Longer-term changes in the ITCZ can result in severe droughts or floods.

WAM – West African Monsoon. The WAM is the result of a seasonal shift in the Intertropical Convergence Zone, and the large seasonal temperature differences between the land and the ocean. As a result, summer sees winds from the ocean bringing heavy rains to west Africa. The WAM provides most of the rain in the Sahel and Sudan[2] regions of west Africa.

ENSO - ENSO is the abbreviation for the El Nino/Southern Oscillation. El Nino is a recurring ocean-driven phenomenon that produces extreme weather conditions in many parts of the world. This is the result of interactions between the oceans and the atmosphere. Thus, the temperature of the ocean affects the weather patterns and the amount of rainfall in different parts of the world.

Endorheic Basin – a basin that drains inland rather than into the sea.

Orographic – a climatic effect caused by topographical features, particularly the presence of mountains.

[2] The Sudan region is not to be confused with the country of Sudan. The Sudan region lies to the south of the Sahel, and receives slightly more rainfall.

14. REFERENCES

Africa Resources Working Group, 2009. A Commentary on the Environmental, Socioeconomic and Human Rights Impacts of the Proposed Gibe III Dam in the Lower Omo River Basin of Ethiopia, JANUARY, 2009, ARWG-GIBE.org

Agoumi A. Vulnérabilité des pays du Maghreb face aux changements climat : Besoin réel et urgent d'une stratégie d'adaptation et de moyens pour sa mise en œuvre. IISD, Climate Change Knowledge Network, 2003, 11p.

Agriconsulting S.P.A. and MDI Consulting Engineers, 2008. Downstream Environmental Impact Assessment for the GIBE III Hydroelectric Project. Government of Ethiopia (April 2008)

Amy C. Tidwell 2006 Assessing The Impacts Of Climate Change On River Basin Management: A New Method With Application to The Nile River. PhD Thesis, Georgia Institute of Technology. 284p.

Anyamba A. and Tucker, C. J. 2005. Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003, *Journal of Arid Environments* 63, 596–614

ARC-Institute for Soil, Climate and Water, Institute for Agricultural Engineering and IWMI. 2003. Limpopo Basin Profile

AWRMI (2001). Africa Water Resources Management Initiative – A Progress Report, 06/01. World Bank.

Aysegül K*ibaroglu* : politics of water resources in the Jordan, Nile and Tigris-Euphrates: Three river basins, three narratives http://www.sam.gov.tr/perceptions/volume12/Spring07_Aysegul_Kibaroglu.pdf

Bâ, M. (1992). L'Estuaire du Fleuve Sénégal: Impact des Barrages de Diama et Manantali sur la Qualité Chimique des Eaux. Gestion des Ressources Cotières et Littorales du Sénégal, Actes de l'Atelier de Gorée. 27-29 July 1992, IUCN. (In French) biosphere-atmosphere system of West Africa. *Global Change Biology* 8, 1169-1182

Bakker, M. G. N., 2009, Transboundary river floods: examining countries, international river basins and continents, Water Policy 11 (2009) 269–288

Barat L.M, Palmer N, Basu S, Worrall E, Hanson K, and Mills A, 2004, Do malaria control interventions reach the poor? A view through the health equity lens. American Journal of Tropical Medicine and Hygiene 71

Bartel, P. and Muller, J., 2007, Horn of Africa Natural Hazard Probability Assessment, Humanitarian Information Unit, U.S. Department of State, June 2007

Bashir, K.E. 2007. GASH RIVER FLASH FLOODS CHALLENGES TO KASSALA TOWN: MITIGATION AND RISK MANAGEMENT, *Associate Professor, UNESCO Chair in Water Resource, bashar@ucwr-sd.org*

Bates I, Fenton C, Gruber J, Lalloo D, Medina Lara A, Theobald S, Thomson R. and Tolhurst R, 2004, Vulnerability to malaria, tuberculosis and HIV/AIDS infection and disease. Part 2: determinants operating at environmental and institutional level. Lancet Infectious Diseases 4: 368-375.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

BGR Hanover/UNESCO, 2009, Groundwater Resources in Africa, UNESCO website

Bila, M. Lake Chad Basin GEF Project- Actualising a vision for the future, 1st Pan-Africa GEF I-LEARN Structured Learning Workshop on Transboundary Water Resources Management, Nairobi. 29 Oct-2 Nov, 2006 Bila, M, interview by K Pietersen. Regional Coordinator, LCBC GEF Project (10 August 2008).Burchi, S, and M Spreij. Institutions for international freshwater management. Paris: UNESCO-IHP, 2003. Earle, A, Malzbender, D,

