

# *Water Resource Availability and Sectoral Analysis for Sustainable Development in Africa<sup>1</sup>*

*by S. Diop<sup>i</sup>*

## *Abstract<sup>2</sup>*

Overall assessments indicate that Africa is one of the driest continents of the world. With 15 per cent of the global population, Africa has only 9 per cent of global renewable water resources. Water is unevenly distributed through the continent; e.g. Central Africa alone accounts for 48 per cent of the continent's total internal waters while Northern Africa accounts for only 1.5 per cent. In addition Africa's climate is highly variable over the seasons. Africa's water variability and availability is constrained by its groundwater/aquifer resources which represent 15 per cent of its total renewable water resources, but supply about 75 per cent of its population with most drinking water. Indeed, in all regions except in Central Africa, water availability per person is less than both the African and the global average, affecting human well-being in some places in the continent and posing a threat to some natural assets and to food security. At the same time, substantial loss of biodiversity is affecting the provision of ecosystem services. Africa's annual per capita water availability is less than the world's other regions except Asia, the most populous continent.

Differences in water availability and access in African countries do not depend only on natural conditions. They are also influenced by the number of people using the water and compounded by increased water demand because of growing populations, especially in peri-urban areas (3.4 per cent growth between 2005 and 2010).

Africa's borders pose a challenge to equitable sharing and development of water resources. Africa's 63 international river basins cover about 64 per cent of the continent's land area and contain 93 per cent of its total surface water resources. Transboundary water resources in Africa include both transboundary surface waters and shared groundwater basins. Both are affected by environmental change and have declined, being subject to various pressures and uses. Throughout the presentation, various issues and water sector uses (e.g. irrigation and other agriculture, transport, fisheries, dams and diversions, domestic and industrial uses) will be examined, including the drivers of change and the environmental and social impacts of water development as well as aspects of transboundary water management.

Taking into consideration current water availability as well as the various uses in different sectors, water challenges and opportunities will be highlighted in this presentation, including:

- the challenge of reaching the MDG target of halving the proportion of the population without access to drinking water by 2015;
- the challenge of and opportunities for improving access to clean water;
- the challenge of potential conflicts over transboundary water resources as well as the opportunities for cooperation;

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- the challenge of water scarcity and the continent's ability to ensure food security;
- the water/energy challenges and the potential for hydropower development (greater than the entire continent's energy needs);
- the water security challenges – bearing in mind the under-utilized aquifer resources that could contain good quality water and could provide water security during drought periods;
- the challenge of climate change and variability that affects the availability of water resources in Africa;
- the challenge of water pollution and land degradation which reduces the availability of water resources;
- the challenge of institutional water reforms, improving public-private partnerships, and developing the knowledge base and human capacity in relation to integrated water resource management.

Considering the challenge of properly addressing integrated water resource management as a whole, the prospect of improving human well-being in Africa is critically dependent on the capacity to respond to water-related environmental changes which increase risks and reduce opportunities for the advancement of human well-being, in particular efforts to eradicate poverty among poor and vulnerable populations. Because of the complexity of water challenges, including in the various water sectors, responses need to focus on root causes and the underlying drivers of water-related environmental changes rather than only on the pressures or symptoms. Evidence-based policy making requires more reliable data and critically reviewed information, hence the importance of credible scientific assessments for better understanding of our freshwater resources for sustainable management and development.

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<sup>i</sup> *Professor of University, Member, National Academy of Sciences of Senegal; Member of African Academy of Sciences and The Academy of Sciences for the Developing World. - Head, Ecosystems Section Scientific Assessment Branch - Division of Early Warning and Assessment (DEWA) - United Nations Environment Programme - 1, UN Avenue – Gigiri - P.O.Box 30552 - Nairobi, 00100 Kenya - E-Mail: [salif.diop@unep.org](mailto:salif.diop@unep.org) - Personal Website: <http://www.esalifdiop.org>*

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## 1. Introduction:

Africa's water is held in large rivers, widespread aquifers, large dams, lakes and wetlands as well as atmospheric water vapour and soil moisture. The rivers provide transportation arteries, habitat for fish and other freshwater organisms and water for drinking and irrigation. Most economies in Africa are closely tied to natural resources. Water is directly or indirectly used in almost every economic sector including agriculture, manufacturing, trade, mining, tourism, transport and telecommunications.

Agriculture - largely rain-fed - is the single most important driver of economic growth for most African countries. The agricultural sector accounts for about 20 per cent of Africa's GDP, 60 per cent of its labour force and 20 per cent of total merchandise exports, and is the main source of income for 90 per cent of the rural population (UNECA 2007). Compared to other sectors, GDP growth originating in agriculture is about four times more effective in raising the incomes of poor people, with even higher potential multipliers from investing in agricultural water (World Bank 2009). Water is both an ecosystem 'good', providing drinking water, irrigation and hydropower, and an ecosystem 'service', supplying people, whether they are aware of it or not, with functions such as cycling nutrients and supporting habitats for fish and other aquatic organisms, as well as 'cultural services' such as scenic vistas and recreational opportunities.

The purpose of this synthesis is to analyse the increasing water challenges the African continent is facing with its growing populations and to identify opportunities for the continent to overcome some of the challenges. The opportunities include the possibility of tapping into the important water resources of the continent for the purpose of irrigation, industry, hydropower, tourism, sectors for which less than ten per cent of the water resources in Africa are currently utilized.

## 2. Analysis of the main challenges, constraints and opportunities:

**2.1. Challenge 1:** The Millennium Development Goal's safe water target is to halve the proportion of the population without sustainable access to safe drinking water by 2015

### 2.1.1. **The Situation:**

Sub-Saharan Africa accounts for more than one-third of the current proportion, with about 330 million people without access to safe drinking water. Africa's progress towards the MDG drinking water target is slow and uneven, and the continent as a whole will not reach the goal. Although the proportion of people in sub-Saharan Africa using improved sources of drinking water increased by 14 per cent from 1990 to 2008, only 60 per cent of its population had access to such resources by the end of that period (WHO/UNICEF 2010). Based on current trends, sub-Saharan Africa will not reach the MDG water target until 2040 (UNDP 2006a). A recent survey revealed a bleak future in which only two countries (Kenya and South Africa) are estimated to have more than 75 per cent of what is needed to achieve the MDG sanitation target, and five countries are estimated to have more than 75 per cent of what is needed to achieve the MDG target for drinking water (WHO and UN-Water 2010).

