Mapping, Assessment & Management of Transboundary Water Resources in the IGAD Sub-Region Project

Volume VI

IWRM COMPONENT

INTERGOVERNMENTAL AUTHORITY ON DEVELOPMENT

AFRICAN WATER FACILITY

SAHARA AND SAHEL OBSERVATORY

Mapping, Assessment & Management of Transboundary Water Resources in the IGAD Sub-Region Project

Volume VI

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IWRM Modelling of Transboundary Water Resources in the IGAD sub-region

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Study conducted with the support of:
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PREFACE

The IGAD sub-region represents one of the marginal regions of the world in terms of rainfall available for natural vegetation growth and crop production. About 80% of the IGAD sub-region is arid and semi arid with low level of water use. It has a population estimated at **206 million in 2010** and projected to reach **462 million in 2050** in an area of **5.2 million km^2**.

The most obvious manifestation has been periodic droughts and desertification that have consigned millions to perpetual poverty and deaths. The populations derive their livelihoods from water and land based primary production activities such as nomadic pastoralism and subsistence agriculture in a region where rainfall variability is high. The sub-region is the home of the greatest numbers of pastoral communities estimated to be about **17 million**. Dependable water availability is therefore vital to the development of the region.

The mounting concerns over water scarcity in the IGAD sub-region have focused attention to several socioeconomic challenges of water resource management.

Firstly, as the sub-region expects to advance economically and socially, the demand for water will increase as a result of population growth, rising incomes, changing dietary patterns, urbanization and industrial development. While demand will increase in all sectors, agriculture will account for the bulk of the water and will therefore be the focal point for adjustment of demand pressure.

Secondly, there are concerns as to whether the IGAD sub-region will have enough water to meet the food security needs of a rapidly growing population. Along with food security, water security has also become a fundamental issue for human development in the sub-region

While it is a fact that water occupies pivotal position in development in the IGAD sub-region, none of the **member countries has adequate information** to manage their water resources for the attainment of economic efficiency and equity in water allocation for different uses. Yet, four IGAD countries namely **Eritrea, Kenya, Djibouti and Somalia** are in the category of those experiencing water scarcity i.e. with **less than 1000 m^3 per person per year** or less.

Indeed by the year 2025 even Ethiopia and Uganda which are presently with adequate water will be water stressed (1000-2000 m^3/person/year) while Djibouti, Eritrea, Kenya, Somalia and Sudan will be in water barrier situation «500 m3/person/year » and therefore water will be limiting any sustainable development.

None of the IGAD Member States has at the present time water per capita necessary for industrial development (2400 m^3/day). This lack of water will severely constrain food production, ecosystem maintenance and economic development among other needs and uses.

Water resources link the IGAD Member states internally and externally with adjacent regions. Six transboundary river basins and six transboundary aquifer systems have been identified in this stage of the IGAD sub-region study. **The ratio of water demands to available supply averages which is 9% in 2011 will increase to 15% in 2031** as projected by this study which is known as "*Mapping, Assessment and Management of Transboundary Water Resources in the IGAD Sub-region Project*". However, there are specific problems that call the need for adequate knowledge of surface and ground water resources.

This Study (the first sub-regional study) has provided a platform for refocusing efforts within the sub-region towards better quantification and understanding of the extent of water scarcity and other water related factors that impact socioeconomic development in the sub-region. The most significant of the drivers of water demand in all sectors is population, which in the sub-region is projected to increase by 165% between 2010 and 2030, and by 136% between 2030 and 2050. This study demonstrates that these increases will create significant increases in water withdrawals for domestic supply and for industry.

The other significant sector is agriculture, which combines irrigation and livestock. Again here population is the most important parameter of change, driving the demand for food and hence the need to raise agricultural productivity through irrigation development.

The regional process has highlighted the **low level of water use** and hence of water security currently estimated as about 3% of the annually renewable water resources as a basic indicator of the overall lack of water infrastructure development to ensure water security for the social and economy and environmental use. The IGAD sub-region is one of the most vulnerable areas to climate variability and recurrent droughts.

Hence, there is need to further understand in depth the environmental situation and consolidate IGAD capacities to monitor the linkages between climate and the water system along with identification and mapping of the water resources and the major risks associated with degradation, pollution and water quality deterioration. Policies, strategies, and objectives of cooperation and how to achieve them should be set out in a second stage of the IGAD project study.

It is important to note that the IGAD project was implemented at national and sub-regional levels with active participation of the focal national institutions by employing national and regional consultants. The project coordination is done by OSS with the establishment of national coordination units in the focal national water institutions of the IGAD Member States. Steering Committee of the project was in place and the regional coordination and facilitation was done by IGAD.

We would like to thank everyone who contributed to the success of this project: the Ministries in charge of Water and national institutions, the IGAD and OSS cooperation partners (particularly the African Water Facility), the national teams, national and

international consultants, the project team within the Executive Secretariat of OSS and The IGAD Secretariat.

Our satisfaction was to pass the ownership of all project results by national teams and the establishment within the Executive Secretary of IGAD powerful tools to ensure the continuity of the project.

This final project report is made up of 7 individual documents namely

- Introduction, Overview and General Recommendations
- Volume 1: Institutional Framework Component Report
- Volume 2: Socioeconomic Component Report
- Volume 3: Environment Component Report
- Volume 4: GIS/Database Component Report
- Volume 5: Water Resources Modelling/Hydrology Component Report
- Volume 6: IWRM Component Report

We also thank SEREFACO Consultants Limited and its team for the excellent work carried out despite all the difficulties encountered particularly the lack of reliable data.

The Executive Secretary of OSS	The Executive Secretary of IGAD
Dr. Ing. Chedli FEZZANI	Eng. Mahboub Mohamed MAALIM

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ASAL	Arid and semi-arid land
AQUASTAT	Global Information System on Water and Agriculture of FAO
BCM	Billion cubic metres
Cap-Net	International Network for Capacity Building in Sustainable Water Management
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
DB	Database
EIA	Environmental Impact Assessment
FAO	Food and Agricultural Organisation
GEF	Global Environment Facility
GWP	Global Water Partnership
IGAD	Inter-government Authority on Development
IWRM	Integrated Water Resources Management
NBI	Nile Basin Initiative
SEI	Stockholm Environment Institute
SSO	Sahara and Sahel Observatory
SWAT	Soil Water and Assessment Tool
ToR	Terms of Reference
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention for Combating Desertification
UNCED	UN Conference on Environment and Development (Rio Summit)
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WEAP	Water Evaluation and Planning System

EXECUTIVE SUMMARY

The water resources management challenges of IGAD countries are many and tend to have cross-border implications. They include; endemic poverty, rapidly growing populations, desertification, highly variable rains that affect rainfall and frequently cause droughts, famine and starvation, land degradation due to deforestation, civil strife. Implementing IWRM in transboundary basins provides a viable mechanism for addressing the challenges. The concept of IWRM is represented by its principles which provide a backbone to the process of preparing transboundary water management plans. They define the need for conserving the water resources, importance of a participatory approach to water resources development and management, the role of women in water resources provision and management and the economic value of water.

The modelling of water resources management in the IGAD region is challenging. Water resources are sparsely distributed in space and highly variable in time. Additionally, data on water demand and usage are scarce and can be unreliable in areas where they exist. The WEAP model was used for modelling water resources management in many regions around the world. It provides a means of analysing the effect of polices interventions (both structural and non-structural) on water resources availability and demand in a region. The model was successfully developed for 6 transboundary basins in the IGAD region. The demand and supply data used were based on the socioeconomic and water resources modelling studies (see table below). The possible use of the models in testing the effect of alternative water management scenarios was investigated. The main idea behind the development of the models was the models will evolve over time as more information about water resources, demand and other policy issues becomes available.

The model was set up for a base year of 2011 while simulations were carried out for 20 years ending in 2031. Initial water resources scenario assessments showed that all basins have considerable water resources which, if well managed, can serve the needs of the basin inhabitants. The annual water resources and water demand estimates for 2011 and 2031 are shown the table below. It is generally clear from the table that the available water resources in the basins are sufficient to meet current and future demands. The ratio of water demands to available supply averages only 9% in 2011 to 15% in 2031. The problem is one of spatial and temporal variation in water availability. The rivers mainly flow during the wet season which lasts only 4-5 months between June and October annually. The other 7-8 months are generally dry with many of the rivers drying up. This generally implies that, to meet the projected demands, investment in water storage (in form of dams and reservoirs) is inevitable. Some preliminary estimates of required storage were computed. The estimates need further refining as more data becomes available.

Basin	Available water resources (x 10^6 m^3)		Domestic demand (x 10^6 m^3)		Agriculture demand (x 10^6 m^3) - 2011	Total demand (x 10^6 m^3)	
	Surface water	Ground water	2011	2031		2011	2031**
Juba-Shebelle	64,600	43,700	578	1,054	1,192	1,770	2,824
Turkana-Omo	28,700	19,300	707	1,293	680	1,387	2,680
Gash-Barka	2,800	1,400	53	225	225	278	503
Danakil	1,000	600	52	99	60	112	211
Ogaden	14,100	6,500	91	165	310	401	566
Ayesha	123	-	4	7	0	4	11
Total	111,323	71,500	1,485	2,843	2,467	3,952	6,795

*** Irrigation demands assumed at 2011 values. For total demands including irrigation demand projections, see the specific scenarios in the main report.*

The following recommendations can be drawn from the IWRM modelling study:

- The implementation of IWRM is complicated by lack of political will, lack of institutional and legal tools and also lack of human resources capacity. There are many international organisations with experience in supporting developing countries to start the process of IWRM implementation. These include Global Water Partnership, UNESCO, UNDP, Cap-Net, IWMI, UNEP and others. These organisations should be brought on board as early as possible to share their experiences and also support the implementation of IWRM in the transboundary basins of IGAD.
- The IWRM models were built from the data available at the time of analysis. More detailed analysis will require further data collection concerning water demands and demand growth rates including specific information about planned future developments in the water sectors of the IGAD sub-region. In particular, livestock water demands represent a significant water user in the IGAD countries but data on this were not available.
- The IWRM models were built in such a that further refinements can be made by users. WEAP model can be used for a range of applications including scenario assessment, impacts of climate change, irrigation management, water supply modelling, etc. Training of model users will help in ensuring that the use of the model is integrated in their daily work and a critical mass of professionals can be built to implement the model at Transboundary basin level.

1

INTRODUCTION

1. CONTEXT

The purpose of a water management model is to prepare a water allocation plan that takes into account the needs of the different water users/stakeholders in a basin. In addition, a water management model is useful in considering the impacts of different future scenarios (changes in hydrology, management decisions, socio-economic changes etc) on the entire system. The model is then used to test the impacts of proposed mitigation measures (like changes in water allocation to a given sector, changes in sector priorities or bulk water transfers into and out of a basin).

The IGAD Sub-region stretches over an area of 5.2 million km^2 and has a population of about 194 million people (2005) which is growing at an annual rate of 2.5% (1990-2007). About 80% of the Sub-region is arid and semi-arid lowlands, receiving less than 400 mm of rainfall per year. Global land use statistics indicate that farmlands constitute 7% of total land area, forests 19%, permanent pastures 28%, and other lands which apparently are not under productive use 46%.

The IGAD Sub-region is one of the most vulnerable areas to climate variability and recurrent droughts, and suffers some of the worst effects of these environmental conditions that are exacerbated by its being prone to conflict. The Sub-region comprises seven countries – Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda – that encompass the Horn of Africa. A combination of conflict, climate variability and change and rapid population growth has had an adverse impact on the Sub-region including worsening the effects of drought. Recent famines have been on a large scale, building on the endemic high levels of poverty and food insecurity. Levels of human development are low and social, economic and political inequalities among the people as well as among regions within the individual countries are pervasive.

2. OBJECTIVES OF THE IWRM COMPONENT

The overall objective of the MAM-TWR assignment was to assess and analyze the water resources, socio-economic and environmental condition of the sub region and come-up with a set of strategy, recommendations, and action plans to enable member states to implement and operate an integrated transboundary water resources management process. For the IWRM part, the main objective was to contribute towards promoting IWRM principles in transboundary water resources within the IGAD Sub-Region; planning joint development of major priority transboundary aquifer basins that offer noticeable potential for water based development activities; and initiating arrangements for joint planning and implementation of transboundary water development activities within major transboundary water systems.

3. ACTIVITIES

The major activities under the IWRM component of the study were:

- Conceptualisation of an IWRM model;
- Elaboration of the IWRM model in light of the transboundary basins;
- Development of an IWRM model for the transboundary basins of the IGAD Sub-Region.

The process of conceptualising the IWRM model involved a number of steps including: (1) justification for the need of an IWRM model; (2) assessment of the existing bottlenecks for implementing IWRM; (3) identification of opportunities for IWRM implementation; and (4) IWRM modelling.

Justification of the need for IWRM in the transboundary basins of IGAD Sub-region was aimed at assessment of the IGAD strategies for environmental management and review of the conceptual and practical basis for IWRM. The bottlenecks for implementing IWRM in IGAD are related to the existing institutional and legal tools which do not specifically address IWRM issues. These are coupled with other factors like high poverty rates, lack of capacity for IWRM as well as high frequencies of climate extremes (floods and droughts) in the region. The Water Evaluation and Planning System (WEAP) model was used for analysing the effect of alternative water management interventions on the water resources systems of the different transboundary basins. Long-term mean monthly values of water resources and water demands were used in the modelling process. Future scenarios were based on the development prospects in the transboundary basins. In addition, future threats due to climate change and other changes were factored into the process. The basins considered in the IWRM component of the study were; (1) Juba-Shebelle; (2) Turkana-Omo; (3) Gash-Barka; (4) Danakil; (5) Ogaden and (6) Ayesha.

The models were developed to address a number of issues, including;

1. To make optimum use of available information. Sources of information included the national reports, information from IGAD and OSS as well as information from regional and international sources like FAO, World Bank, UNESCO, UNDP and others.
2. The models were required to give a realistic representation of the supply and demand conditions spatial locations within each basin. The use of WEAP, a GIS based modelling system addressed this by ensuring that all demand centres are located as close as possible to the actual location of demand relative to the source of supply (the rivers).w
3. The models were required to be flexible enough to allow for future development and refinement as more information becomes available.

2

WATER RESOURCES MANAGEMENT IN THE IGAD SUB-REGION

1. INTRODUCTION

The IGAD[1] Strategy identified the sustainable management of natural resources and environmental protection as a key challenge upon which the foundation of socioeconomic development depends. The region experiences persistent economic crises, which to a large extent, have roots in severely degraded natural resources and the environment. This, exacerbated by recurrent droughts and other natural and man-made disasters, results in perpetual poverty and under-development which in turn accelerates the degradation of natural resources and the environment, thereby closing the vicious cycle.

It is the goal of the member countries to break the cycle by specifically ensuring environmental sustainability in their economic and social activities. The IGAD Natural Resources an Environment Strategy (2007) points out that such a strategy would realize the long-term vision of IGAD whereby the people of this region would develop a regional identity and live in peace and a clean environment having alleviated poverty through appropriate and effective economic, food security, environmental protection and natural resources management programmes. Such a strategy would ensure that people and livelihoods are at the centre of concern for sustainable development and human beings are entitled to a healthy and productive life in harmony with nature.

2. CHALLENGES FOR INTEGRATED WATER RESOURCES MANAGEMENT AT TRANSBOUNDARY LEVEL

The freshwater resources of the IGAD region are made up of surface water, groundwater and open water bodies. The region also has sizeable wetland areas, particularly in Uganda, Ethiopia and Sudan which act as storage for water, and filters for polluted water, among others. Freshwater availability is one of the most critical ingredients for social and economic development. Freshwater and wetland ecosystems support multiple functions ranging from water for drinking, sanitation, agriculture, energy generation, manufacturing, transport, and habitat for species as source of food and trade. The region is yet to fully maximize the management and use of its water resources. There is still potential for improved water supply for enhanced agricultural production, support of industrialization, provision of safe drinking water, and sanitation and other infrastructure services.