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Bousso, T., Diadhiou, H.D., Diouf, P.S. and Le Reste, L. (1993). L'aquaculture en milieu continental au Sénégal. p 343-363 In: Diaw, A.T., Bâ, A., Bouland, P., Diouf, P.S., Lake, L-A., Mbouw, M.A., Ndiaye, P. and Thiam, M.D. (eds.) Gestion des ressources côtières et littorales du Sénégal. IUCN. (In French)

Braune,E., Moseki, C. and Duah, A. 2009. Draft Issue Paper: Groundwater and Society in Africa – learning to cope with the effects of climate variability and change.

Brooks, N. 2004. *Drought in the African Sahel: long-term perspectives and future prospects*. Tyndall Centre Working Paper No. 61.

Byers, B.A. 1997. Environmental Threats and Opportunities in Namibia: A Comprehensive Assessment. Research Discussion Paper 21, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia.

CEEPA, 2006 climate change and Africa Agriculture Policy Note No. 20

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kiolli, R. K., Kwon, W.-T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C. G., Räisänen, J., Rinke, A., Sarr, A. & Whetton, P., 2007. Regional climate projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*

CIA (2003). The World Factbook. U.S. Central Intelligence Agency.

Claussen M , Brovkin V, Ganopolski A, et al. 2003. Climate change in northern Africa: The past is not the future. *Climatic Change* 57 (1-2), 99-118.

COBISS: 1.01, Geografski zbornik, XXXX (2000)Interim evaluation 2008

Conway, D., Hanson, C. E., Doherty, R. & Persechino, A., 2007. GCM simulations of the Indian Ocean dipole influence on East African rainfall: present and future. *Geophys.Res. Lett.* **34**(3).

CSE (1988). Aménagement optimal des eaux de l'oued Ouergha: Réalisation du barrage Mjara. Conseil Supérieur de l'Eau, Rabat, Marocco. (In French)

DANIDA, 2008, IWRM and Transboundary water resource management: Kenya Briefing

De Moor, F.C., Barber-James, H.M., Harrison, A.D. and Lugo-Ortiz, C.R. 2000. The macroinvertebrates of the Cunene River from the Ruacana Falls to the river mouth and assessment of the conservation status of the river. African Journal of Aquatic Science 25 (1) : 105–122

Department of Water Affairs and Forestry, South Africa. Directorate of National Water Resources Planning. 2004. Internal Strategic Perspective: Limpopo Water Management Area.

Dessai, S. & Hulme, M. (2007) Assessing the robustness of adaptation decisions to climate change uncertainties: a case study on water resources management in the East of England. *Global Environ. Change* **17**(1), 59–72

Diagana, A. (1994). Etudes hydrogéologiques dans la vallée du Fleuve Sénégal de Bakel à Podor : Relations eaux de surface et eaux souterraines. Thèse de doctorat de troisième cycle, UCAD. (In French)

Diene, M. (1995). Etude hydrogéologique, hydro chimique et isotopique de la nappe superfi cielle du ferlo septentrional (nord du Sénégal). Thèse de doctorat de troisième cycle. (In French)

Diop, Isabelle Niang. Synthèse des communications nationales des pays du Sahel à la Convention changement climatique. UICN-BRAO. Ouagadougou. 2003.

Diop, S., Nakamura, T., Smith D. and Dkhaka, E. (2000). Implication of Dams on the Freshwater and Coastal Environment and its Resources in Senegal. World Commission on Dams env107.

Dunn, C. 2006. Environmental control of disease vectors in Tanzania, Ifakara Health and Development Research Centre

Elkrail, A. B., and Ibrahim, A.E., 2008. Regional Groundwater Flow Modelling of Gash River Basin, Sudan.Journal of Applied Sciences in Environmental Sanitation, 3 (3): 157-167.

FAO 2009. AQUASTAT country factsheets www.fao.org/nr/water/aquastat/main/index.stm

FAO Corporate Document Depository: Irrigation potential in Africa: A basin approach...

Fritz Käser, Markdorf, FRG and Inyambo Nyumbu, Lusaka 2009 :, Nile Initiative Water - Planning and Management of Water Resources in the Nile Basin, Africa (reg.) GTZ, Interim evaluation 2008, Brief Report, 11p.