• *There are large disparities in the provision of safe water:* sub-Saharan Africa has by far the lowest coverage rates of piped water among world's regions (50 per cent) (WHO/UNICEF 2010). The increase in the number of people with access to other improved sources of drinking water was 3.5 times higher than that in people with piped water on premises. Only five per cent of the rural population receives piped water in their homes compared to 35 per cent of urban dwellers (WHO/ UNICEF 2010).

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*Limited access to water means that Africa has a high incidence of water-related disease:* The incidence of water-related and waterborne diseases such as cholera, malaria, Guinea worm and river blindness in Africa is high, mainly due to limited access to water and sanitation.

- *The lack of safe water is weakening the economy:* In economic terms, the lack of proper water and sanitation services in developing countries translates into a loss of revenues and an inability to generate and sustain livelihoods, due in large part to the debilitating effects of water-related disease. In addition, the time and energy lost in hauling water from long distances, predominantly undertaken by women and girls, deprives them of time to engage in livelihood-generating activities and attending school.

### **2.1.2. The Constraints:**

There are many reasons for the lack of progress in providing the people of Africa with safe drinking water, including:

- *Exploding peri-urban areas and more affluent consumers:* In some regions, growing populations have caused the ranks of the destitute to swell. In Cairo and other large cities on the continent, sprawling city limits and rapidly growing populations (from both natural growth and migration from rural areas) have created extensive squatter settlements or slums, challenging the abilities of water management institutions to provide adequate water and sanitation infrastructure. On the other hand, as some city dwellers become more affluent and industrial development expands with economic growth, the demand for better and more water services also grows.

- *Lack of access, regulation and public utilities:* Throughout Africa, there are areas where water and sanitation services are more easily accessible than others.

### **2.1.3. The Opportunities:**

In spite of the situation and the formidable challenges, there are opportunities to improve the availability of safe water in Africa and lessons can be learned from some African countries that have seen the most progress. The strongest performers in terms of piped water-service expansion are Benin, Burkina Faso, Chad, Ethiopia, Mali and Senegal, all showing growth rates of four to eight per cent per year (Banerjee and others 2009). While rural populations continue to lag behind urban populations globally, countries as diverse as Morocco and Uganda have sustained rapid increases in rural coverage (UNDP 2006a).

- *Improve financing:* According to the 2006 UNDP Human Development Report, governments need to spend about one per cent of GDP on water and sanitation. Additionally, increased international aid would play a crucial role in catalysing access to improved water sources. More funding from tariffs, taxes and transfers, in the right mix, can help meet national goals for sustainable water access (Hashimoto Action Plan 2010).

- *Encourage concessions in privatization schemes:* Private investment by domestic and foreign companies that assume responsibility for financing and operating water systems can improve efficiency, reduce water losses, increase supply, extend meters and revenue collection and enlarge coverage. In Morocco, which created four concessions between 1997 and 2002, coverage increased, as did consumer satisfaction scores (UNDP 2006a).

- *Subsidize connections for the poor:* Subsidizing connections for poor households and implementing innovative payment strategies may remove an important barrier to expanding the water-supply network.

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In Côte d'Ivoire, for example, a Water Development Fund surtax is included in bills, with about 40 per cent of the proceeds used for connection subsidies.

*Target informal settlements:* Some utilities have shown an unwillingness to extend services to households lacking legal title, fearing that it could jeopardize their revenue collection. Using creativity to deal with this dilemma may solve water access problems for people in these settlements.

- *Institute or improve regulation:* Regulatory authorities are important to ensure that providers are managed in a way that secures both equity and efficiency, independent of politics. Where administrative capacity and regulatory institutions are lacking, citizens can take a pro-active role, pressing for more information and publicizing underperformance by water utilities (UNDP 2006a).

- *Target rural communities:* Opportunities in rural communities include adoption of free-standing small-scale systems capable of treating water; recovering wastewater for re-use and capturing resulting gases as a source of energy for power, lighting and cooking - support to community-level projects on water resource management, water supply and sanitation in over 30 countries has demonstrated this.

- *Encourage entrepreneurship for simple water purification techniques:* Solutions using local ingenuity and simple tools and mechanisms have been shown to improve access to safe drinking water.

**2.2. Challenge 2:** The Millennium Development Goal's sanitation target is to halve the proportion of the population without sustainable access to basic sanitation by 2015. Increasing people's access to water will help Africa reach this target, while ensuring that water sources are not contaminated by sanitation facilities will help it to reach the MDG safe drinking water target.

**2.2.1. The Situation:**

- There are about 2.6 billion people in the world who do not have access to improved sanitation facilities, of which about 585 million are in Africa. Less than half of the people living in 35 African countries do not have such access. Use of improved sanitation facilities in sub-Saharan Africa is very low, at an overall 31 per cent, with great disparities between urban and rural areas. The MDG target requires that 63 per cent of the region's population has access to improved sanitation by 2015. That amounts to 370 million more people than the estimated 242 million who were using such facilities in 2006 (WHO/UNICEF 2010). Most African countries will not meet the target.

- *Access to sanitation in Africa is increasing, but there are large disparities in its provision:* The coverage rates for sanitation are far lower than those for water, even in higher-income groups. Notable increase in the use of improved sanitation facilities has been made in North Africa, but throughout the continent, regional disparities are still very apparent. Sub-Saharan Africa is the only region where more than half the population still does not have any access to better sanitation, with a striking contrast between urban areas, which are better served, and rural ones (WHO/UNICEF 2010).

- *Although sanitation coverage is rising, population growth is outpacing provision efforts:* Although Africa had one of the world's lowest sanitation coverage rates in 1990, the number of people using improved sanitation facilities in sub-Saharan Africa has improved over the years. However, efforts to reach the MDG sanitation target have been unable to catch up with the population growth.

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- *Lack of sanitation is a cause of waterborne disease:* Cholera epidemics are a major risk in areas with high concentrations of people and poor sanitation. Heavy rains can flood latrines, contaminating water and exposing populations to cholera bacteria. Groundwater can also become contaminated by improper sanitation.

- *Economies and human livelihoods suffer from the lack of sanitation:* Lack of sanitation hurts local economies when resulting poor health leads to lost working days, school absenteeism and increased time to take care of the sick.

### **2.2.2. The Constraints:**

The obstacles to providing proper sanitation facilities are the same as those faced in the provision of safe drinking water: exploding peri-urban and slum areas, economic growth and higher demand, geographical isolation, dearth of public utilities and regulation, and the high costs of water provision.

- *Lack of financial and technical resources:* Sanitation investments have lagged behind water supply by almost a decade. Poor economic performance and associated financial and technological limitations continue to be at the root of the slow progress in supplying adequate sanitation services, which suffers from chronic under-funding.