[1] IGAD (2003) IGAD Strategy, InterGovernmental Authority on Development, IGAD Secretariat, Djibouti.

Although five of countries of the IGAD region share one of the greatest rivers in the world, many inequities over this common resource exist and are especially difficult to redress. Studies show that the Nile River Basin has enough water to sustain its population. Furthermore, if rainfall were evenly distributed over the basin, the per capita water share of the basin population would be more than 10,000 m3 per capita per year, ten times the water scarcity limit of 1,000 m3 per capita per year downstream. Therefore, this calls for increased cooperation among affected member states, for there is tremendous opportunity and benefits in the exploitation of the Nile Basin water resources. The same argument holds for cooperation in the utilization of the countries' wetland resources and other freshwater bodies in the region.

The state and integrity of the freshwater resources in the region continues to play a major role in the livelihoods of many communities. The role played by fresh water as sources of energy, food and human well-being is a major contribution to national economies. However, knowledge gaps exist in quantitative estimates of the region's freshwater and wetlands resources. Given that the IGAD region is expected to be water-stressed by 2025, there is need to have proper exploration and assessment of its current freshwater reserves so as to better formulate appropriate integrated water resources management plans.

Appendix A1 shows the main challenges to water resources management in each of the IGAD countries. Overall, most challenges are common across the Sub-region and require collective efforts to address them. This would be best handled using a transboundary approach to water resources management within an IWRM framework which allows for coordinated actions at basin level and harnesses the synergies between countries and cultures. In general the crosscutting water resources management issues for the Sub-region include:

- Endemic poverty, with most of the countries in the region classified as some of the poorest in the world;
- Limited human and institutional capacity to deal with water resources management challenges;
- Aging, fragmented and inadequate infrastructure for water resources assessment and monitoring;
- Highly variable and irregular rainfall. These result in:
    - Higher inter-annual variations of rainfall volumes, durations and extreme events
    - Shorter and more intense wet seasons and longer and drier dry seasons leading to crop and pasture failures and reduced crop and pasture yields.
    - Increased evapotranspiration from reservoirs due to climate change;
- Increase in demand for irrigation water with the risk of conflicts between farmers and other users over water rights;
- Growth in demand for fertilisers with increased risks of groundwater and surface water pollution;
- Water shortages resulting from the exhaustion, or pollution, of groundwater;

- Increased pressure on aquifers and the risks of transnational conflicts over water rights;
- Water pollution from municipal, agricultural and industrial sources. Lack of treatment for grey water;
- Population explosion averaging at about 2.7% in the Sub-region and rural-urban migration causing high concentrations of poor people in cities;
- Soil erosion and removal of vegetation cover is a big problem especially in the highland areas;
- Food security issues. Frequent severe droughts leading to famine and starvation;
- Limited funding for water resources infrastructure developments;

3. OPPORTUNITIES FOR TRANSBOUNDARY WATER RESOURCES MANAGEMENT IN IGAD SUB-REGION

Transboundary water resources management is about joint management of often differing national human, political, social, institutional and financing objectives and capacities. The key challenges for effective transboundary water management include: obtaining political commitment and allocation of financial resources across countries and relevant levels of government; and identifying the role of transboundary water management in a broader regional cooperation or integration agenda

The border areas between the different IGAD countries are often occupied by people of the same or similar ethnicity. These peoples have been cooperating for a long time through sharing resources, trade and even intermarriages. While this relationship sometimes results in conflict, it also provides a strong foundation upon which joint initiatives can be initiated and implemented. Sharing of the natural resources and infrastructure can often be contentious and lead to conflict if not done in a mutually beneficial manner to the neighbours.

The IGAD area as a Sub-region is endowed with features that bind it internally and distinguish it from other sub regions. The people within the Sub-region share common challenges, hazards and hopes. A common vision can therefore be set that guides efforts to deal with transboundary environmental and developmental issues. IGAD as an institution is well placed to manage and that facilitate intervention in various sectors of its priority areas for the benefit of the region. The IGAD framework provides a natural focal point for resolution of disputes and sharing of resources. However, specific agreements are recommended where there are substantial resources to be shared.

3.1. IGAD environment and natural resources strategy[2]

IGAD has formulated an Environment and Natural Resources strategy with an overall goal to "**assist and complement the efforts of the member states in environment and natural resources management**". The approach to achieving this is by promoting: (i) Harmonization

[2] IGAD (2007) IGAD Environment and Natural Resources Strategy, *InterGovernmental Authority on Development*, IGAD Secretariat, Djibouti

of compatible environmental governance systems; (ii) Provision of reliable, timely and readily available environment and natural resources data and information; (iii) Capacity building for environment and natural resources management; and (iv) Research into and adoption of new, appropriate and affordable technologies. While justification for a transboundary approach to water resources management can be seen in all guiding principles of the IGAD Environment and Natural Resources Strategy, the key principles that address the issue include;

- **Principle 3:** Adherence to the principle of subsidiarity, which requires that decisions and actions are taken at the most appropriate level possible in the hierarchy. Thus, actions should be taken at the regional level by IGAD if it is agreed that the actions of individual member states are insufficient.
- **Principle 5:** Subscription to the principle of variable geometry, which recognizes that member states are at different levels of development and move at different speeds and constellations depending on their priorities.
- **Principle 11:** Promotion of integrated environment and natural resources management for sustainable development.

3.2. Progress of IWRM implementation in the sub-region

Several of the IGAD countries have started, or have already been through, the process of putting in place elements or substantial elements of the IWRM process envisaged by the international community during the World Summit on Sustainable Development in Johannesburg 2002 (Table 1). The countries are at different stages of policy and legal reform, creating an enabling environment, preparation of IWRM plans and incorporation of the IWRM plans in national development plans, linking IWRM the plans to national budgets for the water sector, preparation of water efficiency tools and increasing and encouraging stakeholder participation. Despite this, several challenges still remain, including articulation of better governance, dialogue with other non-water sectors (agriculture, energy, mining, finance etc), capacity building for institutions and individuals, linkages between IWRM and

Country	Policy and Legislation	Institutional Arrangements	Institutional Capacity	IWRM plans	Water Efficiency	Stakeholder Engagement	Environmental Sustainability	Monitoring and Information	Allocation Mechanisms
Djibouti	✓✓	✓×	✓×	✓×	××	✓×	✓×	✓×	✓×
Eritrea	✓×	✓×	✓×	✓✓	××	✓✓	✓×	✓×	✓×
Ethiopia	✓✓	✓✓	✓×	✓✓	✓✓	✓✓	✓×	✓×	✓×
Kenya	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓×	✓×	✓×
Somalia	××	××	××	××	××	✓×	××	××	××
Sudan	✓×	✓×	✓×	✓×	✓×	✓✓	✓×	✓×	✓×
Uganda	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓×	✓✓	✓×

✓✓ Substantial achievements ✓× Some but little achievements ×× little progress

TABLE 1. Progress in Implementation of IWRM in IGAD Region.

Extracted from GWP (2009) Beyond African Declarations: Supporting the Implementation of the Sharm el Sheikh Commitments – Improving Africa's Water Security. Presentation at World Water Week.

climate change, as well as financing mechanisms. A transboundary approach to development of water resources in most of the IGAD countries contributes to a more focussed and coordinated policy framework, to some extent improving the basis for dialogue between neighbouring countries.

3.3. Relevant agreements and conventions

The IGAD sub region countries are Parties to a number of agreements and conventions that are aimed at fostering joint management of shared resources. These include the United Nations Convention to Combat Desertification (UNCCD), United Nations Framework Convention on Climate Change (UNFCCC), and the United Nations Convention on Biological Diversity (CBD). The agreements and conventions are useful tools for cooperation and would be included in any bilateral or multilateral agreements on the sharing, managing and conservation of natural resources and infrastructures of a transboundary nature. The status of accessions of the IGAD member states to the selected regional and international instruments is shown in Table 2. CITES is the Convention on the International Trade in Endangered Species of Wild Fauna and Flora, CMS is the Convention onw Migratory Species while Ramsar is the Convention on Wetlands.

Guidance for transboundary water resources management can be found in the UN Convention on the Non-Navigational Uses of International Watercourses that was adopted in 1997. The Convention is an example of a global treaty applicable to international freshwater and its principles have been widely applied in the development of regional and river basin agreements on water and play an important role in developing relationships between riparian states. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes established a framework for co-operation between the 56 member countries of the United Nations Economic Commission for Europe to prevent and control pollution of transboundary watercourses and is also relevant in similar processes within the IGAD region.

Country	CBD	UNCCD	UNFCC	CITES	CMS	Ramsar
Djibouti	✓	✓	✓	✓	✓	✓
Eritrea	✓	✓	✓	✓	✓	✓
Ethiopia	✓	✓	✓	✓	-	**(almost)**
Kenya	✓	✓	✓	✓	✓	✓
Somalia	✓	✓	✓	✓	✓	-
Sudan	✓	✓	✓	✓	✓	✓
Uganda	✓	✓	✓	✓	✓	✓

Extracted from IGAD Environment and Natural Resources Strategy (2007).

TABLE 2. Accession of IGAD countries to key international conventions/agreements

4. MAJOR TRANSBOUNDARY BASINS

Six major transboundary river basins have been identified in the IGAD Sub-region. These are:

- Ayesha basin Eritrea and Ethiopia;
- Gash-Baraka basin shared between Eritrea and Sudan;
- Juba-Shebelle basin Ethiopia, Kenya and Somalia;
- Nile basin shared between Eritrea, Ethiopia, Kenya, Sudan, Uganda and 5 other countries outside the IGAD region;
- Ogaden basin shared between Ethiopia and Somalia;
- Turkana-Omo basin shared between Ethiopia, Kenya Sudan and Uganda.

3

IWRM AND TRANSBOUNDARY WATER MANAGEMENT

1. INTRODUCTION TO IWRM

According to the Global Water Partnership – Technical Advisory Committee (2000) integrated water resources management (IWRM) is *a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.* The concept embodies integration across sectors, integration of use, integration of demand, integration with the environment, and integration with the people. IWRM is necessary to combat increasing water scarcity and pollution. Methods include water conservation and reuse, water harvesting, and waste management. An appropriate mix of legislation, pricing policies and enforcement measures is essential to optimise water conservation and protection.

The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking account of social, economic and environmental interests. It recognises the many different and competing interest groups, the sectors that use and abuse water, and the needs of the environment. The integrated approach co-ordinates water resources management across sectors and interest groups, and at different scales, from local to international. It emphasises involvement in national policy and law making processes, establishing good governance and creating effective institutional and regulatory arrangements as routes to more equitable and sustainable decisions. A range of tools, such as social and environmental assessments, economic instruments, and information and monitoring systems, support this process.

In the current assignment, the IWRM concept is being applied within a context of transboundary water resources in the IGAD Sub-region. The long-term goal is to develop a shared vision for the Sub-region, based on IWRM principles, which will assist in developing basin awareness, and facilitate the adoption and the implementation of common policies and strategies as well as legal & institutional arrangements for joint development and management of transboundary water resources. It is hoped that this will result in promotion of IWRM principles in transboundary water resources management of the IGAD sub- region where poverty and development problems are particularly correlated to water availability and quality. The assignment is developing a roadmap for creating the enabling environment for the establishment of transboundary water resources management organizations in the Sub-region. The key focus areas are information and knowledge management, monitoring, capacity building and strategic planning. The sections below give a possible conceptual framework for achieving these goals.

2. OPERATIONALISING THE PRINCIPLES OF IWRM IN THE IGAD SUB-REGION

IWRM at the river basin level seeks better water resources management through such means as progressively developing water resources in the basin, building a more integrated institutional framework, and improving environmental sustainability. Broadly, the principles of IWRM are founded in the requirements for integration of land-use and water-use planning; cross-sectoral cooperation; environmental sustainability; economic efficiency; social equity and stakeholder participation in the process of environmental and natural resources management.

IWRM principles recognise that water has many facets covering social, economic, environmental, physical or infrastructural, institutional/political as well as cultural, ethnic and gender dimensions. IWRM, therefore represents a major challenge for policy makers. It requires a break with tradition, from the sectoral to integrated management, from top-down to stakeholder and demand responsive approaches, from supply fix to demand management, from command and control to more co-operative or distributive forms of governance, from closed expert driven management organisations to more open, transparent and communicative bodies. IWRM is ultimately about changing the nature of water governance, which is defined as 'the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society' (GWP 2002)

The 1992 International Conference on Water and the Environment in Dublin, Ireland laid the foundation for guiding integrated management of the world's water resources. The resulting principles continue to be the background upon which IWRM plans and processes are built and include:

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment;
- Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels;
- Women play a central part in the provision, management and safeguarding of water;
- Water has an economic value in all its competing uses and should be recognised as an economic good.

In light of the above principles, IWRM is an impressive concept which includes all elements of good water governance (e.g., coordination, sustainable development, participation, equity and inclusiveness). It also has widespread international acceptance as an approach for effective, sustainable and equitable use of water. However, operationalising IWRM has proved to be a big challenge in the past. The interpretation of the principles will vary with the contextual framework in which application is planned. The weak institutional frameworks in the IGAD region and differences in levels of development means that interpretations will differ. The principles make the IWRM concept so broad that it is necessary to have wide ranging reforms in existing institutions. Sector-wide reforms require cooperation at the highest levels of development and complete stakeholder involvement. Learning from examples of successful application (for example in the Nile Basin, SADC, Senegal River basin etc) will be useful in facilitating the understanding of the application of the IWRM principles in the IGAD Sub-region.

Other international agencies that are instrumental in providing support for implementing IWRM in developing countries include:

- Global Water Partnership – www.gwp.org
- UNESCO Water Portal – www.unesco.org/water
- UNDP – www.undp.org
- Cap-Net – www.cap-net.org
- International Water Management Institute – www.iwmi.cgiar.org
- GEF International Waters Learning and Exchange Network - www.iwlearn.net
- World Bank: Water Resources Management - http://go.worldbank.org/9U3CAQINB0
- The World Bank Institute - http://go.worldbank.org/CO263O7XX0
- WWF Living Waters Programme - wwf.panda.org
- UNEP – United Nations Environmental Programme – www.unep.org
- Integrated Water Resources Management Organization – www.iwrm.org

The above organisations should be engaged as early as possible in the process of promoting IWRM in IGAD as they have a lot of useful experiences to learn from.

3. FROM NATIONAL TO TRANSBOUNDARY THINKING

Policies for the use and protection of water resources in a country are set by national governments. Although the implementation of these policies is effective at many scales, where policies are implemented at the basin scale, there is the opportunity to deliver 'whole basin' solutions and to resolve upstream-downstream (for a river) and region-to-region (for a lake or groundwater resource) controversies. The 'whole basin' approach allows the assessment of impact at a system level. In other words, national policies, as well as international agreements and regional conventions for transboundary waters, are applied to natural basins. The relationship between administering water resources within a country and managing water in basins thus becomes dynamic and more responsive to changing circumstances, whether environmental, social or economic.

Potential conflicting interests in transboundary water situations can be overcome through mutual trust and understanding, appropriate legal and institutional frameworks, joint approaches to planning and management, and sharing of the ecological and socio-economic benefits, and related costs. Any basin corporation may face a wide array of challenges depending on its unique situation. The establishment of transboundary cooperation is a complex, long process and requires patience. Approaching transboundary issues may require flexibility in national policies.

Transboundary cooperation frameworks will typically result in more options, including multi-purpose uses and joint projects, and more complexity because of differing viewpoints. Approaching transboundary issues may require changes in national policies and legislation. Top-down basin-wide approaches based on constructive ambiguity principles are often essential to foster trust and trigger action for cooperation due to the political nature of allocation of transboundary water resources.

4

WATER MANAGEMENT MODELLING

1. INTRODUCTION

Different models have been developed for water resources management. There are two basic types of optimization approaches used in water resources management models, namely:

- Hydrology inferred optimization models that optimize allocations based on hydrologic specifications and
- Economic optimization models that optimize allocations based on economic considerations.