Gichere, S. 2001. The Contribution of Environmental Goods and Services to Kenya's Economy, with Reference to Poverty Eradication. A Consultancy Report Commissioned by Biodiversity and Economics Component of the IUCN's Eastern Africa Regional Programme, Nairobi.

GIWA. Regional assessment 41, Guinnea Current, Global International Waters Assessment. UNEP. 2005

Gleick, P.H. (1998). The World's Water 1998-1999. Island Press, Washington DC, US.

Gleick, P.H. 2001. "Making Every Drop Count." Scientific American, February, pp. 28-33.

Gleick, P.H., A. Singh, and Hua Shi. Emerging Threats to World Water Resources, A Report to the Pacific Institute for Studies in Development, Environment and Security, Oakand, California. 2001.

Goulden, M., Conway, D. and Persechino, A., 2009. Adaptation to climate change in international river basins in Africa: a review, *Hydrological Sciences–Journal–des Sciences Hydrologiques,* 54(5) October 2009

Goulden, M., Conway,D. and Persechino,A. 2008. Adaptation to climate change in international river basins in Africa: a review. Tyndall Centre for Climate Change Research. Working Paper 127.

Hakima LAKHDARI, Atmane AYAD : Les conséquences du changement climatique sur le Développement de l'agriculture en Algérie : Quelles stratégies d'adaptation face à la rareté de l'eau ? *Cinquième colloque international : Énergie, Changements Climatiques et Développement Durable, Hammamet (Tunisie), 15-17 Juin 2009.*

HEYNS, P. (2003). Water Resources Management in Southern Africa. In M. Nakayama (Ed.). International Waters in Southern Africa

Hirji, R., 2004. Kenya Water Resources Sector Memorandum, World Bank, Washington

http://earthtrends.wri.org/pdf_library/country_profiles/wat_cou_384.pdf

http://hdrstats.undp.org/en/countries/data_sheets/cty_ds_SDN.html

http://www.fao.org/docrep/w4347e/w4347e00.HTM

http://www.ramsar.org/cda/ramsar/display/main/main.jsp?zn=ramsar&cp=1-26-76%5E20247_4000_0__

http://www1.american.edu/ted/LEONE.HTM

Hulme, M. 1994. Regional climate change scenarios based on IPCC emissions projections with some illustrations for Africa. Area. vol. 26, No.1, 33-44

Hulme, M., Doherty, R., Ngara, T., New, M. and Lister, D. 2001. African climate change: 1900-2100. *Climate Research* 17, 145–168.

IGRAC, 2009, Transboundary Aquifers of the World, Update, Special Edition for the 5th World Water Forum, Istanbul, March 2009, International Groundwater Resources Assessment Centre, UNESCO/WMO

Integrated Water Resources Management in a Water-Scarce Region: Tunisia's WaterSector Investment Project I Feature Stories, Issue 27 | October 2008

Integrating the Climate Change Dimension into Water Resources Management in the Mediterranean presented by Morocco, Spain and Greece with the contribution of the MED EUWI Secretariat Euro-Mediterranean Ministerial Conference on Water 29 October 2008 – Dead Sea, Jordan, 17p.

Intergovernmental Panel on Climate Change. 2001. *IPCC Third Assessment Report, Climate Change 2001: The Scientific Basis*. Cambridge University Press.

International Rivers, 2009. Fact Sheet: Gibe III Dam, Ethiopia, May 2009

IPCC (2001). Intergovernmental Panel on Climate Change Climate change: Impacts, Adaptation and Vulnerability. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. (eds.) Cambridge University Press.

IPCC. 2007. Climate Change 2007: Synthesis report. An Assessment of the Intergovernmental Panel on Climate Change. Adopted section by section at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007)

JICA (1999). Country Profile on Environment: Senegal. Japan International Cooperation Agency.

Jozef Roskar, Assessing the water resources potential of the Nile river based on data, available at the Nile forecasting center in Cairo, UDC: 556. 53(282.263.1)

Kluge, T. Undated. Integrated Water Resource Management in Africa: German Research Efforts. Slide Presentation. CUVE Waters.
http://www.glowa.org/eng/conference_eng/pdf_eng/day1/Kluge_IWRM_Afrika.pdf

Le Barbe L. and Lebel T. Rainfall Climatology of the HAPEX-SAHEL region during the years 1950- 1990. In Goutorbe J.P., Dolman A.J.; Gash J.H.C.; Kerr Y.H.; Lebel T.; Prince S.D. and Strickler J.N.M.; (eds): HAPEX SAHEL; Elsevier, 1079 pp. 1997.