### **2.2.3. The Opportunities:**

The improvement of sanitation services is inextricably linked to the improvement of water provision. Thus, the opportunities outlined in the previous section apply here and there are lessons to be learned from countries that have made the most strides in increasing sanitation coverage.

- *Recognize the potential to generate revenues from sanitation technologies:* The business opportunities afforded by investing in sanitation are now being recognized and Africa could benefit from market-based approaches.

- *Encourage and support simple solutions from entrepreneurs:* Entrepreneurs are increasingly bringing out low technology and affordable toilets. In Tanzania, for example, a concrete slab to install above pit latrines is now available for about US\$5.

- *Introduce urban water tariffs:* A study in Egypt showed that if urban water tariffs were raised to cover operational and maintenance costs, enough financial resources could be freed up to finance urgently required investment in sanitation infrastructure (UNDP 2006).

- *Increase sanitation's share in total aid:* Aid for sanitation and drinking water is increasing in absolute terms, but its share of total aid decreased from eight per cent in 1997 to five per cent in 2008 (WHO and UN-Water 2010). If water and sanitation targets were achieved, sub-Saharan Africa would save about US\$2 per capita - equivalent to about 12 per cent of public health spending. Reduced spending would release resources for other priorities, including addressing HIV/AIDS (UNDP 2006).

- *Adopt system financing:* This opportunity is especially relevant if national plans include clear funding estimates for attaining their targets.

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• *Build partnerships between the government and civil society for educational campaigns:* There is an opportunity to increase capacity building through stronger partnerships between the government and civil institutions.

**2.3. Challenge 3:** Given the many watersheds shared by numerous African nations and the potential for discord over water management in them, there is a need and an opportunity to avoid conflict by cooperating in transboundary water basins.

### **2.3.1. The Situation:**

• *Africa has a large number of shared watersheds:* There are 263 international river basins covering almost half of the total land surface of the globe and affecting 40 per cent of the world's population. Of these, Africa has 63 shared basins covering about 63 per cent of the continental area. Africa has more rivers shared by three or more countries than any other continent. Every country in Africa has at least one international river, with the Congo basin shared by as many as 11 countries.

• *There is a potential for conflict over water resources:* There are a number of ways in which disagreements over water use can arise among parties that share the resource: where one country transfers or threatens to transfer water outside the basin (for example, there is a planned project to transfer water from the Ubangi River to Lake Chad); when activities in upstream sections of a basin threaten downstream users and vice-versa (in the Okavango Transboundary watershed, for example, there is the potential for disputes between users in Angola and Namibia in the upper part of the river and those in Botswana downstream); where development outside a river basin threatens the river's water availability or quality, or vice-versa (for example, urban and industrial developments outside the Congo basin watershed make demands on the basin's waters); where there is competition for the same water among different economic sectors both within and between countries, including irrigation, hydroelectricity, industry, navigation, tourism and mining; and finally, when richer countries or large corporate development projects threaten water use by poorer users in another part of the basin (Roy and others 2010).

*There are at least 94 international water agreements in Africa:* Worldwide, about 3 600 international water treaties were signed between 805 AD and 1984. Of the 145 international agreements signed between two or more states sharing water-basins in the last century, about 94 occurred in Africa, dating back from late 1800s (Wolf 1998). Overall analysis of the continent river basins shows the number of countries sharing river basins in Africa's top shared basins and the number of transboundary treaties in those watersheds. It also illustrates the number of treaties in each of Africa's major basins.

### **2.3.2. The Constraints:**

• *Population growth is reducing shared water supplies:* Continuing population growth and existing hydro-political complexities in Africa's international river basins will inevitably place high stress on shared water resources and on the agreements that govern them. Africa's ever-growing population will certainly increase the demand for water. As demand increases and water supply decreases, the possibility of conflicts between transboundary nations could rise.

• *Climate change threatens to stress shared waters:* Projected climate changes may have negative impacts on supply and demand, and may further exacerbate situations in which water is shared among countries.

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- *Water is declining in shared aquifers:* Africa's aquifers contain large amounts of fossil water, which is thousands of years old. Their recharge rate is now much less than the withdrawal rate (UNEP 2006). A drop in groundwater levels or a decline in its quality may threaten the political stability of the region, especially where numerous countries share the resource (Turton 2008b).

- *There are seasonal differences in water supplies:*

Conflicts can also occur between upstream and downstream users due to large seasonal variations in water flows and periodic droughts and floods that are characteristic of Africa (Turton and others 2006).

- *Inadequate joint management laws and conflicting national interests stress joint management capacities:* Given that Africa's national boundaries are not aligned with water bodies, water resource management needs to include regional considerations rather than just national objectives (Ashton 2007). Vague or inadequate international laws regarding joint management of shared waters, however, make it hard for riparian states to manage both a single basin with other states and multiple basins in the same state. The water needs and economic situation in each country also varies (Turton 2008b). Conflicting interests and inequity in capacities between riparian states further constrain negotiations on international watershed management (Van der Zaag 2007). The Southern African Development Community (SADC) and the Senegal River Development Organization (OMVS) are the only two organizations that operate basin-wide shared water management (Kliot and others 2001).

### **2.3.3. The Opportunities:**

International water cooperation presents an opportunity to deal with these challenges and constraints through negotiated basin sharing for both withdrawal and in-stream water uses. The sustainability of water availability within a river basin that crosses two or more countries may be assured and even increased via transboundary agreements. Such agreements help ensure equity in the provision of water for all and help maintain peace and security.

There are several examples of transboundary water agreements and other sharing mechanisms that have been successful in helping riparian African nations to negotiate equitable water sharing and which illustrate the potential for such agreements to be a catalyst for wider political cooperation.

- *Learn from successful transboundary cooperation efforts and agreements among African states:* Successful transboundary water distribution is inherently dependent on political cooperation between the riparian states involved. In the absence of strong rules and laws, treaties are the best form of formal river basin management.

**2.4. Challenge 4:** With a growing population, Africa needs more food and must secure the water needed to ensure its supply at the same time as water resources are becoming scarcer.

#### **2.4.1. The Situation:**

- *Agricultural growth is the mainstay of most African economies:* Farming is the source of livelihood for about 70 per cent of Africa's population that are rural-based. In sub-Saharan Africa, mostly small-scale farming represents about 30 per cent of GDP and at least 40 per cent of export value. In a number of Africa's smaller nations, agriculture plays a much greater role, accounting for 80 per cent or more of

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export earnings. Studies have shown that other economic sectors on the continent tend to perform well when there is positive growth in the agricultural sector.