Other criteria, such as equity or environmental quality can also be used. Following are some models with a brief description of their suitability to achieve our needs from modelling

Within an IWRM framework, the purpose of a water management model is to prepare a water allocation plan that takes into account the needs of the different water users/ stakeholder in the basin. In addition, a water management model is useful in considering the impacts of different future scenarios (changes in hydrology, management decisions, socio-economic changes etc) on the entire system. The model should then be used to test the impacts of proposed mitigation measures (like changes in water allocation to a given sector, changes in sector priorities or bulk water transfers into and out of a basin). Below are some commonly used water management models.

2. EXAMPLES OF WATER MANAGEMENT MODELS

2.1. Water evaluation and planning system (WEAP)

WEAP is a general multi-purpose, multi-reservoir simulation program which determines the optimal allocation of water for each time-step according to demand priorities and supply preference. It operates at a monthly time step on the basic principle of water balance accounting (SEI, 2008). The model can represent any water resource system incorporating natural inflows, precipitation, evaporation, and evapotranspiration as input data. Operational features that can be represented include storage and release of water by reservoirs, physical discharge controls at reservoirs outlets, water flow in channels, consumptive demands, and hydropower release. These operational features can be specified as steady-state or time-varying. In addition, WEAP allows users to develop their own set of variables and equations to further refine and adapt the analysis to local constraints and conditions with possible data exchange with other software such as excel (SEI, 2005).

2.2. The water allocation system model (WAS)

The Water Allocation System Model is an annual steady state model with extraction from water sources limited to annual renewable amounts. Seasonal variation and multiyear issues are not modeled. It is assumed that each source of supply has an annual renewable and a constant extraction cost per cubic meter up to that amount. Different sources can be drawn on the same water resources (e.g. the same river or aquifer).agricultural demands are treated in a very simple mean. WAS model can be applied to regions larger or smaller than an actual country and optimizes allocation based on economic considerations. It treats demand as a function of price by representing demand by the demand curve.

2.3. Water rights analysis package (WARP)

WARP simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system availability and reliability for specified water use requirements. Basin-wide impact of water resources development projects and management strategies may be evaluated. The software package is generalized for application to any river\reservoir system, with input files being developed for the particular river basin of concern (www.ceprofs.tamu.edu).

2.4. MODSIM_DSS

MODSIM_DSS is a freeware simulation model. The model can simulate physical operation of reservoirs and water demand. The data sets can be developed for daily, weekly, and monthly time steps. It is generalized river basin decision support system and network flow model developed at Colorado State University designed to meet the growing demands and pressure on river basin manager. It has been linked with stream-aquifer models for analysis of the conjunctive use of groundwater and surface water resources, as well as water quality simulation models for assessing the effectiveness of pollution control strategies. It can be used with GIS for managing the intensive spatial data base requirements of river basin management. Results of network optimization are presented using graphical plots (http://modsim.engr.colostate.edu).

3. WATER MANAGEMENT MODELLING USING WEAP

3.1. Introduction

The Water Evaluation and Planning Integrated Water Resources Management (IWRM) model (WEAP) seamlessly integrates water supplies generated through watershed- scale hydrologic processes with a water management model driven by water demands and environmental requirements and is governed by the natural watershed and physical network of reservoirs, canals and diversions.

The WEAP model was developed by the Stockholm Environment Institute (SEI) and can be downloaded from www.weap21.org. It is a general multipurpose, multi- reservoir simulation program which determines the optimal allocation of water for each time step on the basic principle of water balance accounting.

The model provides a comprehensive flexible and user-friendly framework for planning and policy analysis. WEAP has an integrated approach of simulating both the natural inflows and engineered components of water system. This allows the planner access to a comprehensive view of the factors that must be considered in managing water resources for present and future use. This enables us to predict the outcomes of the whole system under different scenarios, and carry out comparisons between the different alternatives to evaluate a full range of water development and management options (SEI, 2005).

3.2. Advantages of WEAP

Based upon the following criteria, WEAP was selected to perform water resources management modelling for the IGAD transboundary basins.

- The model can be used at different levels spatially and temporally;
- The mode is easy to use with a friendly interface;
- The model has been successfully used in many national and international applications;
- The model is able to simulate hydrology, groundwater utilization, surface-groundwater interactions, and wastewater treatment;
- The model has in-built capability to build and compare scenarios;
- The model is based on priority –based water allocation system and can therefore be used in negotiation situations;
- The model can enable stakeholders to get involved in management procedures through interactive data-driven model. This helps increase public awareness and acceptance;
- The model enables users to have interactive control over data input, editing, model operation and output display;

4. WEAP MODELLING APPROACH

The design of WEAP was guided by a number of methodological considerations: an integrated and comprehensive planning framework; use of scenario analyses in understanding the effects of different development choices; Demand-management capability; Environmental assessment capability; and Ease-of-use. These are discussed in turn below.

4.1. Integrated and comprehensive planning framework

WEAP places the evaluation of specific water problems in a comprehensive framework. The integration is over several dimensions: between demand and supply, between water quantity and quality, and between economic development objectives and environmental constraints.

4.2. Scenario analysis

Based on a variety of economic, demographic, hydrological, and technological trends, a «reference» or «business-as-usual» scenario projection is established, referred to as a Reference Scenario. One or more policy scenarios can then be developed with alternative assumptions about future developments.

The scenarios can address a broad range of «what if» questions, such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water pollution are added? What if a water-recycling program is implemented? What if a more efficient irrigation technique is implemented? What if the mix of agricultural crops changes? What if climate change alters the hydrology? These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

4.3. Demand management capability

WEAP has the capability of representing the effects of demand management on water systems. Water requirements may be derived from a detailed set of final uses, or «water services» in different economic sectors. For example, the agricultural sector could be broken down by crop types, irrigation districts and irrigation techniques. An urban sector could be organized by county, city, and water district. Industrial demand can be broken down by industrial subsector and further into process water and cooling water. This approach places development objectives and providing end-use goods and services at the foundation of water analysis, and allows an evaluation of effects of improved technologies on these uses, as well as effects of changing prices on quantities of water demanded. In addition, priorities for allocating water for particular demands or from particular sources may be specified.

4.4. Environmental effects

WEAP scenario analyses can take into account the requirements for aquatic ecosystems. They also can provide a summary of the pollution pressure different water uses impose on the overall system. Pollution is tracked from generation through treatment and outflow into surface and underground bodies of water. Concentrations of water quality constituents are modeled in rivers.

4.5. Ease of use

An intuitive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. The main functions, namely loading data, calculating and reviewing results, are handled through an interactive screen structure that prompts the user, catches errors and provides on-screen guidance. The expandable and adaptable data structures of WEAP accommodate the evolving needs of water analysts as better information becomes available and planning issues change. In addition, WEAP allows users to develop their own set of variables and equations to further refine and/or adapt the analysis to local constraints and conditions.

5

WEAP MODEL SETUP FOR TRANSBOUNDARY BASINS IN IGAD

1. INTRODUCTION

A WEAP model was set up for each of the 6 transboundary river basins in IGAD Sub-region. The modelling exercise was geared towards generating data and information that will aid discussions on the establishment of tranboundary water resources management frameworks in the IGAD countries. In particular, the models was required to address broad questions related to

- The adequacy of the identified water resources to meet current demands
- Assessment of the adequacy of supply to meet projected demands
- Sensitivity assessment of water sharing strategies across countries and water use sectors
- Analysis of different prioritisation schemes to reduce water demand shortfalls.
- Quantification of the required additional water sources, in case there is a shortage.

The water demands by category were based on the findings of the socioeconomist in phase II. Water availability figures were obtained from the findings of the Water Resources Modeller/Hydrologist. Long term mean monthly values (January to December) as well as mean annual values for both water availability and demand were used in the modelling.

WEAP model is scenario driven but the modelling process goes through a number of iterative processes as shown in Figure 1. The sections below briefly describe the approach that was adopted to WEAP modelling

2. DEMAND ESTIMATION AND PROJECTION

The current water demands were obtained from the socioeconomist's findings. Key water demand categories included;

- Domestic which was lumped together with industrial demand and estimated as the per capita annual water demand;
- Agriculture and irrigation which was aggregated by area (number of hectares, annual water-use/hectare);
- Ecosystem demands (in-stream flow requirements) were not considered at this stage as data were not available. This is an important demand category and should be considered in future

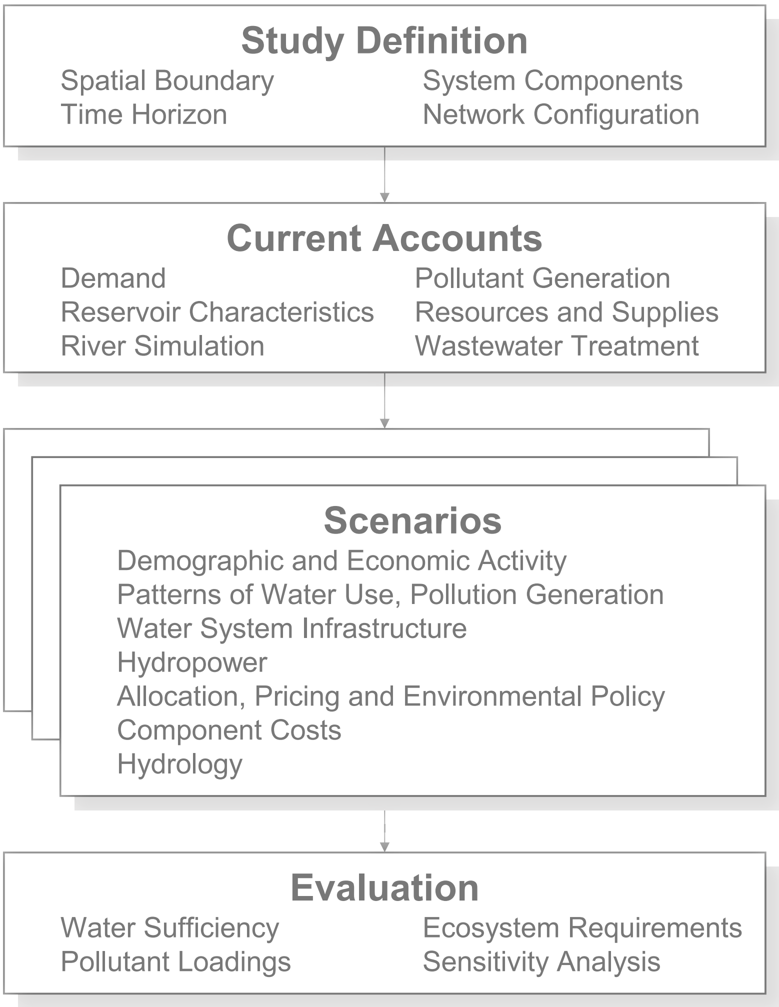

Figure 1: WEAP modelling process

- Livestock demands were included in the estimates of agriculture demand

To define the water demand, the following information was required

- Basic water requirements data, categorized by sector and/or specific water users
- Prioritisation of the water demands, i.e. what demands must be met first? Generally, it was assumed that domestic water demand had to be met first before agriculture demands were considered
- Population projections for cities and towns, production activity level projections for industry and agriculture
- Water consumption (water consumed by a demand site that is lost to the system, lost to evaporation, embodied in products, or otherwise unaccounted for)

Future development scenarios were set on the basis of the socioeconomist's findings on realistic development prospects in each of the transboundary basins taking into account economic prospects, climate variability and change, human impact (population, pollution etc), environment impact and changes in system operation (e.g. reservoir operation rules). The scenarios were applied as either demand or supply measures as well as integrated measures. Demand measures impact on the water demand values, supply measures impact on the water availability values while integrated measures as a combination of demand and supply measures. Adequacy of the available supply to meet demand was assessed on the basis of the demand deficit at each time step and also an aggregation of this over the entire modelling horizon. The demand centres were located in consultation with the GIS/ Database specialist.

3. WATER SUPPLY ESTIMATION

The water supply was based on the hydrologist's estimation of water resources in each transboundary basin. The data was at monthly time step.

4. ANALYSIS SETUP

WEAP calculates a water and pollution mass balance for every node and link in the system on a monthly time step. Water is dispatched to meet instream and consumptive requirements, subject to demand priorities, supply preferences, mass balance and other constraints.

WEAP operates on a monthly time step, from the first month of the Current Accounts year through the last month of the last scenario year. Each month is independent of the previous month, except for reservoir and aquifer storage. Thus, all of the water entering the system in a month (e.g., headflow, groundwater recharge, or runoff into reaches) is either stored in an aquifer or reservoir, or leaves the system by the end of the month (e.g., outflow from end of river, demand site consumption, reservoir or river reach evaporation, transmission and return flow link losses). Because the time scale is relatively long (monthly), all flows are assumed to occur instantaneously. Thus, a demand site can withdraw water from the river, consume some, return the rest to a wastewater treatment plant that treats it and returns it to the river. This return flow is available for use in the same month to downstream demands.

The basic steps in setting up an analysis included

- Setting up the analysis area as determined by the geographic extents of the transboundary basin in questions. GIS tools were used for this.
- Identification of supply and demand centres. The demand centres may include towns, irrigation farms, industrial complexes etc. The supply areas included rivers and reservoirs.
- Demand sites, reservoirs or special location along a river made up the nodes. Nodes were linked by lines that represent the natural or man-made water conduits such as river channels, canals and pipelines. These lines included rivers, diversions, transmission links and return flow links. River reaches were defined as the section of a river or diversion between two river nodes, or following the last river node.
- Entry of the demand and supply information mentioned above.

5. SCENARIO SETUP

Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. Using WEAP, scenarios were built and then compared to assess their water requirements. Other assessment criteria may include costs and environmental impacts. The assumed common starting year for all scenarios was 2011 for the establishment of the Current Accounts

The scenarios were used to address a «what if» questions, such as:

- What if population growth and economic development patterns change?
- What if reservoir operating rules are altered?
- What if groundwater is more fully exploited?
- What if water conservation is introduced?
- What if ecosystem requirements are tightened?
- What if a more efficient irrigation technique is implemented?
- What if the mix of agricultural crops changes?
- What if climate change alters the hydrology?

In a nutshell, scenarios in WEAP encompass any factor that can change over time, including those factors that may change because of particular policy interventions, and those that reflect different socio-economic assumptions.

6

ASSUMPTIONS AND GENERAL VARIABLES

1. GENERAL ASSUMPTIONS

A number of key assumptions were made in the current IWRM modelling with the aim of simplifying analysis and investigating the key scenarios in detail. The assumptions were based on available data in the IGAD countries and include

1. The population data for the different constituent regions of each country were derived by the socio-economist. It was assumed that the number of people to be considered in the sharing of the basin water resources is proportional to the ratio of the regional area that falls within the basin. For example, if the percentage of the area of Oromia region that falls within Juba-Shebelle basin is 48%, then the proportion of the total Oromia population that is considered in the share of Juba-Shebelle water resources is also 48%.
2. The population growth rates were assumed to be equivalent to the national averages for the different countries.
3. The domestic and industrial water demands were lumped into a single figure assumed at 80 litres per capita per day. The daily domestic demand is assumed at 50 litres per capita and daily industrial demand is assumed at 30 litres per capita. The demand estimates represent a target that ensures a healthy and dignifies life for the population. The 80 litres per capita per day converts to a demand of about 30 m^3 per capita per annum.
4. The irrigation water demand rate was fixed at 12,000m^3/year. This was in line with current estimated regional averages for the entire IGAD region. However, the irrigation water demand is a function of the difference between two climatic variables, namely precipitation and potential- (or reference-) evapotranspiration during the growing season. This function varies widely over the IGAD basin due to large variations in climate resulting in large variations in irrigation water demand from a minimum of 1,100 m^3/year in Uganda to a maximum of 29,000m^3/year in Somalia.
5. The mean monthly historical hydrological variables will be replicated in future. Therefore, future projections of water resources are set at the mean monthly estimates of the SWAT simulated values.
6. Whenever conditions resulted in demand deficits, when total water demand was higher than available supply, preliminary water demand management options were considered to try and balance the two. In order of preference, the measures considered were

- Provision of storage. This was simulated as a total storage for the given river in the system. No reservoir siting was carried out.
- Improvements in irrigation methods result in a 10% reduction in irrigation water demand every year.