Linthicum, K.J., Anyamba, A, Tucker C.J., Kelley, P.W., Myers, M., Peters, C., 2000. Climate and Satellite Indicators to forecasst rift valley fever epidemics in Kenya.

Maarten de Witt and Jacek Stankiewicz. Changes in Surface Water Supply Across Africa with Predicted Climate Change Available: DOI: 10.1126/science.1119929

Manfred Heinl & Paul J. Brinkmann : A groundwater model of the Nubian aquifer system *Hydroloffcal Sciences - Journal - des Sciences Hydrologtques,* 34,4, 8/1989

Marianne Alker 2008 :The Nubian Sandstone Aquifer System A case study for the research project "Transboundary groundwater management in africa", German Development Institute, 273p.

Maynard, K., Royer, J. F. and Chauvin, F. 2002. Impact of greenhouse warming on the West African summer monsoon, *Climate Dynamics* 19, 499-514.

Mendelsohn J. an Obeid S. 2004. Okavango River: the flow of a lifeline. Struik Publishers, Cape Town. 176 pp.

Messouli M., El Alami El Filali A., Ghallabi B., Rochdane S., A. Ben Salem & Hammadi F Z. Impacts of Climate Change and Population Grouth in a Multiethnic Oasis Environment: the Case of the Ziz Valley, Southeast Morocco

Ministère de l'Agriculture et du Développement Rural 2006: Rapport sur la situation du secteur agricole Alger, 77p.

Ministry of Mines and Energy, 1997. GILGEL GIBE HYDROELECTRIC PROJECT, ENVIRONMENTAL ASSESSMENT MAIN REPORT, Ethiopian Electric Light and Power Authority.

Mohamed, Y.A.; Loulseged, M. 2008. *The Nile Basin Water Resources: Overview of key research questions pertinent to the Nile Basin Initiative*. Colombo, Sri Lanka: International Water Management Institute. 34p. (IWMI Working Paper 127)

Nathalie Rousset, René Arrus : 2007. L'agriculture du Maghreb au défi du changement climatique : quelles stratégies d'adaptation face à la raréfaction des ressources hydriques ? halshs-00134115, version 1 - 28 Feb 2007

National Investment Brief, 2008. ERITREA High-Level Conference on: Water for Agriculture and Energy in Africa: the Challenges of Climate Change. Sirte, Libyan Arab Jamahiriya, 15-17 December 2008.

NBA:*CIDA*-Niger Basin Authority. Regional Synthesis Report on the National Multi-Sectoral Studies for the Sustainable Development of the River Niger Basin. Consultants: Traoré Mamadou, Abdou Hassane. January 2005.

NeWater 2005, Transboundary river basin Management: the Nile basin Case study Background report to Deliverable 1.3.1. Report of the NeWater project - New Approaches to Adaptive Water Management under Uncertainty www.newater.info

Nguyen Quang Trac, 1984 Nubian sandstone aquifer modelling and groundwater resources planning for new valley,UNESCO Technical Report PP/1981-1983/2/7.3/03 OF EGYP ; Serial No. FMR/SC/HYD/84/113, 19p.

Niang-Diop , I. (2002) V&A Studies on coastal zones: the case of Senegal, Proceeding, AIACC V&A Training Workshop, Trieste.

Niang-Diop, I. (1993). Coastal erosion in Senegal. The case of Rufi sque. p 75-89 In: Awosika, L.E., Ibe, A.C. and Shroader, P. (eds.) Coastlines of Western Africa. ASCE, New York, US.

Niasse, M, Afouda, A, Amani Abou (Editors). Water, Climate Change and Desertification In West Africa: *Regional Strategy for Preparedness and Adaptation, IUCN-BRAO, GWP-WA, CILSS.* Ouagadougou, October 3rd, 2003

OKACOM,. 1994. Agreement between the governments of the Republic of Angola, the Republic of Botswana and the Republic of Namibia on the establishment of a permanent Okavango River Basin Water Commission (OKACOM), 7 pp.

Olsson, L., Eklundh, L. and Ardo, J. 2005. A recent greening of the Sahel —trends, patterns and potential causes. *Journal of Arid Environments* 63, 556–566.