- *Agriculture is the largest user of water in Africa:* Globally, agriculture accounts for 70 per cent of water consumption (UNEP 2008) but in Africa, as much as 86 per cent of total annual freshwater withdrawal goes to agriculture. Thus, the demand for food is the most important driver of water use in Africa.
- *There is inadequate water for sustainable food production:* Inadequate water for food production continues to compromise the wellbeing and economic productivity of Africa's people, thus curtailing their ability to generate revenue required for improving the availability and access to water for food.
- *Africa suffers from food insecurity and 30 per cent of the population lives with chronic hunger:* Lack of water contributes to food insecurity, a situation in which people lack adequate physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life. Economic water scarcity is a contributing factor to food insecurity, especially in sub-Saharan Africa.

#### **2.4.2. The Constraints:**

- *Per capita food intake is rising:* As Africa's population rapidly becomes more urbanized, increasing amounts of water are needed to meet food requirements. Not only are there more people to feed in cities, but urbanization is also generally accompanied by a rise in personal income and an increase in per capita food intake. In addition, people tend to shift away from staples towards richer diets containing products that require more water to produce such as meat, fruits, vegetables, sugars and oils.
- *Food production is not increasing:* About one third of the continent's people live in drought-prone areas, and the rising population and increasing affluence and demand for different foods has not been matched by a corresponding increase in food production.
- *Green water efficiency is very low:* A large portion of water for crop production in Africa comes from rainfall that is eventually transpired by crops as soil moisture (green water), around six per cent is from surface and groundwater sources (blue water). Green-water use efficiency is still very low, with studies showing that only 15 per cent of the terrestrial rainwater is used by plants for the production of food, fodder and fibre in sub-Saharan Africa, partly due to excessive losses caused by poor land management practices.
- *Irrigation capacity is underdeveloped:* There is under-investment in water infrastructure for irrigation across the continent, with only seven per cent of cultivated land equipped for irrigation in 2005 (FAO 2005). In sub-Saharan Africa, the proportion was only 3.8 per cent of arable land. In comparison, 28.7 per cent of the Near East and North Africa's cultivated land was irrigated, and in South Asia, the proportion was as high as 39 per cent.

#### **2.4.3. The Opportunities:**

- *Learn from the 1960-1990 Green Revolution:* There are lessons to be learned for Africa from the Green Revolution, which saw the yield of major cereals (rice, wheat and maize) more than double during the period 1960-1990 in Asia and Latin America, arresting the threat of famine and lowering the prices of staple crops (FAO 2005). By focusing on small farmer-based agriculture, countries that had food deficits 40 years ago are now food exporters. National governments controlled their own agricultural policies and the main focus of agricultural research was to promote local and appropriate technologies. Although there

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are natural, social and economic differences, the Asian food crisis at that time was described in the same terms as those used for Africa today: high population growth rates, widespread poverty, hunger and malnutrition.

• *Promote a greener, Green Revolution in Africa*: By initiating a green (ecological friendly), Green Revolution, Africa has an opportunity to grow more food using the same amount of water or the same amount of food using less water. The use of irrigation, synthetic fertilizers, chemical pesticides, early - maturing and high-yielding dwarf seed varieties (the dwarf varieties of rice and wheat were less susceptible to falling over, enabling the application of large amounts of water and fertilizer to boost yields) were critical components of the Green Revolution technology package in Asia. Record yields were realized but higher rates of poisoning from the chemical pesticides were also recorded in many areas, in addition to intense eutrophication of aquifers and waterways. In Asia, the ecological costs of the Green Revolution have risen and a growing number of farmers are turning back to non-chemical or less-chemical agriculture.

Alternative sustainable farming practices include agroforestry and intercropping cereals with legumes to improve nitrogen-deficient soils and reduce reliance on synthetic fertilizers and pesticides. Increasing productivity on existing cropland is fundamental if Africa is to avoid destroying vital ecosystems such as its biodiversity-rich wetlands and rainforests.

Africa can avoid the environmentally damaging aspects of such a revolution by focusing on a green, Green Revolution.

• *Increase irrigation to increase food security*: The estimated rate of agricultural output increase needed to achieve food security in Africa is 3.3 per cent per year. The potential for meeting this increase exists, since two-thirds of African countries have developed less than 20 per cent of their agricultural production and less than 5 per cent of the cultivated area is under irrigation in all but four countries (UNECA 2006). Without investment in irrigation, it will be difficult to increase food production, reduce the financial burden of agricultural imports and increase food security. Irrigation increases yields of most crops by 100 to 400 per cent. In sub-Saharan Africa, only four per cent of cropland is irrigated, so farmers need to make significant investments in irrigation to increase their productivity.

Irrigation makes it possible to:

- control soil moisture and therefore exploit an extended cropping season to boost agricultural yields and outputs;
- supplement unreliable rainfall, and grow a wider range of crops, including high-value crops for the export market;
- maintain food production levels and contribute to price stability through control over production levels;
- achieve food security at local levels through increased income and improved health and nutrition;
- bridge national gaps between production and demand of food crops.

• *Avoid the pitfalls of over-irrigation*: Irrigation development was an important component of the Asian Green Revolution, used to double yields by supplementing unreliable rainfall

• *Invest in simple and inexpensive irrigation technologies*: These offer the best advantages for increasing irrigation for food production, but must be managed carefully to avoid environmental damage, which is already extensive, and the spread of water-borne diseases. Parts of sub-Saharan Africa have large untapped reserves of groundwater and there is great potential for harvesting water runoff and farming lowlands and valley bottoms that catch it naturally. With investment, this potential could be unleashed. Other water conservation techniques include switching from surface to 'smarter' irrigation techniques like micro-irrigation and mulching and using cover crops to minimize the loss of available green water.

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Increases in the level of irrigation can come from both surface and ground water, drawing lessons from within and outside the region on viable small- to medium-scale irrigation techniques that require limited infrastructural development and can reach many farmers.

Methods such as pumping from rivers on an individual and small group basis, and locally manufactured drip systems are still to be fully exploited (IAASTD 2009). Surface irrigation is easy to operate and maintain, and can be developed at the farm level with minimal capital investment, with an indicative field application efficiency of around 60 per cent. Most energy requirements for surface irrigation systems come from gravity, and the systems are less affected by climatic and water quality characteristics (FAO 1989a, 1989b).

Sprinkler irrigation has a high irrigation field application efficiency of around 75 per cent, and is easy to design and simple to install and operate. It can be adapted for all types of soils, many kinds of field crops and small irregular plots, and is less expensive than many other modern irrigation systems (FAO 1989b, 2007a). Drip irrigation is the most advanced irrigation method with the highest field application efficiency of around 90 per cent. Water is applied to each plant separately in small, frequent, precise quantities through dripper emitters. Switching from sprinkler irrigation to drip systems has resulted in a reduction in water use of 30-60 per cent.