2. SCENARIO SETUP

A number of scenarios have been addressed in the current study. Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. Using WEAP, scenarios can be built and then compared to assess their water requirements, costs and environmental impacts. This being a preliminary study, and owing to the data limitations, the emphasis has been placed on assessing water requirements only. The choice of scenarios was based on the conditions in the reference scenario for each basin where demands were set at current values and future populations derived using the national average population growth figures. The major questions that were assessed include

- How much storage is required to meet current irrigation requirements?
- How much more storage would be required to double irrigation capacity?

3. SCENARIOS CONSIDERED

These were:

- **Current conditions:** These were assumed as water supply and demand conditions for the year 2011
- **Reference period:** Taken as the period 2012-2031. Population was assumed to grow at the national average rates and irrigation demand fixed at 2011 levels
- **Storage requirement:** Inclusion of storage to reduce on unmet demand in reference period. The storage can either be as surface reservoirs and dams or groundwater storage (for example by enhancement of recharge).
- **Doubling of irrigated areas:** Only considered in basins where water resources can support expansion. Topographical and other factors may limit the extent to which this is achievable. However, the aim here is to demonstrate whether the available water resources can support such and endeavour.
- **Exploitation of groundwater.** This is only considered in 3 basins namely Ogaden, Ayesha and Danakil. The assumption is that the exploitable resources are up to 10 times the aquifer productivity given in Table 4. While the groundwater resources for the rest of the basins are useful (especially in meeting the rural domestic demands) they represent a very small proportion of the total water resources and would not significantly change the conclusions of this study. Therefore, analyses for Turkana-Omo, Juba-Shebelle and Gash-Barka are based on surface water resources

3.1. Irrigation data

The irrigation data used in this study was derived FAO's AQUASTAT global map of irrigated areas (http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm). The map is based on the "area equipped for irrigation" as reported by the different countries. The data necessary for modelling irrigation water consumption included specifying three values, namely;

- The area under irrigation in hectares. This was derived from AQUASTAT
- The annual gross water requirement in cubic metres per hectare (m3/ha). This value depends on the crop water requirements. It also on whether irrigation provides all the crop water requirements or it is used to augment rainfall during dry months. Whenever possible, this value was obtained from the national reports. Other sources included reports from FAO, World Bank and the UN
- The percentage of diverted water that is consumed. This was assumed to be 90% in all cases.

Table 3 below gives the Irrigated areas for the different sub-basins organised by countries that share each transboundary basin.

Country	Total irrigated area (ha)	Irrigated area by basin (ha)*					
		Turkana-Omo	Juba-Shabelle	Ogaden	Gash-Baraka	Ayesha	Danakil
Ethiopia	292,384	46,953	48,783	1,721		0	4,756
Kenya	101,706	9,720	7,134				
Uganda	9,041						
Sudan	1,863,099				13,677		
Djibouti	859						
Eritrea	19,590				5,057		4,756
Somalia	196,753		142,814	23,429		0	
Total	**2,483,432**	**56,673**	**198,731**	**25,150**	**18,734**	**0**	**9,512**

Extracted from the global map of irrigated areas of FAO (2007)

Table 3. Irrigated areas in the transboundary basins of IGAD region

3.2. Groundwater resources

Given the scarcity of data on groundwater resources in the sub-region, the figures adopted here are those provided by the British Geological Survey of the Natural Environment Research Council through its project on Groundwater Resilience in Africa (http://www.bgs.ac.uk). The aquifer map of Africa was generated from using data from UNESCO, national hydro-geological maps and aquifer properties across the continent.

Basin	Aquifer yield classification	Aquifer productivity (l/s)	Mean annual productivity (m^3/year)	Aquifer saturated thickness (m)	Aquifer storage and flow types
Juba-Shebelle	Moderate	1-5	78,840	25-250	Intergranular and fracture flow
Ogaden	High	5-20	394,200	100-250	Intergranular and fracture flow
Ayesha	Low to moderate	0.5-1	23,652	25-100	Fracture flow
Turkana-Omo	Moderate to High	1-20	315,360	25-100	Fracture flow
Danakil	Moderate	1-5	88,301	25-100	Fracture flow
Gash-Barka	Low	0.1-0.5	7,884	< 25	Fracture flow within weathered material

Table 4. Groundwater resources and aquifer properties in the IGAD sub-basins

7

JUBA-SHEBELLE BASIN

1. MODEL SETUP

Demand centres were conceptualised as nodes where the demand is concentrated. Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Juba-Shebelle basin is shown in Figure 2.

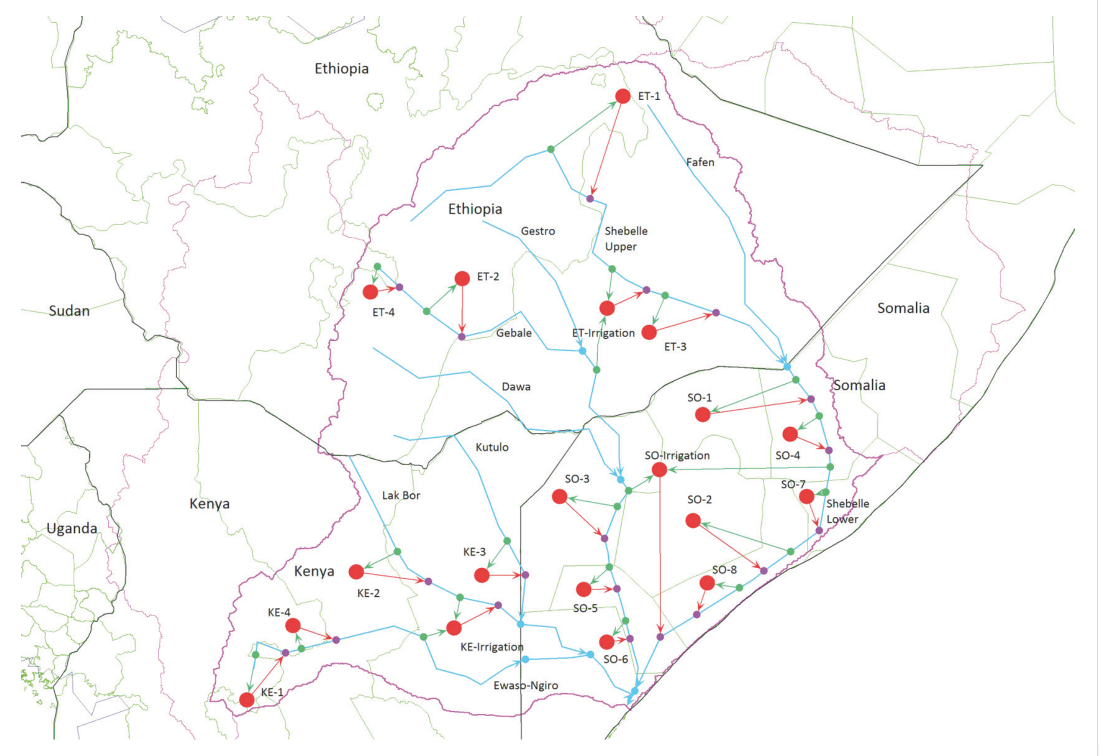

FIGURE 2: Model setup for Juba-Shebelle basin. For the names of the different demand centres see Table 5 (population data) and Table 3 (Irrigation data).

2. POPULATION PROJECTIONS

Table 5 shows the basin population updated to 2011 while Table 6 shows the population projections.

No	Region	Country	Total population	Ratio of area in Basin	Population in Basin	Reference year	Population Grouth rate	2011 population
ET-1	Harari People	Ethiopia	183,344	1.00	183,344	2007	3.21	208,043
ET-2	Oromia	Ethiopia	27,158,471	0.48	13,026,600	2007	3.21	14,781,489
ET-3	Somali	Ethiopia	4,439,147	0.61	2,726,945	2007	3.21	3,094,308
ET-4	SNNP	Ethiopia	15,042,531	0.02	360,990	2007	3.21	409,621
KE-1	Central	Kenya	3,724,159	0.13	493,684	1999	2.69	678,870
KE-2	Eastern	Kenya	4,631,779	0.33	1,508,323	1999	2.69	2,074,112
KE-3	North-Eastern	Kenya	962,143	0.79	759,619	1999	2.69	1,044,561
KE-4	Rift Valley	Kenya	6,987,036	0.13	925,097	1999	2.69	1,272,111
SO-1	Bakool	Somalia	226,000	1.00	226,000	2007	2.81	252,493
SO-2	Bay	Somalia	1,106,000	1.00	1,106,000	2007	2.81	1,235,653
SO-3	Gedo	Somalia	576,777	1.00	576,777	2007	2.81	644,391
SO-4	Hiiraan	Somalia	219,300	0.73	160,656	2007	2.81	179,489
SO-5	Jubbada Dhexe	Somalia	362,601	0.99	360,712	2007	2.81	402,997
SO-6	Jubbada Hoose	Somalia	968,286	0.61	589,109	2007	2.81	658,169
SO-7	Shabeellaha Dhexe	Somalia	863,571	0.45	389,080	2007	2.81	434,691
SO-8	Shabeellaha Hoose	Somalia	1,399,868	0.98	1,368,441	2007	2.81	1,528,859
	Total							**28,899,857**

Somalia population figures were obtained from http://data.un.org

Table 5. Population data for the regions in Juba-Shebelle basin

Region	2011	2016	2021	2026	2031
Oromio	14,781,489	17,311,196	20,273,838	23,743,506	27,806,975
Somali	3,094,308	3,623,869	4,244,058	4,970,387	5,821,020
SNNP	409,621	479,724	561,824	657,974	770,580
Kenya_Central	678,870	775,224	885,255	1,010,902	1,154,382
Kenya_Eastern	2,074,112	2,368,498	2,704,667	3,088,549	3,526,917
Kenya_North-Eastern	1,044,561	1,192,819	1,362,120	1,555,450	1,776,221
Kenya_RiftValley	1,272,111	1,452,666	1,658,848	1,894,294	2,163,157
Baay	1,235,653	1,419,297	1,630,235	1,872,522	2,150,818
Gedo	644,391	740,161	850,165	976,517	1,121,648
J_Hoose	658,169	755,987	868,342	997,396	1,145,631
S_Dhexe	434,691	499,295	573,501	658,735	756,637
S_Hoose	1,528,859	1,756,080	2,017,070	2,316,849	2,661,182
All Others	1,043,022	1,202,722	1,386,959	1,599,516	1,844,763
Total	**28,899,857**	**33,577,537**	**39,016,880**	**45,342,599**	**52,699,932**

Table 6. Population projections in Juba-Shebelle basin

3. DEMAND DATA

3.1. Domestic demand

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m^3 per capita per annum.

3.2. Irrigation demand

The irrigation water demand rate was fixed at 12,000m^3/year. The irrigated area in Ethiopia, Kenya and Somalia is 48783 ha, 7134 ha and 142814 ha respectively.

4. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 5,500x10^6 m^3 with the monthly distribution as shown in Figure 3.

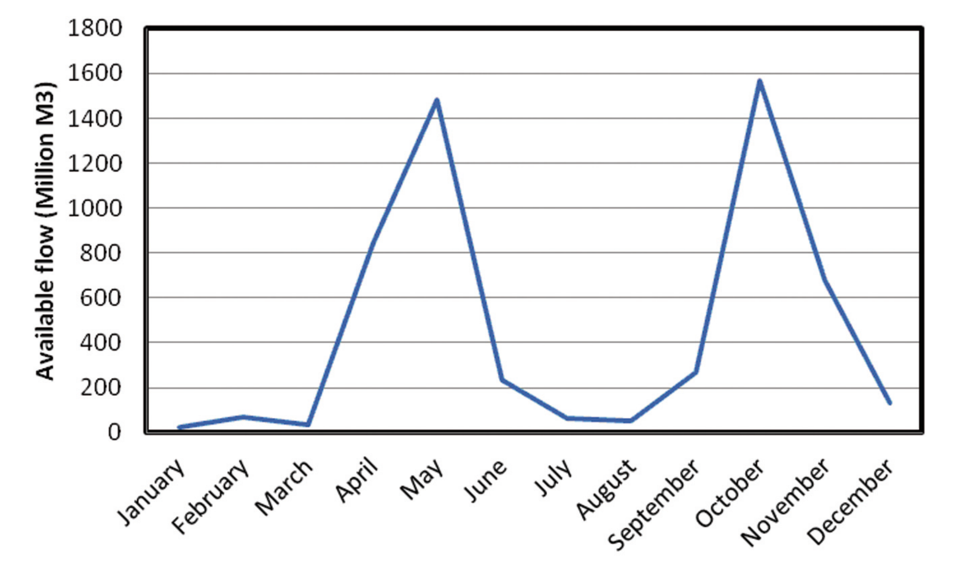

FIGURE 3: Monthly variation of available water resources in Juba-Shebelle basin

5. RESULTS

5.1. Scenario: reference

Results show that the population growth figures in the region would result in domestic water demand growing from 11% of supply to 19.3% of supply (Table 7). Up gto 50% of this demand is accounted for by Oromia region in Ethiopia. The irrigated areas are shown in Table 3. The fact that temporal and spatial disctribution of supply is not uniform means it is not possible to meet all the domestic demand from the river resources. Table 8 shows the nodes that have demand deficits in Juba-Shebelle basin. The demand deficit can be met from other resources like groundwater and water harvesting. Another option is to construct storage in form of dams and reservoirs to store water during the wet months and use it during the dry months.

Region	2011	2016	2021	2026	2031
Domestic demand					
Baay	24.7	28.4	32.6	37.5	43
Bakool	5	5.8	6.7	7.7	8.8
Gedo	12.9	14.8	17	19.5	22.4
Harari People	4.2	4.9	5.7	6.7	7.8
Hiiraan	3.6	4.1	4.7	5.4	6.2
Jubbada_Dhexe	8.1	9.3	10.6	12.2	14
Jubbada_Hoose	13.2	15.1	17.4	19.9	22.9
Kenya_Central	13.6	15.5	17.7	20.2	23.1
Kenya_Eastern	41.5	47.4	54.1	61.8	70.5
Kenya_NorthEaster	20.9	23.9	27.2	31.1	35.5
Kenya_RiftValley	25.4	29.1	33.2	37.9	43.3
Oromia	295.6	346.2	405.5	474.9	556.1
SNNP	8.2	9.6	11.2	13.2	15.4
Shabeellaha_Dhexe	8.7	10	11.5	13.2	15.1
Shabeellaha_Hoose	30.6	35.1	40.3	46.3	53.2
Somali	61.9	72.5	84.9	99.4	116.4
Total (domestic)	**578.1**	**671.7**	**780.3**	**906.9**	**1053.7**
Irrigation demand					
Ethiopia	292.7	292.7	292.7	292.7	292.7
Kenya	42.8	42.8	42.8	42.8	42.8
Somalia	856.9	856.9	856.9	856.9	856.9
Total (irrigation)	**1192.4**	**1192.4**	**1192.4**	**1192.4**	**1192.4**
Overall demand	**1770.4**	**1863.9**	**1972.7**	**2099.2**	**2246.4**

Table 7. Domestic and irrigation demand in Juba-Shebelle basin (Million m^3)

5.2. Scenario – Reservoir storage

The demand deficits from the reference scenario were quite high averaging more than 25% of the total demand by 2031. To investigate means of reducing the deficit, an additional scenario was simulated by including different sizes of reservoirs to store water during the

Region	2011	2016	2021	2026	2031
Domestic deficit					
Baay	0	0	0	0	0.1
Bakool	0	0	0	0	0
Gedo	0	0	0	0	0
Harari People	0	0	0.1	0.2	0.3
Hiiraan	0	0	0	0	0
Jubbada_Dhexe	0	0	0	0	0
Jubbada_Hoose	0	0	0	0	0
Kenya_Central	2.3	2.9	3.7	4.5	5.5
Kenya_Eastern	15.8	18.3	21.1	24.1	28.5
Kenya_NorthEaster	12.6	15	17.8	21.3	25.3
Kenya_RiftValley	4.3	5.5	6.9	8.5	10.3
Oromia	18.4	31.3	46.4	68.3	104.9
SNNP	0.7	1.1	1.5	2.1	3.1
Shabeellaha_Dhexe	0	0	0	0	0
Shabeellaha_Hoose	0	0	0	0	0.1
Somali	0	0.2	1.2	2.5	3.9
Total (domestic)	**54.1**	**74.3**	**98.7**	**131.6**	**182**
Irrigation deficit					
Ethiopia	92.3	94.8	96.9	99.5	101.8
Kenya	7.9	7.9	7.9	7.9	7.9
Somalia	270.1	275.7	282.7	290.8	297.9
Total (irrigation)	**370.3**	**378.4**	**387.5**	**398.2**	**407.6**
Overall demand	**424.5**	**452.7**	**486.2**	**529.8**	**589.8**

TABLE 8. Demand deficit in Juba-Shebelle basin (Million m^3).

wet months for usage during the dry months. The average storage volumes needed to ensure that all demand deficits in the system are reduced to zero are shown in Table 9. The table shows that a total of water storage capacity 356 Million m3 would be required to meet the projected demands by 2031.