Omar Salem 2002, Management of Shared Groundwater Basins in Libya African Water Journal

Omar Salem, Philippe Pallas : The Nubian Sandstone Aquifer System (NSAS) *Proceedings of the International Workshop* Managing shared aquifer resources in Africa *: Tripoli, Libya, 2– 4 June 2002*

OMVS/SOGED. (2003). Etude pour la restauration du réseau hydraulique du basin du fl euve Sénégal, AGER. Organisation pour la mise en valeur du fl euve Sénégal/ Société de Gestion et d'Exploitation de Diama. (In French).

ORASECOM, 2008. Orange-Senqu River Basin Preliminary Transboundary Diagnostic Analysis. UNDP/GEF Report.

Oyebande, L. Stream flow regime change and ecological response in the Lake Chad basin in Nigeria. Hydro-ecology: Linking Hydrology and Aquatic Ecology. IAHS Publ. No. 266:101-111. 2001.Brooks, N., Di Lernia, S., Drake, N. Chiapello, I., Legrand, M., Moulin, C. and Prospero, J. 2005. The environment-society nexus in the Sahara from prehistoric times to the present day. *The Journal of North African Studies* 304, 253-292.

Oyebande, Lekan ; Amani, Abou, Mahé, Gil & Diop, Isabelle Niang. *Climate Change, Water and Wetlands in West Africa: Building linkages for their Integrated Management*. Special Commissioned Paper. IUCN-BRAO. Ouagadougou. April 2002.

Pahl-Wostl, C., Downing, T., Kabat, P., Magnuszewski, P., Meigh, J. R., Schlueter, M., Sendzimir, J. & Werners, S., 2005. Transition to Adaptive Water Management: The NeWater Project: NeWater Working Paper 1. Institute of Environmental Systems Research, University of Osnabrück, Germany.

Pietersen, Kevin and Hans Beekman (With contributions from: Jude Cobbing, Lekan Oyebande and Sam Sunguro. "Strenghtening Cooperation among River Basin Organizations" A Comparative Study of the Linkages between River/Lake Basin Organizations and the Respective Cooperating National Governments in Seven Major African Basins. PREPARED FOR: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. 2008

R Schulze, J Meigh and M Horan. 1997. Present and potential future vulnerability of eastern and southern Africa's hydrology and water resources. South African Journal of Science

République Tunisienne, 28 Juin 2007 :Evaluation du Cout de la Dégradation de L'eau. Bureau Régional Moyen-Orient & Afrique du Nord Département Développement Durable. Document de la Banque Mondiale, 68p

Revenga, C. and Cassar, A. (2002). Freshwater Trends and Projections: Focus on Africa. World Wide Fund for Nature (WWF) Global Network /World Wildlife Fund.

Roland E Schulze 2000. Modelling Hydrological Responses to Land Use and Climate Change: A Southern African Perspective Source: Ambio, Vol. 29, No. 1, pp. 12-22 Published by: Allen Press on behalf of Royal Swedish Academy of Sciences Stable Available: http://www.jstor.org/stable/4314988

S. DIALLO Ousmane : Joint Management of the North Western Sahara Aquifer System (NWSAS) MENA SEMINAR 2008, Worl Water Week, Stockholm, 2008

S. DIALLO Ousmane: Transboundary groundwater management and climate nexus in the circum-Sahara International Conference on Groundwater & Climate In Africa Kampala, Uganda24 –28 June

SADC. 2005. Regional Water Policy.

SADC. 2005. Preparation of a Regional Strategic Water Infrastructure Development Programme.

SADC-Water Division. 2008. Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin

Sanchez, P. A., and Swaminathan, M.S., 2005, Hunger in Africa: the link between unhealthy people and unhealthy soils, Lancet 2005; 365: 442–44.

Schulze, R. E. 2009. Personal Communication

SEDEC ASSOCIATES.Federal Ministry of Environment, Housing and Urban Development. 2008 State of the Nigerian Environment Report. 2008.

Southern African Regional Poverty Network. Undated. Economic indicators for the SADC Region. Available: www.sarpn.org.za/

Stakhiv, E. Z., 1998. Policy implications of climate change impacts on water resources management. *Water Policy* **1**(2), 159–175.

Sullivan, C., Meigh., J., and Lawrence, P., 2005. Application of Water Poverty Index at Different Scales: A cautionary tale, Agricultural Ecosystems and Environment. CEH, UK.

Tazebe Beyene, Dennis P. Lettenmaier and Pavel Kabat :Hydrologic Impacts of Climate Change on the Nile River Basin: Implications of the 2007 IPCC Climate Scenarios, http://www.hydro.washington.edu/Lettenmaier/Publications/Tazebe_Nile_Aug07.pdf

Thomas Downing, Lasse Ringius, Mike Hulme and Dominic Waughray. 1997. Adapting to Climate Change in Africa.