- *Link irrigation development to issues of social equity and environmental sustainability:* The large-scale irrigation schemes of the past have lost favour because of their social, environmental and financial costs. Now, project planners are seeking the participation of farmers in designing and managing irrigation plans. In implementing small-scale irrigation projects, there are opportunities to extend benefits to enhance social and environmental sustainability.

- *Secure sustainable investment for the green, Green Revolution:* Technologies such as the development of under-utilized irrigation potential, and the development of high-yielding and more drought-tolerant varieties can work for Africa if there is good investment (World Bank 2008). African farmers can reduce reliance on food imports and protect against the import of low-price grains. Governments in Africa are taking ownership of their own agricultural policies through initiatives such as the Comprehensive Africa Agriculture Development Programme (CAADP), which provides the framework for supporting the design and implementation of national agriculture and food security strategies (MDG Africa Steering Group 2008). This initiative presents an opportunity for development partners and the private sector to support national governments, and to reduce donor fragmentation so that financing can be channelled to effectively support the implementation of national-scale agriculture strategies within the framework.

- *Invest in targeted breeding of drought-tolerant varieties:* For example, the African Development Bank funded and African Rice Initiative coordinated project contributed to a six per cent increase in the continent's rice output during 2007 (World Bank 2008). Such targeted breeding can produce crop varieties that are higher-yielding, more drought-tolerant, utilize fertilizers more efficiently, and are more resistant to pests. It is important to note that genetically modified organisms (including crops) are still considered an emerging issue in Africa since they present the following concerns and uncertainties in light of increasing cooperation and trade:

- the issues of bio-safety;
- the impact of GMOs on the environment;
- trade with non-GMO partners;
- ethics issues;
- intellectual property rights;
- access to seeds by small-scale farmers.

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**2.5. Challenge 5:** Develop Africa's water resources for hydroelectricity to boost energy security.

**2.5.1. The Situation:**

*Hydroelectricity supplies 32 per cent of Africa's energy electricity consumption in Africa is the lowest in the world; Many African nations have a per capita electricity consumption of less than 80 kWh/yr, compared to 26 280 kWh/yr in Norway, 17 655 kWh/yr in Canada, and 13 800 kWh/yr in the United States. Access to electricity is uneven; only one in four people in Africa has access to electricity. More than 90 per cent of the rural population relies on biomass energy sources that include wood, crop waste, charcoal and manure for cooking and heating, and candles and kerosene for lighting. Electricity supply is often unreliable; even where access to electricity is available, it does not necessarily mean that electricity is available on demand. People frequently have to cope with unreliable supply and this disrupts economic activity at all levels and hampers progress; wars have destroyed existing electricity service in some areas; and Africa's hydro potential is underdeveloped.*

**2.5.2. The Constraints:**

*Constraints to hydropower development in Africa include the unavailability of suitable sites, large capital requirements, long lead times to develop, concerns over social and environmental impacts, political instability, and the impacts of climate variability on water resources (World Bank 2010). Low demand and dispersed populations also hinder rapid exploitation as well as the increase in demand from population and economic growth that challenge the ability of countries to provide increased power.*

*Climate change will affect rainfall, which could limit hydro potential in some areas; Climate change is expected to affect Africa's water resources. Hydro dams will need to avoid the environmental and social impacts historically characteristic of large dam developments. The capacity to generate hydropower is unequal across the continent: across Africa, available sites for hydro development are unevenly distributed. For example, the average potential in North Africa is 41 000 GWh compared to 653 361 GWh in Central Africa. In spite of its enormous hydroelectric potential, the Central Africa sub-region is the least electrified with only 2.6 per cent power production of total African power hydropower production while the Southern Africa sub-region is the most electrified (MDG Africa Steering Group 2008).*

**2.5.3. The Opportunities:**

*Africa has enormous hydroelectricity potential; Africa is the 'under-dammed' continent. Only three per cent of its renewable water is used, compared with 52 per cent in Asia. So there is plenty of scope for an African dam-building boom.*

*The need is to develop hydropower because it will boost the economy and human well-being; invest in hydroelectricity rather than fossil fuels, which makes sense in an era of climate change; learn from the many African countries that have developed hydropower successfully; learn from and copy successful regional power pools; and develop small-scale hydropower projects to avoid the environmental and human costs associated with large dams.*

*Meanwhile, regional power pools are able to reduce costs and improve conditions on the supply side. Operational costs are lower, due to investment in least-cost power generation plants on a regional basis. Benefits on the supply side, all contributing to increased reliability, include reduced coincident peak loads on the regional power pool, compared with the sum of the individual peak loads for each national power*

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grid; shared power generation reserves for the interconnected power grids; and increased robustness to deal with local droughts or other unexpected events.

The Grand Inga dam in the Democratic Republic of Congo (DRC) is one of the key projects that will support regional pools. The project is estimated to cost US\$80 billion and to have a total installed capacity of 44 000 MWh. Difficulties associated with the project include an absence of political consensus and legal harmonization. Nigeria is expected to be the largest consumer. The carbon-emission reduction potential is expected to help attract necessary investment. Most of the power will be used for industry or for export. Inga 1 and Inga 2 were commissioned in 1972 and 1982, as part of an industrial development scheme in the DRC. The two dams currently operate at only 40 per cent capacity because they have never received maintenance. The World Bank is partially financing a project to rehabilitate these dams. When Inga 2 was built, a 1 800-km transmission line was also built to transport the power to state-owned copper mines in the Katanga province, bypassing nearly every city and village in between. A component of the Grand Inga project could be expanded for household electricity access, particularly in the DRC, where access is estimated to be 13 per cent in urban areas and only three per cent in rural areas.