Demand node	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Active volume
Ewaso Ngiro reservoir	21.5	25	22	25	25	25	22.3	18	25	25	25	25	7.0
Genale reservoir	92.3	82.2	46.8	150	150	150	124.7	94.1	111	150	150	126.5	103.2
Lak Bor reservoir	19.8	15.8	10.9	20	20	20	15.3	10.4	6.1	20	20	20	13.9
Shebelle reservoir	181	120.5	59.4	173.4	300	300	249.4	187.9	219.7	300	300	253	240.6
Total	**314.7**	**243.5**	**139.2**	**368.4**	**495**	**495**	**411.8**	**310.3**	**361.7**	**495**	**495**	**424.5**	**355.8**

TABLE 9. Storage volumes in Juba-Shebelle basin(Million m^3).

6. COMMENTS

The above simulations demonstrate that:

- Water resources in the Juba-Shebelle basins are already quite stretched. During the dry months, the water resources are not sufficient to meet the current water demands;
- Construction of water storage reservoirs would help in addressing the current water demand needs in the basin. A total storage of at least 360 million m3 is necessary for this;
- Implementation of water demand management measures is needed. This is especially true for irrigation water demand management which accounts for 70% of the demand deficit.

8

TURKANA-OMO BASIN

Demand centres were conceptualised as nodes where the demand is concentrated.

Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Turkana-Omo basin is shown in Figure 4.

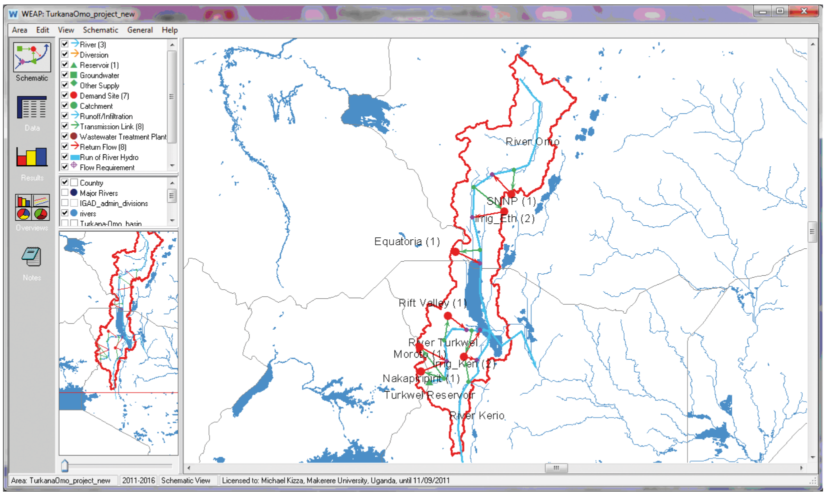

Figure 4: Model setup for Turkana-Omo basin

1. POPULATION PROJECTIONS

Table 10 shows the basin population updated to 2011 while Table 11 shows the population projections.

2. DEMAND DATA

ID	Region/District	Country	Total population	Ratio of area in Basin (%)	Population in Basin	Reference year	Population Growth rate	2011 population
ET-1	Oromia	Ethiopia	27,158,471	13.2	3,576,493	2007	3.21	4058303
ET-2	SNNP	Ethiopia	15,042,531	72.7	10,940,179	2007	3.21	12413994
KE-3	Rift Valley	Kenya	6987036	42.3	2,952,359	1999	2.69	4059822
SU-1	Equatoria	Sudan	1,341,000	0.8	10,713	2007	2.14	11660
UG-1	Moroto*	Uganda	170,500	6.6	11,178	2007	3.20	14842
UG-2	Nakapiripirit**	Uganda	156,500	29.5	46,223	2007	2.00	55,241
Total Population								**20,613,862**

** From www.moroto.go.ug*
*** From www.nakapiripirit.go.ug*

Table 10. Population data for the regions in Turkana-Omo basin.

Region	2011	2016	2021	2026	2031
Nakaprirpirit	55,241	64,978	76,430	89,901	105,747
Moroto	14,842	17,458	20,535	24,154	28,412
Rift Valley	4,059,822	4,636,046	5,294,056	6,045,459	6,903,512
Equatoria	11,660	12,962	14,410	16,019	17,808
SNNP	12,413,994	14,538,527	17,026,654	19,940,599	23,353,237
Oromia	4,058,303	4,752,842	5,566,244	6,518,852	7,634,490
Total	23,568,609	27,396,937	31,851,354	37,034,884	43,067,596

TABLE 11. Population projections in Turkana-Omo basin.

2.1. Domestic demand

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m^3 per capita per annum.

2.2. Irrigation demand

The irrigation water demand rate was fixed at 12,000 m^3/year. The irrigated areas in Ethiopia and Kenya parts of the basin are 46,933 ha and 9,720 ha respectively. There is no documented irrigation on the Sudan and Uganda parts of the basin.

3. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 28,108x106 m^3 with the monthly distribution as shown in Figure 5.

4. RESULTS

4.1. Scenario: Reference

Domestic demand grows from 618 million m^3 (48% of total demand) in 2011 to 1,141 million m^3 (62%) in 2031 (Table 12). The total water demand was projected to increase from 1,298 million m^3 in 2011 to 1,821 million m^3 in 2031.

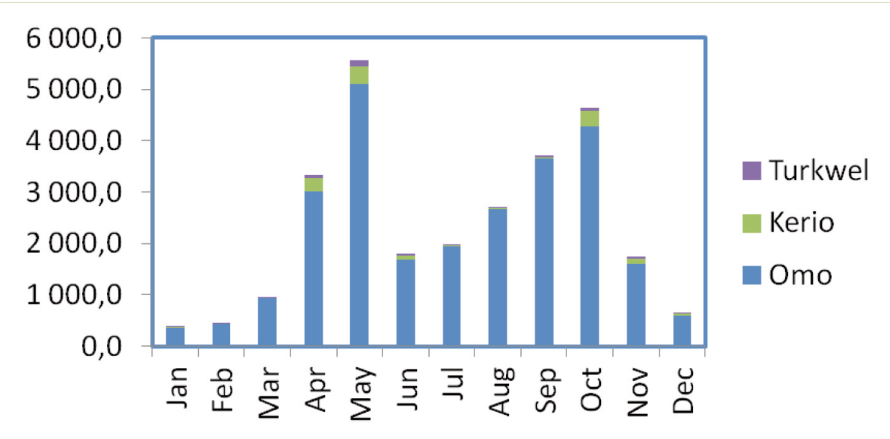

FIGURE 5: Monthly variation of available water resources in Turkana-Omo basin (million m^3).

As a percentage of available water resources, this represents an increase from 5% in 2011 to 7% in 2031.

Analysis of monthly demand-supply balance shows that the water resources are adequate to meet the water demand under reference conditions apart from Nakapiripirit, Moroto and Rift Valley provinces served by River Turkwel and River Kerio. There is also a demand deficit of 9 million m^3 for irrigation in Kenya. The total demand deficit in 2031 is 57 million m^3, which represents less than 1% of the total demand for the year.

4.2. Scenario – Irrigation demand management

Demand Node	2011	2016	2021	2026	2031
Equatoria	0.3	0.4	0.4	0.5	0.5
Moroto	0.4	0.5	0.6	0.7	0.9
Nakapiripirit	1.7	1.9	2.3	2.7	3.2
Oromia	127.7	142.6	167.0	195.6	229.0
Rift Valley	121.8	139.1	158.8	181.4	207.1
SNNP	372.4	436.2	510.8	598.2	700.2
Domestic Total	**618.4**	**720.7**	**839.9**	**979.0**	**1,141.3**
Irrigation (Ethiopia)	563.4	563.4	563.4	563.4	563.4
Irrigation (Kenya)	116.6	116.6	116.6	116.6	116.6
Irrigation Total	**680.1**	**680.1**	**680.1**	**680.1**	**680.1**
Overall Total	**1,298.5**	**1,400.8**	**1,520.0**	**1,659.1**	**1,821.4**

TABLE 12. Domestic and irrigation demand in Turkana-Omo basin (Million m^3).

the demand deficits from the reference scenario are relatively low at less than 1% of the total demand by 2031. As such, only demand management measures aimed at reducing the deficit were investigated. A reduction in irrigation water demand of 2% per year, starting in 2012, would be sufficient for balancing the system and ensuring there are no demand deficits.

Demand Node	2011	2016	2021	2026	2031
Domestic deficit					
Equatoria	0	0	0	0	0
Moroto	0	0.1	0.1	0.2	0.3
Nakapiripirit	0	0	0	0.1	0.1
Rift Valley	2.3	4.5	8.1	20.3	47.6
SNNP	0	0	0	0	0
Domestic Total	**2.3**	**4.6**	**8.2**	**20.6**	**48**
Irrigation (Ethiopia)	0	0	0	0	0
Irrigation (Kenya)	9	9	9	9	9
Irrigation Total	**9**	**9**	**9**	**9**	**9**
Overall Total	**11.3**	**13.6**	**17.2**	**29.6**	**57**

TABLE 13. Demand deficit in Turkana-Omo basin (Million m^3).

4.3. Scenario – Doubling of irrigated area for ethiopia

Analysis for the sensitivity of the system to expansion of irrigation infrastructure showed that doubling the area under irrigation in Ethiopia is possible. This is because River Omo contributes to over 90% of the water resources in the basin. The irrigated area in Ethiopia would have to be increased 5-fold before demand outstrips supply in the Omo basin. While the actual potential for expansion in Ethiopia (in terms of available irrigable land) may be less than this. Possibilities of inter-basin water transfers can be investigated.

5. COMMENTS

The above water resources management simulations for Turkana-Omo basin demonstrate that:

- The Turkana-Omo basin has a vast reserve of water resources in the form of River Omo flows. This reserve can support additional expansion of irrigated areas in Ethiopia;
- While the Turkwel river basin can support the water demands under current conditions, meeting future demands will require both demand side and supply side water conservation measures.

9

GASH-BARKA BASIN

1. MODEL SETUP

Demand centres were conceptualised as nodes where the demand is concentrated. Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Gash-Barka basin is shown in Figure 6.

2. POPULATION PROJECTIONS

Table 14 shows the basin population updated to 2011 while Table 15 shows the population projections.

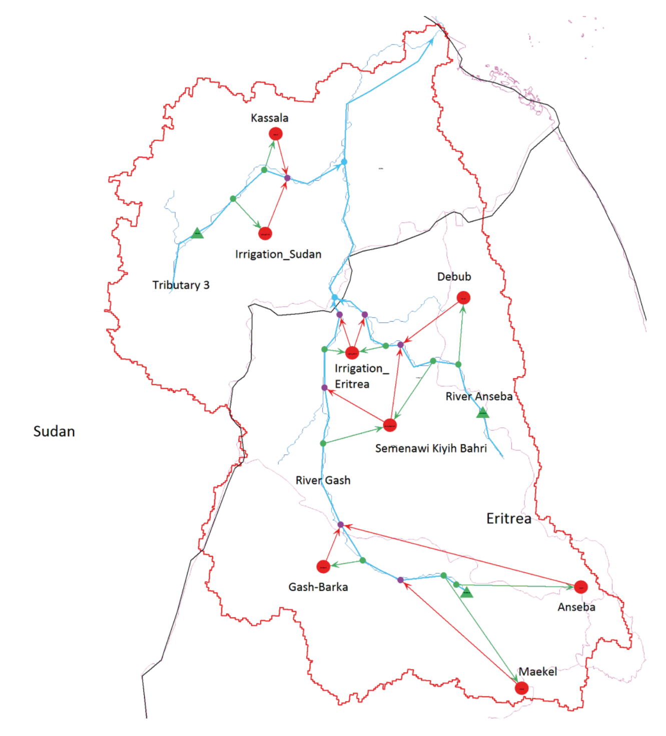

FIGURE 6: Model setup for Gash-Barka basin.

3. DEMAND DATA

ID	Region/District	Country	Total population	Ratio of area in Basin (%)	Population in Basin	Reference year	Population Growth rate	2011 population
SU-1	Kassala	Sudan	1,752,000	7.4	128,960	2007	2.14	140,358
ERI-1	Anseba	Eritrea	484,200	50.8	246,080	2005	3.20	297,272
ERI-2	Debub	Eritrea	952,100	13.2	125,997	2005	3.20	152,208
ERI-3	Gash Barka	Eritrea	625,100	47.1	294,440	2005	3.20	355,693
ERI-4	Maekel	Eritrea	675,700	6.7	45,295	2005	3.20	54,718
ERI-5	Semenawi Keyih Bahri	Eritrea	653,300	98.2	641,775	2005	3.20	775,284

Population estimates from http://faostat.fao.org

TABLE 14. Population data for the regions in Gash-Barka basin

Region	2011	2016	2021	2026	2031
Semenawi Keyih Bahri	**775,284**	**907,526**	**1,062,326**	**1,243,530**	**1,455,643**
Gash Barka	**355,693**	**416,365**	**487,385**	**570,520**	**667,835**
Anseba	**297,272**	**347,979**	**407,334**	**476,815**	**558,146**
Debub	**152,208**	**178,171**	**208,562**	**244,137**	**285,780**
Kasala	**140,358**	**156,033**	**173,459**	**192,830**	**214,365**
Maekel	**54,718**	**64,051**	**74,977**	**87,766**	**102,736**
Total	**1,775,533**	**2,070,125**	**2,414,042**	**2,815,597**	**3,284,505**

TABLE 15. Population projections in Gash-Barka basin.

3.1. Domestic demand

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m3 per capita per annum.

3.2. Irrigation demand

The irrigation water demand rate was fixed at 12,000m^3/year. The irrigated areas in Eritrea and Sudan are 5,057 ha and 13,677 ha respectively.

4. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 4,500x106 m^3 with the monthly distribution as shown in Table 16.

5. RESULTS

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
River Anseba	2.7	1.0	0.3	0.5	4.6	2.6	16.1	35.6	8.6	5.4	2.3	2.7	82.2
River Gash	2.7	0.5	-	0.5	6.7	10.4	117.8	184.8	36.3	13.4	3.1	2.7	378.9
Tributary	22.8	4.8	0.8	15.6	131.2	147.7	1,210.6	1,722.2	500.3	203.6	47.7	35.6	4.9
Total	**28.1**	**6.3**	**1.1**	**16.6**	**142.5**	**160.7**	**1,344.6**	**1,942.6**	**545.1**	**222.3**	**53.1**	**41.0**	**4,504.0**

TABLE 16. Monthly variation of available water resources in Gash-Barka basin (million m^3).