Timmerman, J.G. 2005. Transboundary river basin management regimes: the Nile basin case study. Background report to Deliverable 1.3.1. of the NeWater project, Lelystad.

Turton, A and Manzungu. A Preliminary Basin Profile of the Orange/Senqu River. 2005

UNDP 2009. Human Development Report, Country Reports

UNEP (2002). Africa Environment Outlook, Past, Present and Future Perspectives. United Nations Environment Programme. Earthprint Limited, UK.

UNEP and WRC South Africa. 2008. Our Freshwater under Threat - Vulnerability Assessment of Freshwater Resources to Environmental Change –Africa Report.

UNEP and WRC-South Africa. Assessing the Vulnerability of Africa's Water Resources to Environmental Change. 2007.

UNEP, 2004. Abe, J., Wellens-Mensah, J., Diallo, O.S. and C. Mbuyil Wa Mpoyi. Guinea Current, GIWA Regional assessment 42.

UNEP, 2004. Odada, E.O., Olago, D., Kulindwa, K.A.A., Bugenyi, F., West, K., Ntiba, M., Wandiga, S. and Karimuryango, J. East African Rift Valley Lakes, GIWA Regional assessment 47. University of Kalmar, Kalmar, Sweden.

UNEP, 2005. Tayaa, M., Saine, A., Ndiaye, G. and M. Deme. Canary Current, GIWA Regional assessment 41. University of Kalmar,

UNEP/DEWA WATER ASSESSMENT STRATEGY : Contribution to the overall implementation of the UNEP Water Policy and Strategy *September 2005*

UNESCO 2009: Water Adaptation in National Adaptation Programmes for Action Freshwater in Climate Adaptation Planning and Climate Adaptation in Freshwater Planning. Gunilla Björklund, Håkan Tropp, Joakim Harlin Alastair Morrison and Andrew Hudson. UNESCO 2009

UNESCO, 2004. Gash HELP Basin website, http://portal.unesco.org/science/en/ev.php-URL_ID=3740&URL_DO=DO_TOPIC&URL_SECTION=201.html, accessed 15/10/09

UNESCO-ISARM. 2009. Atlas of Transboundary Aquifers. Global Maps, Regional Cooperation and Local Inventories. S. Puri and A. Aureli (eds). International Hydrological Programme, Division of Water Sciences.

UNITED NATIONS ECONOMIC COMMISSION FOR AFRICA ECA Office for North Africa Water, Environment And Sustainable Development In North Africa Twenty-first meeting of the intergovernmental committee of experts (ICE) Rabat (Morocco) 4-6 April 2006

URT, 2007. Poverty and Human Development Report, MKUKUTA Monitoring System, Ministry of Planning, Economy and Empowerment, United Republic of Tanzania.

USAID: http://www.usaid.gov/locations/sub-saharan_africa/initiatives/ieha.html

Vorosmarty, C.J., Green, P., Salisbury, J., and Lammers, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science 289, 284–288.

West African summer monsoon, *Climate Dynamics* 19, 499-514.

Wolski, P and Beuster, H. 2009. Assessment of hydrological effects of climate change and water resource developments in the Okavango Basin. Unpublished paper.

World Ban.k (2001). African Development Indicators 2001. The World Bank Washington D.C.

World Bank : June 28, 2002 Algeria National Environmental Action Plan for Sustainable Development Staff Sector Assessment Note Report No. 22890-AL

World Bank, 2007 :Making the Most of Scarcity Accountability for Better Water Management Results in the Middle East and North Africa MENA DEVELOPMENT REPORT, Washington, D.C.

World Bank. GEF Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem: Project Appraisal Document. 2002a.

Xinshen Diao,Rachid Doukkali, Bingxin Yu. Policy Options and Their Potential Effects on Moroccan Small Farmers and the Poor Facing Increased World Food Prices A General Equilibrium Model Analysis Development Strategy IFPRI Discussion Paper 00813, October 2008, 36p.

Y. A. Mohamed, B. J. J. M. van den Hurk, H. H. G. Savenije, and W. G. M. Bastiaanssen : Hydroclimatology of the Nile: results from a regional climate model Hydrology and Earth System Sciences, 9, 263–278, 2005 www.copernicus.org/EGU/hess/hess/9/263/SRef-ID: 1607-7938/hess/2005-9-263, European Geosciences Union