**2.6. Challenge 6: Meet Africa's growing demand for water in a time of ever-scarcer water resources.**

**2.6.1. The Situation:**

*More than 40 per cent of Africa's population lives in the arid, semi-arid and dry sub-humid areas; the amount of water available per person in Africa is far below the global average and is declining: the continental annual average water availability per person is 4 008 m<sup>3</sup>/capita/year, well below the global average of 6 498 m<sup>3</sup>/capita/year (FAO 2009). Annual per capita water availability has declined from 37 175 m<sup>3</sup> in 1750 to 4 008 m<sup>3</sup> in 2008. It has been predicted that the proportion of the African population at risk of water stress and scarcity will increase from 47 per cent in 2000 to 65 per cent in 2025, affecting 18 countries; groundwater levels are falling; and rainfall is also declining in some regions.*

**2.6.2. The Constraints:**

*Demand for water is increasing with population growth and economic development: with population projected to reach nearly two billion people by the year 2050 (UNFPA 2009), water supplies will be stretched to provide adequately for all uses. Africa's average annual population growth rate between 2005 and 2010 was 2.3 per cent, the highest in the world (UNFPA 2009). Development of water resources is inadequate; prices for access to water are generally distorted; and water provision is highly inefficient.*

**2.6.3. The Opportunities:**

*Further develop and manage water resources sustainably: given the presence of ample available water resources and their underdevelopment, one of the opportunities for addressing Africa's water scarcity is to further develop and manage its water sustainably (UNECA 2006). Economic development is needed to ensure a sustainable flow of funds for water infrastructure. There is also considerable scope for improved agricultural production and food security through irrigation and rain-fed agriculture, which does not necessarily lead to increased demand for water; improved water-use productivity; improved urban planning for better water provision; rationalized water prices; and protection of Africa's water towers.*

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- 2.7. Challenge 7:** Prevent water pollution, and address land degradation related to rainfall variability and the impacts of such degradation on water resources.

**2.7.1. The Situation:**

*The Sahel has been subject to enormous rainfall fluctuations.* Over the past three decades, the Sahel has suffered from land degradation; groundwater resources are being polluted by saltwater intrusion, and Africa's scarce water supplies are being polluted by point sources.

**2.7.2. The Constraints:**

Lack of valuation of ecosystem services; political instability and conflict within and between countries; poor agricultural practices and farming on marginal lands that affect water use or water resources; and lack of structured water monitoring and good governance.

**2.7.3. The Opportunities:**

*Maintain vital ecosystem functions:* for example in 1998, South Africa established the National Water Act to set aside or allocate water of a certain quantity and quality to maintain the basic ecological functions of aquatic ecosystems. This amount of water is called an Environmental or Ecological Reserve.

The aim of the Reserve is to protect the legitimate right of rivers and other ecosystems to their own water when water allocation decisions are made. Although stakeholders sometimes interpret such protection or allocation as being in direct competition with human needs, the Reserve represents an opportunity to maintain the health of rivers and other ecosystems that provide water-related ecosystem goods and services (maintaining water flows, for example) for the benefit of society. Sustaining various ecological functions through the Reserve in turn guarantees and prolongs the sustainability of ecosystems.

Other opportunities will be to foster the greening of the Sahel by encouraging adaptation to drought; and support scientific assessments of both land degradation and water quality. There is a need for both systematic global and national assessments of land degradation and desertification focusing on slow variables to understand long-term trends in land degradation and the potential for recovery. Such studies could allow the planning of effective responses to long-term drought (UNEP 2007).

*There is considerable knowledge and expertise among scientists in Africa to help plan and implement sustainable water strategies to address land degradation and pollution. One more reason why establishing centres of excellence staffed with African scientists networking with other water research and management experts would build Africa's capacity to monitor water quality, collect data and identify good water management approaches.*

According to researchers at a meeting organized by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Niger (23-25 September 2006), the degradation of drylands in Africa can be reversed. Rehabilitation does not necessarily lead to full land recovery, but may restore the land to 50-75 per cent of its former productivity, depending on soil and economic conditions. Through rehabilitation by tree planting, sustainable farming practices and groundwater replenishment, the land can become more productive again. Farmer-led rehabilitation initiatives in the Sahel in the past 30 years have started paying dividends.

- 2.8. Challenge 8:** Manage Africa's water under the impacts of global climate change.

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### **2.8.1. The Situation:**

*Global warming and its human cause are undeniable; warming patterns in Africa are consistent with global ones; Africa is already subject to important spatial and temporal rainfall variability: inter-annual rainfall variability is large over most of Africa and multi-decadal variability is also substantial in some regions. In West Africa (4°-20°N; 20°W-40°E), a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20-40 per cent noted between the periods 1931-1960 and 1968-1990. Increased inter-annual variability, however, has been observed in the post-1970 period, with higher rainfall anomalies and more intense and widespread droughts reported; drought in Africa is common and some regions are becoming drier; Africa's repeated drought cycles kill thousands of people each event; and floods also occur regularly with severe impacts on peoples' livelihoods.*

### **2.8.2. The Constraints:**

*Africa is one of the most vulnerable continents to climate change and climate variability; the convergence of multiple stressors limits Africa's capability to address climate change impacts; increased rainfall variability contributes to Africa's economic limitations in adapting to climate change impacts; population growth in peri-urban areas will exacerbate flooding events; climate change will likely increase aridity, with important impacts on food production; climate change will increase water stress in Africa; climate variability and change could result in low-lying lands being inundated; climate change impacts in productive aquatic ecosystems will be costly economically and in terms of food supplies; and it is likely that climate change will affect disease vectors.*

### **2.8.3. The Opportunities:**

*Reinforce traditional adaptation mechanisms:* Although Africa as a whole, especially its governments, has a low capacity for adaptation, many African communities in arid and semi-arid areas have developed traditional adaptation strategies to face great inter-annual climate variability and extreme events. An unusually persistent drought may increase people's vulnerability in the short term, but it can encourage adaptation in the medium to long term. This is particularly true for the drought-prone area in the Sahel region, which is susceptible to frequent climatic hazards.

*Provide early warning:* It is as important for local communities to have early warning systems as it is to be supplied with relief, because at the onset of adverse environmental changes the critical decisions are made at the household level.

*Better forecasting and early warning systems are a prerequisite for adaptation:* particularly to predict and prevent the effects of floods, droughts and tropical cyclones as well as for indicating the planting dates to coincide with the beginning of the rainy season and predicting whether there will be disease outbreaks in areas that are prone to epidemics (UNFCCC 2006). Improved early warning systems and their application will reduce vulnerability to future risks associated with climate variability and change (IPCC 2007a).

*Introduce adaptation measures informed by a more reliable system of seasonal predictions:* Such measures include managing agriculture and water resources better, diversifying livelihoods and improving production efficiencies in arid lands and marginal areas by intensifying livestock densities, using natural fertilizers and practicing soil and water conservation (UNFCCC 2006, IPCC 2007a). Improvement in present-day rain-fed agriculture can enhance resilience for future periods of drought stress through technological steps like water-harvesting systems, dam building, water conservation and agricultural practices, drip irrigation, and developing drought resistant and early-maturing crop varieties and

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alternative crop and hybrid varieties. Biotechnology research could also yield tremendous benefits if it leads to: drought- and pest-resistant rice, drought-tolerant maize and insect-resistant millet, sorghum and cassava, among other crops; supports public-private partnerships that develop innovative adaptation measures and improved physical infrastructure, which may improve adaptive capacity. Building improved communication and road networks for better exchange of knowledge and information, for example, gives people an opportunity to migrate more easily in case of extreme events due to climate change. However, general deterioration in infrastructure threatens the supply of water during droughts and floods.