5.1. Scenario: Reference

Domestic demand grows from 53.3 million m^3 (19% of total demand) in 2011 to 99 million m^3 (30%) in 2031 (Table 17). The total water demand is projected to increase from 278 million m^3 in 2011 to 323 million m^3 in 2031. As a percentage of available water resources, this represents an increase from 6% in 2011 to 7% in 2031.

Analysis of monthly demand-supply balance shows that the water resources are inadequate to meet the water demand. The water demand deficit rises from 45 million m^3 in 2011 to 60

Demand node	2011	2016	2021	2026	2031
			Domestic demand		
Anseba	8.9	10.4	12.2	14.3	16.7
Debub	4.6	5.3	6.3	7.3	8.6
Gash Barka	10.7	12.5	14.6	17.1	20.0
Kassala	4.2	4.7	5.2	5.8	6.4
Maekel	1.6	1.9	2.2	2.6	3.1
Semenawi Keyih Bahri	23.3	27.2	31.9	37.3	43.7
Total (domestic)	**53.3**	**62.1**	**72.4**	**84.5**	**98.5**
			Irrigation demand		
Eritrea	60.7	60.7	60.7	60.7	60.7
Sudan	164.1	164.1	164.1	164.1	164.1
Total (irrigation)	**224.8**	**224.8**	**224.8**	**224.8**	**224.8**
Overall demand	**278.1**	**286.9**	**297.2**	**309.3**	**323.3**

TABLE 17. Domestic and irrigation demand in Gash-Barka basin (Million m^3).

million m^3 by 2031. The domestic demand deficit accounts for 19% of total deficit in 2011 but this percentage rises to 35% by 2031. The maximum demand deficit, which occurs in 2031 represents less than 20% of the total demand for the year and 4% of the available annual flow.

5.2. Scenario – Provision of storage

Region	2011	2016	2021	2026	2031
			Domestic demand deficit		
Anseba	1.8	2.3	3.0	4.0	5.2
Debub	0.1	0.2	0.3	0.4	0.6
Gash Barka	2.2	2.7	3.6	4.8	6.3
Kassala	0.0	0.0	0.0	0.0	0.0
Maekel	0.3	0.4	0.6	0.7	1.0
Semenawi Keyih Bahri	4.1	5.2	6.4	7.8	9.5
Total (domestic deficit)	**8.6**	**10.7**	**13.8**	**17.9**	**22.6**
			Irrigation demand deficit		
Eritrea	14.3	14.7	15.1	15.4	15.8
Sudan	21.6	21.6	21.7	21.8	21.9
Total (irrigation deficit)	**35.9**	**36.4**	**36.8**	**37.2**	**37.7**
Overall demand deficit	**44.5**	**47.1**	**50.6**	**55.1**	**60.3**

TABLE 18. Demand deficit in Gash-Barka basin (Million m^3).

To address the demand deficit, model simulation was carried out to estimate the required reservoir storage capacities. The demand deficits are mainly caused by the extensive dry period between November and April when river discharges drop to near zero. Water storage during the wet season (June-October) is necessary to mitigate this situation. The results showed that a total storage of 60 million m3 would be required to reduce the demand deficit under current demand conditions. The reservoir storage was assumed to be introduced in 2012.

5.3. Scenario – Doubling of irrigated area

Analysis for the sensitivity of the system to expansion of irrigation infrastructure showed that doubling the area under irrigation in both Eritrea and Sudan is possible. However, the required reservoir storage to achieve this would have to be more than doubled from 60 million m^3 (required for current irrigation water needs) to 135 million m^3.

6. COMMENTS

The above water resources management simulations for Gash-Barka basin demonstrate that the available water resources can meet current and projected water demands as long as water storage is allowed for to meet demand deficits during the dry months of November-April.

10

DANAKIL BASIN

1. MODEL SETUP

Demand centres were conceptualised as nodes where the demand is concentrated. Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Danakil basin is shown in Figure 7.

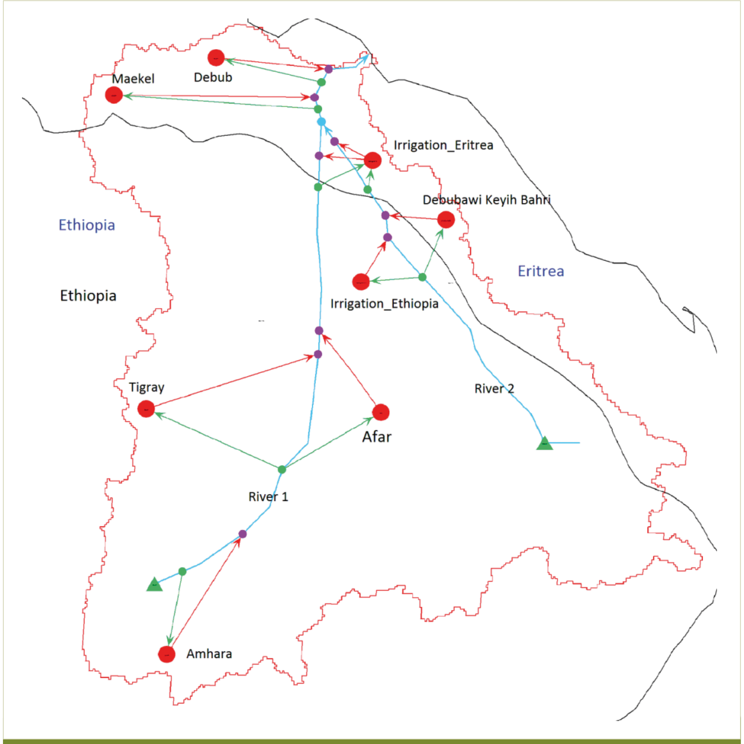

FIGURE 7: Model setup for Danakil basin.

2. POPULATION PROJECTIONS

Table 19 shows the basin population updated to 2011 while Table 20 shows the population projections.

ID	Country	Region/ District	Total population	Ratio of area in Basin (%)	Population in Basin	Reference year	Population Growth rate	2011 population
ETH-1	Afar	Ethiopia	1,411,092	47.4	668,264	2007	3.21	758,290
ETH-2	Amhara	Ethiopia	17,214,056	1.1	190,035	2007	3.21	215,635
ETH-3	Tigray	Ethiopia	4,314,456	10.6	457,562	2007	3.21	519,203
ERI-1	Debub	Eritrea	952,100	12.8	121,590	2005	3.20	146,884
ERI-2	Debubawi Keyih Bahri	Eritrea	293,000	17.7	51,869	2005	3.20	62,659
ERI-3	Maekel	Eritrea	675,700	6.9	46,912	2005	3.20	56,671
Total population								**1,759,342**

TABLE 19. Population data for the regions in Danakil basin;

Region	2011	2016	2021	2026	2031
Tigray	**519,203**	**607,765**	**711,433**	**832,785**	**974,835**
Afar	**758,290**	**887,634**	**1,039,040**	**1,216,272**	**1,423,735**
Debubawi Keyih Bahri	**62,659**	**73,347**	**85,858**	**100,503**	**117,646**
Maekel	**56,671**	**66,338**	**77,653**	**90,898**	**106,403**
Debub	**146,884**	**171,938**	**201,266**	**235,597**	**275,784**
Amhara	**215,635**	**252,416**	**295,472**	**345,871**	**404,868**
Total	**1,759,342**	**2,059,438**	**2,410,723**	**2,821,927**	**3,303,271**

Table 20. Population projections in Danakil basin

3. DEMAND DATA

3.1. Domestic demand

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m^3 per capita per annum.

3.2. Irrigation demand

The irrigation water demand rate was fixed at 12,000m^3/year. The irrigated area in the Ethiopian part of the basin is 4180 ha while that on the Eritrea side is 823 ha.

4. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 2,500x106 m^3 with the monthly distribution as shown in Table 21.

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
River 1	0.3	0.0	0.0	0.0	10.7	34.2	409.8	605.3	207.4	67.2	13.5	2.9	1,351.3
River 2	11.8	4.1	1.9	11.1	63.2	59.9	349.3	404.4	143.3	77.7	23.8	18.2	1,168.8
Total	**12.1**	**4.1**	**1.9**	**11.1**	**73.9**	**94.1**	**759.1**	**1,009.8**	**350.7**	**144.9**	**37.3**	**21.2**	**2,520.1**

Table 21. Monthly variation of available water resources in Danakil basin (million m^3).

5. RESULTS

5.1. Scenario: Reference

Domestic demand grows from 53 million m^3 (47% of total demand) in 2011 to 99 million m^3 (62%) in 2031 (Table 22). The total water demand is projected to increase from 112 million m^3 in 2011 to 159 million m^3 in 2031. As a percentage of available water resources, this represents an increase from 4.5% in 2011 to 6% in 2031.

Demand node	2011	2016	2021	2026	2031
		Domestic demand			
Afar	22.7	26.6	31.2	36.5	42.7
Amhara	6.5	7.6	8.9	10.4	12.1
Debub	4.4	5.2	6	7.1	8.3
Debubawi Keyih Bahri	1.9	2.2	2.6	3	3.5
Maekel	1.7	2	2.3	2.7	3.2
Tigray	15.6	18.2	21.3	25	29.2
Total (domestic)	**52.8**	**61.8**	**72.3**	**84.7**	**99**
		Irrigation demand			
Eritrea	9.9	9.9	9.9	9.9	9.9
Ethiopia	50.2	50.2	50.2	50.2	50.2
Total (irrigation)	**60.1**	**60.1**	**60.1**	**60.1**	**60.1**
Overall demand	**112.9**	**121.9**	**132.4**	**144.8**	**159.1**

TABLE 22. Domestic and irrigation demand in Danakil basin (Million m^3).

Analysis of monthly demand-supply balance shows that the water resources are inadequate to meet the water demand under reference contidions. The water demand deficit rises from 15 million m^3 in 2011 to 31 million m^3 by 2031. The domestic demand deficit accounts for 79% of total deficit in 2011 but this percentage rises to 87% by 2031. The maximum demand deficit, which occurs in 2031 represents less than 23% of the total demand for the year and 1.4% of the available annual flow.

Region	2011	2016	2021	2026	2031
		Domestic demand deficit			
Afar	7.6	9.2	11.1	13.2	15.8
Amhara	2.2	2.6	3.1	3.8	4.5
Debub	0	0	0	0	0
Debubawi Keyih Bahri	0	0	0	0	0
Maekel	0	0	0	0	0
Tigray	5.2	6.3	7.6	9.1	10.8
Total (domestic deficit)	**15.0**	**18.1**	**21.8**	**26.1**	**31.1**
		Irrigation demand deficit			
Eritrea	0	0	0	0	0
Ethiopia	4	4.1	4.3	4.5	4.8
Total (irrigation deficit)	**4**	**4.1**	**4.3**	**4.5**	**4.8**
Overall demand deficit	**19.0**	**22.2**	**26.1**	**30.6**	**35.9**

TABLE 23. Demand deficit in Danakil basin (Million m^3).

5.2. Scenario – Provision of storage

To address the demand deficit, model simulation was carried out to estimate the required reservoir storage capacities. The demand deficits are mainly caused by the extensive dry period between November and April during which the rivers usually dry up. Water storage during the wet season (June-October) is necessary to mitigate this situation. The results showed that a total storage of 32 million m^3 would be required to reduce the demand deficit under current demand conditions. The reservoir storage was assumed to be introduced in 2012.

5.3. Scenario – Development of groundwater resources

This scenario was aimed at assessing the impact of developing groundwater resources on the reduction of the demand deficit. The maximum water withdrawal for aquifers in Ayesha basin was assumed to be 900,000 m^3/year or 10 times the well productivities given in Table 4. Recharge rates were assumed at 2% of the surface runoff rates. Table 24 shows the reduction in deficit (as percentages) for domestic and irrigation demands. The domestic demand deficits reduces by about 20%% in 2011 though this figure reduces to 10%% by 2031. Irrigation demand in Ethiopia reduces by 32% due to savings of surface water resources.

Region	2011	2016	2021	2026	2031
Domestic deficit					
Afar	21.7	19.0	16.0	12.7	10.7
Amhara	23.1	18.5	14.4	13.7	10.9
Debub	0	0	0	0	0
Debubawi Keyih Bahri	0	0	0	0	0
Maekel	0	0	0	0	0
Tigray	21.7	19.0	16.0	13.3	10.6
Irrigation deficit					
Eritrea	0	0	0	0	0
Ethiopia	32.4	33.8	36.3	38.2	41.0
Total (irrigation deficit)	**32.4**	**33.8**	**36.3**	**38.2**	**41.0**

Table 24. Percentage reduction in demand deficit due to exploitation of groundwater resources for selected years.

5.4. Scenario – Doubling of irrigated area

Analysis for the sensitivity of the system to expansion of irrigation infrastructure showed that doubling the area under irrigation in both Eritrea and Ethiopia is possible. However, the required reservoir storage to achieve this would have to be increased from 32 million m^3 to 43 million m^3 or an increase of 35%.

6. COMMENTS

The above water resources management simulations for Danakil basin demonstrate that

- The available water resources can meet current and projected water demands as long as water storage is allowed for to meet demand deficits during the dry months of November-April.
- Exploitation of groundwater resources would reduce domestic demand deficits by about 20% in 2011 and 10% in 2031. Irrigation demand in Ethiopia reduces by 32% due to savings of surface water resources.

11

OGADEN BASIN

1. MODEL SETUP

Demand centres were conceptualised as nodes where the demand is concentrated. Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Ogaden basin is shown in Figure 8.

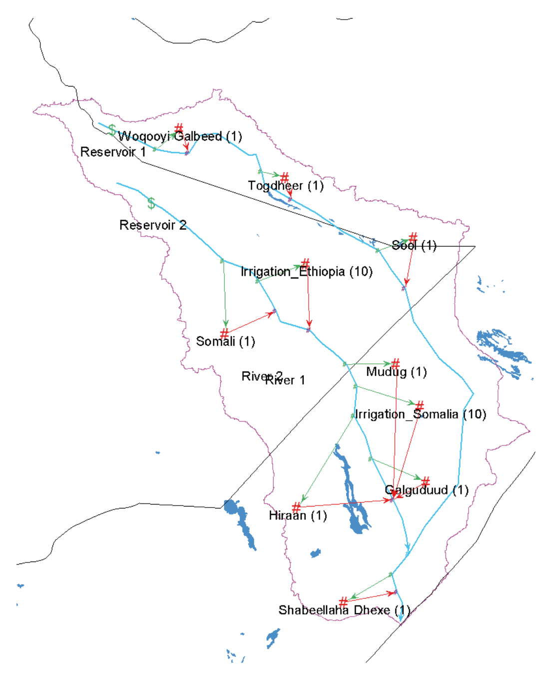

FIGURE 8: Model setup for Ogaden basin.

2. POPULATION PROJECTIONS

The population data for the different constituent regions of each country were derived by the socio-economist. It was assumed that the number of people to be considered in the sharing of the basin water resources is proportional to the ratio of the regional area that falls within the basin. Table 25 shows the basin population updated to 2011 while Table 26 shows the population projections.

ID	Region/District	Country	Total population	Ratio of area in Basin (%)	Population in Basin	Reference year	Population Growth rate	2011 population
ETH-1	Somali	Ethiopia	4,439,147	27.9	1,236,913	2007	3.21	1,403,545
SOM-2	Galguduud	Somalia	627,806	98.4	617,498	2007	2.81	689,885
SOM-3	Hiiraan	Somalia	219,300	26.7	58,644	2007	2.81	65,519
SOM-4	Mudug	Somalia	350,099	47.8	167,392	2007	2.81	187,015
SOM-6	Shabeellaha Dhexe	Somalia	863,571	6.3	54,259	2007	2.81	60,620
SOM-7	Sool	Somalia	143,000	9.2	13,656	2007	2.81	15,257
SOM-8	Togdheer	Somalia	350,000	59.9	209,644	2007	2.81	234,220
SOM-9	Woqooyi Galbeed	Somalia	1,163,143	30.1	350,548	2007	2.81	391,642
Total population								**3,047,703**

TABLE 25. Population data for the regions in Ogaden basin.