- 2.9. Challenge 9:** Enhance Africa's capacity to address its water challenges. To address Africa's mounting challenge of economic water scarcity, it will need to strengthen and sustain financial, human and institutional capacities to effectively develop and utilize water resources.

**2.9.1. The Situation:**

*Africa faces a situation of economic water scarcity;* and current institutional, financial and human capacities for managing water are lacking. There is a lack of sustainable financing mechanisms for water-related investments, including transboundary water resource development, water supply, sanitation, hydropower and irrigation, and under-financing of the water and sanitation sector in many countries has led to deterioration and potential collapse of infrastructure

**2.9.2. The Constraints:**

Inadequate and unsustainable funding arrangements for water resource management; insufficient knowledge base; lack of an effective research and technology base; and weak institutional arrangements and legal frameworks for the ownership, allocation and management of water resources.

In particular, there is a need to fill the following gaps:

- Low institutional and human capacity levels.
- Limited comprehensive studies on vulnerability analysis and on possible adaptation measures and their cost-benefit analysis.
- Lack of quantification of the different components of Africa's water balance. While estimates are available in the literature for continental average annual rainfall and evapotranspiration, research data are lacking for other components such as surface runoff, infiltration, groundwater storage and groundwater discharge.
- Groundwater quantity and quality monitoring is very irregular in most countries due to a lack of expertise to collect and analyse the data for the continent's development.
- Wide gaps in ground and surface water information and knowledge in the water sector across Africa.
- Lack of earth observation systems and lack of in-country and regional capacity for analysing and interpreting observational data.
- Data on economically exploitable small-scale hydropower potential is limited or not available for most African countries, and there are wide variations in how much hydropower potential has been exploited overall.
- Lack of decision-support systems and tools that are relevant to Africa's local water resource management needs.
- Lack of real-time data collection and transmission technology to facilitate sharing, such as through the Internet for meteorological and hydrological data.
- Lack of a coordinated, effective and financially sustainable continental system or database for data collection, assessment and dissemination for national and transboundary water basins,

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and for supporting strategic development decisions on the continent.

*Lack of commitment in the mobilization and leveraging of financial resources by African countries also affects the above data issues directly or indirectly.* A typical example is the implementation of the 2003 Comprehensive Africa Agriculture Development Programme (CAADP), the Africa-owned and Africa-led initiative to boost agricultural production on the continent through irrigation and water management, among other measures. In 2003, member countries made a commitment to spend ten per cent of their total national expenditures on agriculture, but by 2008, only a handful of countries had implemented what they promised.

### **2.9.3. The Opportunities:**

*Reform water institutions;* There is potential to enhance human resources and the capacity of water resource institutions, including the decentralization of water resource management activities to the most appropriate levels for stakeholders, as well as strengthening existing initiatives and improving public-private partnerships. Governments have the opportunity to improve public-private partnership arrangements for the development of water infrastructure.

The financial model of Public-Private Partnerships (PPPs) involves a sharing of risks and responsibilities between the state and private firms, while the state retains control of the assets. Although such partnerships were expected to improve services without the disadvantages of privatization (unemployment, higher prices and corruption), they have fallen short of expectations; costs are often greater for the consumer, the private sector may not always be more efficient and big government contracts are often abused. If governments improve the system for dealing with the private sector by being disciplined and using highly transparent procedures, there is the potential for gains in efficiency and effectiveness in water management. There is evidence that PPPs in Africa have been most successful when planning, communication and commitment are strong, and when governments have implemented effective monitoring, regulation and enforcement.

*Governments must also perform thorough feasibility studies to examine affordability, value for investment and risk transfer and improve the knowledge base through human capacity building.* Opportunities to identify training needs for water resource assessment and management, and to train a cadre of water professionals need to be fostered and acted upon to improve the level of information about Africa's water resources, uses and needs.

Training should aim to ensure that staff are retained and that their knowledge and skills are frequently upgraded (UNECA 2009.). Governments need to ensure that information and education programmes are an integral part of the development process, and to provide water specialists with the training and means to implement IWRM (INPIM 1992). The proper policy frameworks for planning, developing and managing water resources that implement recent advancements in the science and technology of water management also need to be in place to take advantage of available knowledge and skills. This includes local and indigenous knowledge and wisdom about water resources.

## **3. CONCLUSION**

Water in Africa is at the core of sustainable development, being closely linked to the nine challenges discussed above. This synthesis paper indicates that all these challenges are interlinked and they need to be addressed in a holistic manner through the process of Integrated Water Resources Management (IWRM), with the perspective of improving human well-being in Africa. This is a critical step if States

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want to find adequate responses to the mounting water challenges the continent is facing with its growing populations while addressing the significant challenges that remain in order to achieve sustainable development. Although the constraints are many, as highlighted in the text, there are several opportunities for the continent to overcome some of the most important challenges by tapping into the huge under-utilized water resources of the continent for the purpose of irrigation, industry, hydropower, tourism and other sectors for the economic development of Africa.

#### **4. References and Indicative Bibliography**

1. Banerjee S., Diallo A., Foster V., Wodon Q. (2009). Trends in Household Coverage in Modern Infrastructure Services in Africa. World Bank Policy Research. World Bank. [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1372957##](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1372957##). (Last accessed on May 2, 2010).
2. FAO. (1989b). Irrigation Water Management: Irrigation scheduling. Food and Agriculture Organization of the United Nations. FAO Training manual number 4. Rome.
3. FAO. (1989a). Guidelines for designing and evaluating surface irrigation systems. Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper 45. Rome.
4. FAO. (1989b). Irrigation Water Management: Irrigation scheduling. Food and Agriculture Organization of the United Nations. FAO Training manual number 4. Rome.
5. FAO. (2005). Special Event on Green Revolution in Africa. Background document. Committee on World Food Security 31st Session – 23-26 May 2005. Food and Agriculture Organization of the United Nations. [http://www.fao.org/unfao/bodies/cfs/cfs31/cfs2005\\_events\\_en.htm](http://www.fao.org/unfao/bodies/cfs/cfs31/cfs2005_events_en.htm). (Last accessed on April 25, 2010).
6. FAO. (2009). AQUASTAT database. Food and Agriculture Organization of the United Nations <http://www.fao.org/nr/aquastat>. (Last accessed on January 13, 2010). FAO. (2010). 'Water and Food Security'. Food and Agriculture Organization of the United Nations. <http://www.fao.org/worldfoodsummit/english/fsheets/water.pdf> (Last accessed on September 15, 2010).
7. IAASTD. (2009). 'Summary for Decision Makers of the Sub-Saharan Africa (SSA) Report'. International Assessment of Agricultural Knowledge, Science and Technology for Development. Island Press.
8. IPCC. (2007a). Summary for Policymakers: Contribution of Working Group II to the Fourth Assessment. Intergovernmental Panel on Climate Change.
9. IPCC. (2007b). 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.
10. Kliot, N., Shmueli, D., Shamir, U. (2001). Institutions for management of transboundary water resources: their nature, characteristics and shortcomings. *Water Policy* 3: 229-255.