Region	2011	2016	2021	2026	2031
Somali	**1,403,545**	**1,642,952**	**1,923,195**	**2,251,240**	**2,635,241**
Woqooyi Galbeed	**391,642**	**449,848**	**516,705**	**593,499**	**681,705**
Togdheer	**234,220**	**269,030**	**309,014**	**354,940**	**407,691**
Sool	**15,257**	**17,525**	**20,129**	**23,121**	**26,557**
Mudug	**187,015**	**214,809**	**246,735**	**283,405**	**325,524**
Galguduud	**689,885**	**792,416**	**910,186**	**1,045,459**	**1,200,837**
Hiiraan	**65,519**	**75,257**	**86,441**	**99,288**	**114,045**
Shabeellaha Dhexe	**60,620**	**69,629**	**79,978**	**91,864**	**105,517**
Sum	**3,047,703**	**3,531,466**	**4,092,383**	**4,742,815**	**5,497,116**

TABLE 26. Population projections in Ogaden basin.

3. DEMAND DATA

3.1. Domestic demand

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m3 per capita per annum.

3.2. Irrigation demand

The irrigation water demand rate was fixed at 12,000m^3/year. The irrigated area in the Ethiopian part of the basin is 2,649 ha while that on the Somalia side is 23,165 ha.

4. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 3,600x10^6 m^3 with the monthly distribution as shown in Table 27.

River	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
River 1	29.7	27.3	59.2	42.0	185.1	216.7	422.4	509.7	632.4	437.9	229.1	83.0	2,874.6
River 2	4.6	15.0	9.1	122.1	176.0	47.4	24.9	20.6	40.4	177.6	77.8	16.3	731.8
Total	**34.3**	**42.3**	**68.3**	**164.1**	**361.0**	**264.1**	**447.3**	**530.3**	**672.9**	**615.5**	**306.9**	**99.4**	**3,606.4**

TABLE 27. Monthly variation of available water resources in Ogaden basin (million m^3).

5. RESULTS

5.1. Scenario: Reference

Domestic demand grows from 91 million m^3 (23% of total demand) in 2011 to 165 million m^3 (31%) in 2031 (Table 28). The total water demand is projected to increase from 401 million m^3 in 2011 to 475 million m^3 in 2031. As a percentage of available water resources, this represents an increase from 11% in 2011 to 13% in 2031.

Region	2011	2016	2021	2026	2031
Domestic demand					
Galguduud	20.7	23.8	27.3	31.4	36
Hiiraan	2	2.3	2.6	3	3.4
Mudug	5.6	6.4	7.4	8.5	9.8
Shabeellaha Dhexe	1.8	2.1	2.4	2.8	3.2
Somali	42.1	49.3	57.7	67.5	79.1
Sool	0.5	0.5	0.6	0.7	0.8
Togdheer	**7**	**8.1**	**9.3**	**10.6**	**12.2**
Woqooyi Galbeed	**11.7**	**13.5**	**15.5**	**17.8**	**20.5**
Total (domestic)	**91.4**	**106**	**122.8**	**142.3**	**165**
Irrigation demand					
Ethiopia	31.8	31.8	31.8	31.8	31.8
Somalia	278	278	278	278	278
Total (irrigation)	**309.8**	**309.8**	**309.8**	**309.8**	**309.8**
Overall demand	**401.2**	**415.8**	**432.6**	**452.1**	**474.8**

TABLE 28. Domestic and irrigation demand in Ogaden basin (Million m^3).

Analysis of monthly demand-supply balance shows that the water resources are inadequate to meet the water demand under reference contidions. The water demand deficit rises from 83 million m^3 in 2011 to 99 million m^3 by 2031. The domestic demand deficit accounts for 0% of total deficit in 2011 and rises marginally to 3% by 2031. The maximum demand deficit, which occurs in 2031 represents 20% of the total demand for the year and 3% of the available annual flow.

Region	2011	2016	2021	2026	2031
Domestic deficit					
Galguduud	0	0	0	0	0.4
Hiiraan	0	0	0	0	0
Mudug	0	0	0	0	0.1
Shabeellaha Dhexe	0	0	0	0	0
Somali	0	0	0.3	1.2	2.2
Sool	0	0	0	0	0
Togdheer	**0**	**0**	**0**	**0**	**0**
Woqooyi Galbeed	**0**	**0**	**0**	**0**	**0**
Total deficit (domestic)	**0**	**0**	**0.3**	**1.2**	**2.7**
Irrigation deficit					
Ethiopia	8.5	8.8	9.1	9.5	9.8
Somalia	74	76.5	79.4	82.7	86
Total (irrigation)	**82.5**	**85.3**	**88.5**	**92.2**	**95.8**
Overall demand	**82.5**	**85.3**	**88.8**	**93.4**	**98.5**

TABLE 29. Demand deficit in Ogaden basin (Million m^3).

5.2. Scenario – Provision of storage

To address the demand deficit, model simulation was carried out to estimate the required reservoir storage capacities. The demand deficits are mainly caused by the extensive dry period between December and April during which the rivers usually dry up. Water storage during the wet season (June-October) is necessary to mitigate this situation. The results showed that a total storage of 80 million m^3 would be required to reduce the demand deficit under current demand conditions. The reservoir storage was assumed to be introduced in 2012.

5.3. Scenario – Development of groundwater resources

This scenario was aimed at assessing the impact of developing groundwater resources on the reduction of the demand deficit. The maximum water withdrawal for aquifers in Ayesha basin was assumed to be 3,900,000 m^3/year or 10 times the well productivities given in Table 4. Recharge rates were assumed at 2% of the surface runoff rates. Table 30 shows the reduction in deficit (as percentages) for domestic and irrigation demands. The domestic demand deficits reduces by about 20% in 2021 in the Somali region, reduces to 10.5% in the same region in 2026. Reduction in irrigation demand deficits are in the order of 1-3%.

Region	2011	2016	2021	2026	2031
Domestic deficit					
Galguduud	-	-	-	-	57.2
Hiiraan	-	-	-	-	-
Mudug	-	-	-	-	53.6
Shabeellaha Dhexe	-	-	-	-	-
Somali	-	-	20.5	10.5	6.7
Sool	-	-	-	-	-
Togdheer	-	-	-	-	-
Woqooyi Galbeed	-	-	-	-	-
Total reduction - domestic (%)	**-**	**-**	**20.5**	**10.5**	**30.15**
Irrigation deficit					
Ethiopia	2.9	2.8	1.5	2.2	1.4
Somalia	2.4	2.3	2.3	2.2	1.7
Total reduction - irrigation (%)	**2.7**	**2.6**	**1.9**	**2.2**	**1.6**

Table 30. Percentage reduction in demand deficit due to exploitation of groundwater resources for selected years

5.4. Scenario – Doubling of irrigated area

Analysis for the sensitivity of the system to expansion of irrigation infrastructure showed that doubling the area under irrigation in both Ethiopia and Somalia is possible. However, the required reservoir storage to achieve this would have to be increased from 80 million m^3 to 175 million m^3 or an increase of more than 100%.

6. COMMENTS

The above water resources management simulations for Ogaden basin demonstrate that the available water resources can meet current and projected water demands as long as water storage is allowed for to meet demand deficits during the dry months of November-April. Development of groundwater resources would result in reduction of domestic demand of about 25% for those regions were a deficit exists. The reductions in irrigation demand deficit would average 2%.

12

AYESHA BASIN

1. MODEL SETUP

Demand centres were conceptualised as nodes where the demand is concentrated. Domestic demand nodes represent the population of the largest administrative unit in each country that falls within the study basin. For each river, the river flow is assumed to be available for the entire length of the river. The resulting model for Ayesha basin is shown in Figure 9.

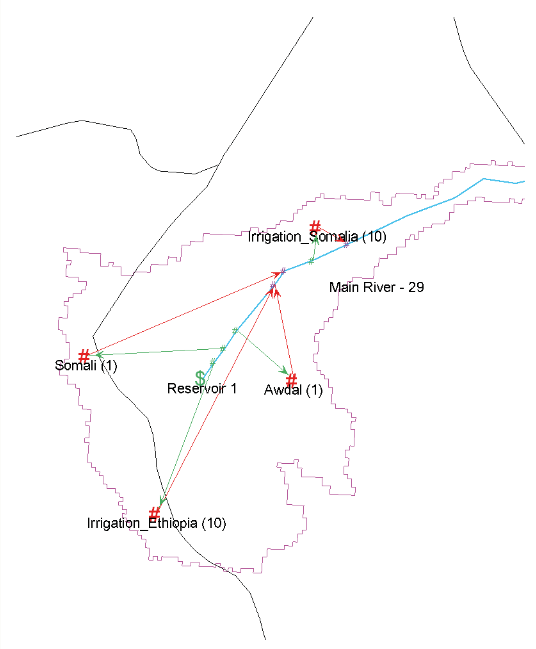

Figure 9: Model setup for Ayesha basin.

2. POPULATION PROJECTIONS

The population data for the different constituent regions of each country were derived by the socio-economist. It was assumed that the number of people to be considered in the sharing of the basin water resources is proportional to the ratio of the regional area that falls within the basin. Table 31 shows the basin population updated to 2011 while Table 32 shows the population projections.

ID	Region/District	Country	Total population	Ratio of area in Basin (%)	Population in Basin	Reference year	Population Growth rate	2011 population
ETH	Somali	Ethiopia	4,439,147	0.3	13,708	2007	3.21	15,555
SOM	Awdal	Somalia	417,311	24.6	102,471	2007	2.81	114,483
Total population								**130,038**

Table 31. Population data for the regions in Ayesha basin

Region	2011	2016	2021	2026	2031
Somali	**15,555**	**17,867**	**20,522**	**23,572**	**27,076**
Awdal	**114,483**	**134,011**	**156,869**	**183,627**	**214,949**
Total	**130,038**	**151,878**	**177,391**	**207,199**	**242,024**

TABLE 32. Population projections in Ayesha basin.

3. DEMAND DATA

12.3.1 DOMESTIC DEMAND

The domestic and industrial water demands have been lumped into a single figure assumed at 80 litres per capita per day. This converts to an average annual domestic demand of 30 m^3 per capita per annum.

3.2. Irrigation demand

There is no documented data about irrigation in Ayesha basin. However, sensitivity analysis of the system was carried out to ascertain whether enough water resources are available for irrigation. Two levels of irrigation were assumed namely; (1) a total irrigated area of 1000 ha and (2) a total irrigated area of 3000 ha. The irrigated area of 1000 ha represents a realistic level for a basin of Ayesha's size while an irrigated area of 3000 ha represents the limiting irrigation level for the available water resources. The proportions of the irrigated area in Ethiopia and Somalia where assumed to be proportional to the areas of the two countries falling within the basin of 970 km^2 and 4269 km^2 respectively. The irrigation water demand rate was fixed at 12,000m^3/year.

4. RIVER FLOW

The river flow data were modelled using SWAT. The annual available water resource is 126x10^6 m^3 with the monthly distribution as shown Table 33.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Flow	0	0	0	0	0.3	1.6	34.8	67	18.9	2.9	0.3	0	125.7

TABLE 33. Monthly variation of available water resources in Ayesha basin (million m^3).

5. RESULTS

5.1. Scenario: Reference

Domestic demand (which is also the total water demand because there are no documented irrigation withdrawals in the region) grows from 3.9 million m3 in 2011 to 7.3 million m3 in 2031 . The water demand for Awdal region in somalia accounts for 88% of this demand while that for Somali region in Ethiopia accounts for 12 percent. The domestic water demand represents.

Analysis of monthly demand-supply balance shows that the water resources are inadequate to meet the water demand under reference contidions. The water demand deficit rises from 1.7 million m^3 in 2011 to 3.7 million m^3 by 2031. The domestic demand deficit accounts for 0% of total deficit in 2011 and rises marginally to 3% by 2031. The maximum demand deficit, which occurs in 2031 represents 52% of the total demand for the year and 3% of the available annual flow.

Region	2011	2016	2021	2026	2031
Somali	**1.53**	**1.87**	**2.27**	**2.73**	**3.28**
Awdal	**0.21**	**0.25**	**0.30**	**0.35**	**0.41**
Sum	**1.74**	**2.12**	**2.56**	**3.08**	**3.69**

Table 34. Domestic demand deficit in Ayesha basin

5.2. Scenario – Provision of storage

To address the demand deficit, model simulation was carried out to estimate the required reservoir storage capacities. The demand deficits are mainly caused by the extensive dry period between December and April during which the river dries up. Water storage during the wet season (June-October) is necessary to mitigate this situation. The results showed that a total storage of 3.7 million m^3 would be required to reduce the demand deficit under current demand conditions. The reservoir storage was assumed to be introduced in 2012.

5.3. Scenario – development of groundwater resources

This scenario was aimed at assessing the impact of developing groundwater resources on the reduction of the demand deficit. The maximum water withdrawal for aquifers in Ayesha basin was assumed to be 250,000 m^3/year or 10 times the well productivities given in Table 4. Recharge rates were assumed at 10% of the surface runoff rates. Table 35 shows the reduction in demand deficit (as percentages) for the two regions of Awdal and Somali. The deficit reduces by 40% in 2011 though this figure reduces to 20% by 2031.

Region	2011	2016	2021	2026	2031
Somali	**7.0**	**5.7**	**4.7**	**3.9**	**3.3**
Awdal	**32.9**	**27.4**	**23.0**	**19.4**	**16.5**
Sum	**39.9**	**33.1**	**27.7**	**23.3**	**19.8**

Table 35. Percentage reduction in demand deficit due to exploitation of groundwater resources for selected years

5.4. Scenario – Inclusion of irrigation in the system

Analysis for the sensitivity of the system to introduction of irrigation showed that;

- Irrigation of 1000 ha (185 ha in Ethiopia and 815 ha in Somalis) would require the storage to be increased from 3.7 million m^3 to 8 million m^3.
- Irrigation of 3000 ha (554 ha in Ethiopia and 2446 ha in Somalia) would require the

storage to be increased from 3.7 million m^3 to 23 million m^3.

6. COMMENTS

The above water resources management simulations for Ayesha basin demonstrate that:

- The available water resources can meet current and projected water demands as long as water storage is allowed for to meet demand deficits during the dry months of November-May.
- Exploitation of groundwater resources would reduce the demand deficit by up to 40% in 2011 and 20% in 2031.
- Development of irrigation would require investment in water storage infrastructure.

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CONCLUSIONS

The water resources management challenges of IGAD countries are many and tend to have cross-border implications. They include; endemic poverty, rapidly growing populations, desertification, highly variable rains that affect rainfall and frequently cause droughts, famine and starvation, land degradation due to deforestation, civil strife. Implementing IWRM in transboundary basins provides a viable mechanism for addressing the challenges. The concept of IWRM is represented by its principles which provide a backbone to the process of preparing transboundary water management plans. They define the need for conserving the water resources, importance of a participatory approach to water resources development and management, the role of women in water resources provision and management and the economic value of water.

The modelling of water resources management in the IGAD region is challenging. Water resources are sparsely distributed in space and highly variable in time. Additionally, data on water demand and usage are scarce and can be unreliable in areas where they exist. The WEAP model has been used for modelling water resources management in many regions around the world. It provides a means of analysing the effect of polices interventions (both structural and non-structural) on water resources availability and demand in a region. The model was successfully developed for 6 transboundary basins in the IGAD region. The demand and supply data used were based on the socioeconomic and water resources modelling studies. The possible use of the models in testing the effect of alternative water management scenarios was investigated. The main idea behind the development of the models was the models will evolve over time as more information about water resources, demand and other policy issues becomes available.

The model was set up for a base year of 2011 while simulations were carried out for 20 years ending in 2031. Initial water resources scenario assessments showed that all basins have considerable water resources which, if well managed, can serve the needs of the basin inhabitants. The annual water resources and water demand estimates for 2011 and 2031 are shown in Table 36. It is generally clear from the table that the available water resources in the basins are sufficient to meet current and future demands. The ratio of water demands to available supply averages only 9% in 2011 to 15% in 2031. The problem is one of spatial and temporal variation in water availability. The rivers mainly flow during the wet season which lasts only 4-5 months between June and October annually. The other 7-8 months are generally dry with many of the rivers drying up. This generally implies that, to meet the projected demands, investment in water storage (in form of dams and reservoirs) is inevitable. Some preliminary estimates of required storage were computed. The estimates need further refining as more data becomes available.

Basin	Available water resources ($x10^6$ m^3)		Domestic demand ($x10^6$ m^3)		Agriculture demand ($x10^6$ m^3)	Total demand ($x10^6$ m^3)	
	Surface water	Ground water	2011	2031	2011	2011	2031**
Juba-Shebelle	64,600	43,700	578	1,054	1,192	1,770	2,824
Turkana-Omo	28,700	19,300	707	1,293	680	1,387	2,680
Gash-Barka	2,800	1,400	53	225	225	278	503
Danakil	1,000	600	52	99	60	112	211
Ogaden	14,100	6,500	91	165	310	401	566
Ayesha	123	-	4	7	0	4	11
Total	111,323	71,500	1,485	2,843	2,467	3,952	6,795

*** Irrigation demands assumed at 2011 values. For total demands including irrigation demand projections, see the specific scenarios in the main report.*

TABLE 36. Annual total water resources and water demands for transboundary basins in IGAD region

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RECOMMENDATIONS

The following recommendations can be drawn from the IWRM modelling study

- The implementation of IWRM is complicated by lack of political will, lack of institutional and legal tools and also lack of human resources capacity. There are many international organisations with experience in supporting developing countries to start the process of IWRM implementation. These include Global Water Partnership, UNESCO, UNDP, Cap-Net, IWMI, UNEP and others. These organisations should be brought on board as early as possible to share their experiences and also support the implementation of IWRM in the transboundary basins of IGAD.
- The IWRM models were built from the data available at the time of analysis. More detailed analysis will require further data collection concerning water demands and demand growth rates including specific information about planned future developments in the water sectors of the IGAD sub-region. In particular, livestock water demands represent a significant water user in the IGAD countries but data on this were not available.
- The IWRM models were built in such a that further refinements can be made by users. WEAP model can be used for a range of applications including scenario assessment, impacts of climate change, irrigation management, water supply modelling, etc. Training of model users will help in ensuring that the use of the model is integrated in their daily work and a critical mass of professionals can be built to implement the model at Transboundary basin level.

LITERATURE SOURCES FOR THE IWRM COMPONENT

Brels, S., Coates, D., and Loures, F. (2008). Transboundary water resources management: the role of international watercourse agreements in implementation of the CBD. CBD Technical Series no. 40, 48 pages. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Economic Commission for Africa (2006) Water in Africa: Management Options to Enhance Survival and Growth. AU/NEPAD Commission

FAO (2003) Review of World Water Resources by Country FAO, Rome

GWP (2000). Integrated Water Resources Management, Global Water Partnership Technical Advisory Committee Background Papers, No. 4, 2000.

IGAD (2007) IGAD Environment and Natural Resources Strategy, InterGovernmental Authority on Development, IGAD Secretariat, Djibouti

IGAD (2003) IGAD Strategy, InterGovernmental Authority on Development, IGAD Secretariat, Djibouti

IGAD (2003) Pilot Project on Water Harvesting on the IGAD Region

IGAD (2009) Environmental Security in the Igad Region: An Approach for Building Sustainable Development and Peace. Workshop Report. Addis Ababa, Ethiopia

Jakob Granit (2000) Management of Shared Water Resources in Southern Africa and the Role of External Assistance, 1st WARFSA/WaterNet Symposium: Sustainable Use of Water Resources; Maputo

Torkil Jønch-Clausen (2004) Integrated Water Resources Management (IWRM) and Water Efficiency Plans by 2005: Why, What and How? Global Water Partnership, Sweden

Protos (2005) Study on IWRM legislation. Final report

SIWI (2007) Transboundary Water Management as a Regional Public Good: Financing development – an example from the Nile Basin

UN Water (2008) Status Report on Integrated Water Resources Management and Water Efficiency Plans. Prepared for the 16th session of the Commission on Sustainable Development.

Woldemichael DT (2009) Climate change and transboundary water resource conflicts in Africa. Workshop report, Mombasa, Kenya

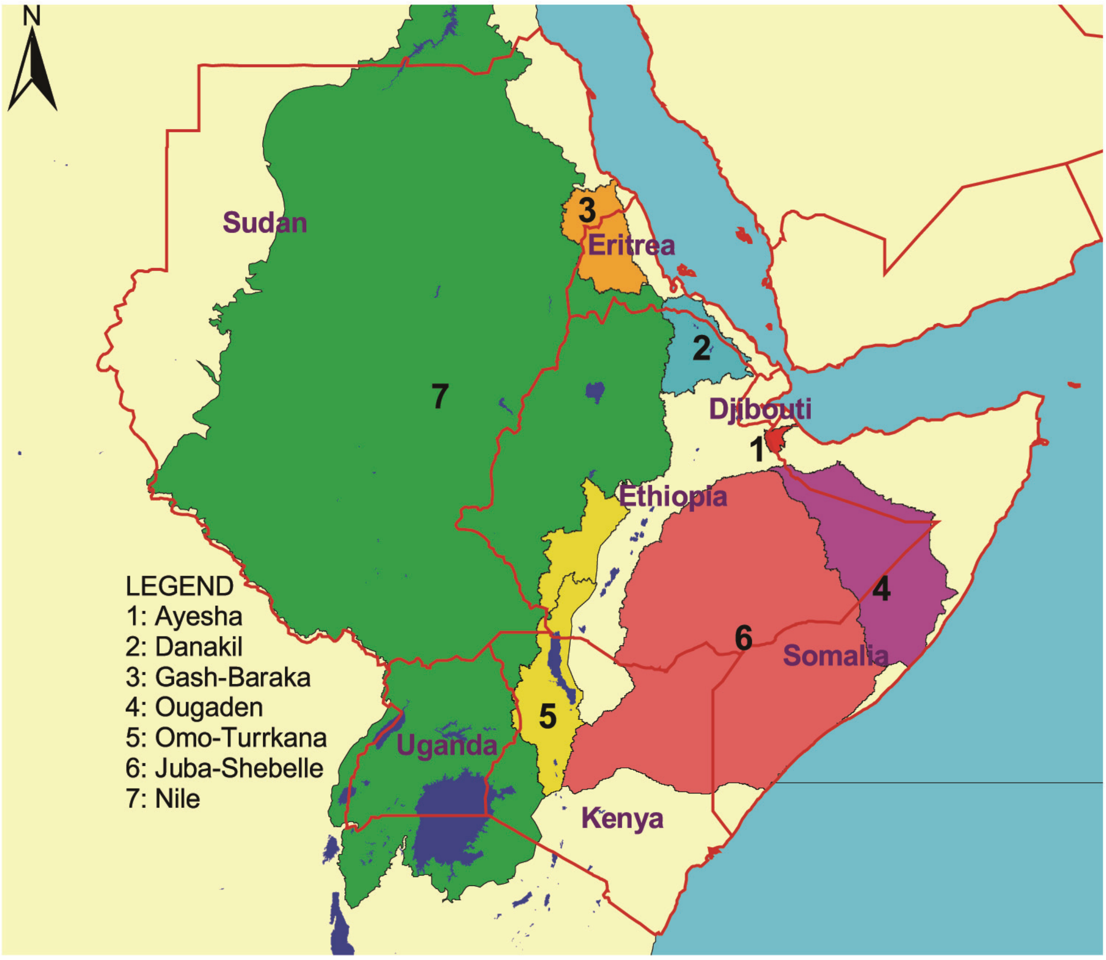
APPENDIX 1: CHALLENGES TO WATER RESOURCES MANAGEMENT IN THE IGAD COUNTRIES

Country	Key challenges in Water Resources Management
Djibouti	• Frequent droughts leading to famine and starvation • Population explosion with a growth rate of over 3% • Soil erosion following loss of vegetation • Water pollution from mineralized groundwater sources • Insufficient capacity for water resources management. Interventions are fragmented and uncoordinated • Rapid desertification. • Depletion of groundwater resources
Ethiopia	• Dependence on rain-fed subsistence agriculture to feed a large population • Frequent droughts causing famine, loss of livelihood and even death • Deforestation, changing land-use • Soil erosion and reservoir/lake sedimentations • Water sources pollution due to use of chemicals in agriculture, and municipal and industrial wastewater disposal. • High incidence of waterborne diseases • Flash flooding during the rainy season causes extensive damage and death • Depletion of groundwater sources due to over-exploitation • Soil pollution and salinity due to inefficient irrigation methods • Involuntary resettlement due to construction of dams, reservoir and other water related infrastructure
Eritrea	• Deforestation and soil erosion leading to land degradation • Variable rainfall leading to drought and famine • Flash flooding in parts of the country leads to loss of property, death and • High levels of poverty with seventy percent living below the poverty line • Low safe water coverage especially in rural areas with only about 50% of the people having access to potable water • War, recurrent droughts and land degradation have adverse impacts on the agricultural sector • Non-functional, and sometimes non-existent, data collection systems mean that resource monitoring assessment is not accurate • Dependency on transboundary water resources for over 50% of supplies means that Eritrea is highly vulnerable to developments and interventions in upstream countries • Pollution of water sources mainly comes from domestic sewage • Salinity and saltwater intrusion in the coastal regions

Country	Key challenges in Water Resources Management
Kenya	• Rapid population growth rate (3%) thereby exerting immense pressure on water resources • Increasing climate variability attributable to global warming and environmental degradation resulting in receding lake levels, drying up of rivers, siltation of reservoirs • Deforestation resulting in catchment degradation and general deterioration of water quality • Frequent flooding, especially in low-lying areas • Infiltration of fertilizers and pesticides into surface and ground water sources • Drought, especially in water stressed areas • Encroachment on recharge areas and unregulated utilization of water resources • Inadequate and fragmented data collection infrastructure • Aging water abstraction infrastructure. Low expenditure on water sector especially in area of resource management • Rapid urbanization (6%) coupled with high occurrence of poverty and rapid growth of informal settlements
Somalia	• Civil strife leading to non-existent governmental structures for management of the water resources. • Scarce water sources that are under extreme pressure • Low access to safe water at only 23% • High incidence to water-borne diseases like diarrhoea, malaria • Nomadic life for the majority of the population makes planning water infrastructure very hard. Existing infrastructure is non-functional due to years of neglect • Frequent droughts lead to famine with over 70% of the population not facing malnutrition and undernourishment • Conflicts over control of land and other resources including the limited water resources • Limited rainfall and lack of water storage capacity. Migration because of drought results in refugee settlements and related problems like congestion • Being a downstream country, Somalia is likely to be affected by development of water resources in upstream countries like Ethiopia • Overexploitation of land and excessive harvesting of trees for commodities such as charcoal lead to deterioration in the environment and rapid desertification

Country	Key challenges in Water Resources Management
Sudan	• Fragmented water resources management by sector which results in uncoordinated interventions • High population growth rate at over 2.5% • High incidence of poverty especially in rural areas. Poverty also varies with geographical location • desertification, driven by climate change, drought, and the impact of human activities • Inequalities in access to resources (including water resources) along gender and tribal lines and have been a cause of conflicts in the past • Inequalities in access to even the most basic services, such as education, sanitation, safe drinking water and job opportunities. • Rapid urbanization with over 40% of the population urban areas by 2006 • Pollution from households, agriculture and industry seriously threatens the quality of freshwater resources. High groundwater tables especially in Southern Sudan exacerbates this further • Land degradation caused by reduction in forest biomass due to deforestation, horizontal expansion of rain-fed mechanized and traditional farming, heavy reliance on forest biomass energy, overgrazing, and bush fires • Water pollution threat comes from herbicides, insecticides, which are applied in the river side agricultural scheme and are washed into the river by irrigation canals. • Inefficiencies in the irrigation system. Considerable losses of water is lost to evaporation and because of poor maintenance of irrigation systems • Lengthy and devastating droughts that are a common feature in the Sahel region and cause population displacement and famine • Floods in Sudan have caused extensive damage and loss of life, especially around the Nile and its main tributary, the Blue Nile. • Sedimentation and aquatic weeds impact on rivers, reservoirs and irrigation. Reduced flood carrying capacity in rivers, resulting in greater flood damage to adjacent properties
Uganda	• Rapid population growth rate at over 3% • Municipal pollution, nutrient loading in water bodies • Land degradation due to deforestation and erosion • Limited capacity for water resources management • Fragmented data collection networks that are most times not operational • Mainstreaming gender issues in water resources management • Increased flooding resulting in property loss and death • Increased occurrence of droughts in parts of the country • Subsistence agricultural practices • Low water supply coverage especially in rural areas where it stood at 63% in 2008

APPENDIX 2: TRANSBOUNDARY RIVER BASINS MAP



APPENDIX 3: USEFUL LINKS

Global Water Partnership – www.gwp.org

UNESCO Water Portal – www.unesco.org/water

UNDP – www.undp.org

Cap-Net – www.cap-net.org

International Water Management Institute – www.iwmi.cgiar.org

GEF International Waters Learning and Exchange Network - www.iwlearn.net

The World Bank: Water Resources Management - http://go.worldbank.org/9U3CAQINB0

The World Bank Institute - http://go.worldbank.org/CO263O7XX0

WWF Living Waters Programme - wwf.panda.org

UNEP – United Nations Environmental Programme – www.unep.org

Integrated Water Resources Management Organization – www.iwrm.org

Water quality simulation models - http://modsim.engr.colostate.edu

Web site for downloading the WEAP software - www.weap21.org

World map of irrigated area of FAO AQUASTAT – http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm

British Geological Survey – http://www.bgs.ac.uk

Mapping, Assessment & Management of Transboundary Water Resources in the IGAD Sub-Region Project

VI

IWRM COMPONENT

Several transboundary river basins and aquifer systems have been identified in the IGAD sub-region. The basis of Integrated Water resources Management (IWRM) is that different uses of water are interdependent. These uses tend to have cross-border implications. Then implementing IWRM in transboundary basins provides a viable mechanism for addressing the challenges. The problem for most countries is the long history of unisectoral development. Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.

It appears that modelling water resources management in the IGAD sub-region is challenging. Water resources are sparsely distributed in space and highly variable in time. Additionally, data on water demand and usage are scarce and can be unreliable in areas where they exist. Thus, the need for Water Evaluation and Planning were obvious.

The WEAP model was used for modelling water resources management in the IGAD sub-region. It allows to analyse the effect of polices interventions (both structural and non-structural) on water resources availability and demand in a region. The demand and supply data were collected at national and international level and used. The model was then successfully developed for six transboundary river basins in the IGAD sub-region. Alternative water management scenarios were simulated. The results have shown very optimistic results, ensuring that the IGAD sub-region has considerable water resources which, if well managed, can serve the needs of the basin inhabitants.

The implementation of IWRM is complicated by lack of political will, lack of institutional and legal tools and also lack of human resources capacity. An overall plan is required to envisage how the transformation can be achieved and this is likely to begin with a new water policy to reflect the principles of sustainable management of water resources. To put the policy into practice is likely to require the reform of water law and water institutions. This can be a long process and needs to involve extensive consultations with affected agencies and the public.

Training of model users will help in ensuring that the use of the model is integrated in their daily work and a critical mass of professionals can be built to implement the model at Transboundary basin level. The IWRM models were built from the data available at the time of analysis. The main idea behind the development of the models was the models will evolve over time as more information about water resources, demand and other policy issues becomes available ■

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