- 
11. MDG Africa Steering Group. (2008). Achieving the Millennium Development Goals in Africa. Recommendations of the MDG Africa Steering Group. June 2008. <http://www.mdgafrica.org/pdf/MDG%20Africa%20Steering%20Group%20Recommendations%20-%20English%20-%20HighRes.pdf>. (Last accessed May 9, 2010).
  12. Roy, D., Barr, J., and Venema, H. (2010). Ecosystem Approaches in Transboundary Integrated Water Resources Management (IWRM): A Review of Transboundary River Basins. (Unpublished report). IISD, Winnipeg, Canada and UNEP, Nairobi.
  13. Turton, A., Earle, A., Malzbender, D., Ashton, P. (2006). Hydropolitical Vulnerability and Resilience along Africa's International Waters. In Hydropolitical Vulnerability and Resilience along International Waters: Africa pp 19-67. United Nations Environmental Programme. [http://www.awiru.up.ac.za/pdf/C\\_CH%202%20UNEP%20Africa.pdf](http://www.awiru.up.ac.za/pdf/C_CH%202%20UNEP%20Africa.pdf). (Last accessed on April 30, 2010).
  14. Turton, A. (2003). The Hydropolitical dynamics of cooperation in Southern Africa: A strategic perspective on institutional development in international river basins. In Hydropolitical dynamics of cooperation in Southern Africa, pp. 83-103. [http://www.anthonyturton.com/admin/my\\_documents/my\\_files/2BA\\_Chapter\\_4.pdf](http://www.anthonyturton.com/admin/my_documents/my_files/2BA_Chapter_4.pdf) (Last accessed on April 30).
  15. Turton A. (2008a). The Southern African Hydropolitical Complex. Management of Transboundary Rivers and Lakes pp. 21-79. Turton A. (2008b). A South African perspective on a possible benefit-sharing approach for transboundary waters in the SADC Region. Water Alternatives (1) 180:200.
  16. UNDP. (2006a). Human Development Report 2006. United Nations Development Programme. <http://hdr.undp.org/en/reports/global/hdr2006/> (Last accessed on May 2, 2010).
  17. UNDP (2006b). 'Human Development Report 2006 Presskit'. United Nations Development Programme. [http://hdr.undp.org/en/media/HDR\\_2006\\_Presskit\\_EN.pdf](http://hdr.undp.org/en/media/HDR_2006_Presskit_EN.pdf), (Last accessed on May 2, 2010).
  18. UNECA. (2006). 'African Water Development Report. Economic Commission for Africa.' United Nations [http://www.uneca.org/awich/AWDR\\_2006.htm](http://www.uneca.org/awich/AWDR_2006.htm) (Last accessed on 30 May 2010).
  19. UNECA. (2006). African Water Development Report. United Nations Economic Commission for Africa. [http://www.uneca.org/awich/AWDR\\_2006.htm](http://www.uneca.org/awich/AWDR_2006.htm) (Last accessed on September 15, 2010).
  20. UNECA. (2009). Economic Report on Africa 2009: Developing African Agriculture Through Regional Value Chains. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia. [http://www.uneca.org/era2009/ERA2009\\_ENG\\_Full.pdf](http://www.uneca.org/era2009/ERA2009_ENG_Full.pdf). (Last accessed on May 25, 2010).
  21. UNEP. (2002). Atlas of International Freshwater Agreements. United Nations Environment Programme.

- 
22. UNEP. (2006). *Hydropolitical Vulnerability and Resilience along International Waters: Africa*. United Nations Environment Program.
  23. UNEP (2006). *Africa Environment Outlook 2*. United Nations Environment Programme, Nairobi. UNEP. (2007 ). Chapter 3: Land. In *Global Environment Outlook GEO4 Environment for development*. United Nations Environment Programme, Nairobi.
  24. UNEP. (2008). *Africa: Atlas of our Changing Environment*. United Nations Environment Programme. Division of Early Warning, Nairobi.
  25. UNFCCC. (2006). *Background paper on Impacts, Vulnerability and Adaptation to Climate Change in Africa for the African Workshop on Adaptation Implementation of Decision 1/CP.10 of the UNFCCC Convention*, Accra, Ghana, 21 - 23 September. United Nations Framework Convention on Climate Change.
  26. UNFPA. (2009). *State of World Population 2009: Facing a changing world: women, population and climate*. United Nations Population Fund. New York: UNFPA. Water footprint. (n.d.). 'Water footprint and virtual water'. <http://www.waterfootprint.org/?page=files/home>. (Last accessed on April 20, 2010).
  27. Van der Zaag P. and Carmo Vaz A. (2003). *Sharing the Incomati waters: cooperation and competition in the balance*. *Water Policy* 5:349-368.
  28. World Bank. (2008). 'New, high yield rice spells millions in savings for African countries'. <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21844287~menuPK:258657~pagePK:2865106~piPK:2865128~theSitePK:258644,00.html>. (Last accessed on April 26, 2010).
  29. World Bank. (2010). *Africa's Infrastructure, A Time for Transformation: Overview*. [http://siteresources.worldbank.org/INTAFRICA/Resources/aicd\\_overview\\_english\\_no-embargo.pdf](http://siteresources.worldbank.org/INTAFRICA/Resources/aicd_overview_english_no-embargo.pdf). (Last accessed on April 29, 2010).
  30. WHO/UNICEF. (2010). *Progress on Sanitation and Drinking Water- 2010 Update*. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. [http://whqlibdoc.who.int/publications/2010/9789241563956\\_eng\\_full\\_text.pdf](http://whqlibdoc.who.int/publications/2010/9789241563956_eng_full_text.pdf) (Last accessed on May 20, 2010).