The Programme for Infrastructure Development in Africa:
Transforming Africa through Modern Infrastructure

Programme for Infrastructure Development in Africa

Interconnecting, integrating and transforming a continent

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Africa Transboundary Water Resources Sector Outlook 2040

Africa Transboundary Water Resources Outlook – 2040

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The completion of the Transboundary Water Resources (TWR) Sector Report and the TWR Outlook Report 2040 as part of the Programme for Infrastructure Development in Africa (PIDA) was a major milestone in defining Africa's performance and prospects in the Transboundary Water Resources sector. This helped to inform on the priority TWR projects which are now an integral part of the project investment portfolio of the PIDA Priority Action Plan (PIDA-PAP) for the period up to 2020.

The support and collaboration of the Regional Economic Communities (RECs) and the Member States led not only to the success of PIDA, but also to ensuring that the ownership of PIDA rests with the RECs and Member States who are ultimately, the drivers of PIDA as well as the beneficiaries.

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ABBREVIATIONS, ACRONYMS AND UNITS

Abbreviations and acronyms

AfDB	African Development Bank Group
ADF	African Development Fund
AEC	African Economic Community
AGIEAC	Authority for the Integrated Water Resources Management for Central Africa
AMCEN	African Ministerial Council for Environment
AMCOW	African Ministers' Council on Water
AMIWASH	African Ministers' Initiative on Water, Sanitation and Hygiene
AMU	Arab Maghreb Union
ANBO	African Network of Basin Organizations
ANEW	African Civil Society Network on Water and Sanitation
AU	African Union
AUC	African Union Commission
AWF	African Water Facility
AWFTF	African Water Facility Trust Fund
AWTF	African Water Task Force
AWV	African Water Vision
BADEA	Arab Bank for Economic Development in Africa
CAADP	Comprehensive Africa Agriculture Development Programme
CAR	Central African Republic
CARPE	Central African Region Programme for the Environment
CEMAC	Economic and Monetary Community of Central Africa
CEN-SAD	Community of Sahel-Saharan States
CEPGL	Economic Community of Great Lakes Countries
CGIAR	Consultative Group for International Agricultural Research
CICOS	International Commission of Congo, Oubangui and Sangha river Basins
CIDA	Canadian International Development Agency
COMESA	Common Market for Eastern and Southern Africa
DANIDA	Danish International Development Agency
DBSA	Development Bank of Southern Africa
DFID	Department for International Development (UK)
DNA	Direcçäo Naçional de Aguas
DRC	Democratic Republic of Congo
EAC	East African Community
EAIF	Emerging Africa Infrastructure Fund
ECA	Economic Commission for Africa
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community for West African States
ENSAP	Eastern Nile Subsidiary Action Programme
EU	European Union
FAO	Food and Agriculture Organization (UN)
FFEM	Fonds français pour l'environnement mondial. (French Fund for Global Environment)
GEF	Global Environment Facility
GIWA	Global International Water Assessment
GIZ	German Agency for Development Cooperation
GNP	Gross National Product
GWh	Gigawatt hour
GWP	Global Water Partnership
GWPCA	Global Water Partnership for Central Africa

HYCOS	Hydrological Cycle Observation System
IAH	International Association of Hydrogeologists
ICCON	International Consortium for Cooperation on the Nile
ICT	Information and Communication Technology
IGAD	Intergovernmental Authority for Development
IGRAC	International Groundwater Resource Centre
IIMA	Interim IncoMaputo Agreement
IMERSCA	Musokotwane Environment Resource Centre for Southern Africa
INBO	International Network of Basin Organizations
IOC	Indian Ocean Commission
ISARM	International Shared Aquifer Resource Management
IUCN	International Union for Conservation and Nature
IUCN-ROSA	World Conservation Union – Regional Office for Southern Africa
IWRM	Integrated Water Resources Management
JIA	Joint Irrigation Authority
JPTC	Joint Permanent Technical Committee
JTC	Joint Technical Committee
JWC	Joint Water Commission
KfW	German Development Bank
KOBWA	Komati Basin Water Authority
LCBC	Lake Chad Basin Commission
LHDA	Lesotho Highlands Development Authority
LHWC	Lesotho Highlands Water Commission
LHWP	Lesotho Highlands Water Project
MDGs	Millennium Development Goals
MFC	Ministerial Follow-up Committee (of ECOWAS)
MLTSF	Medium to Long-Term Strategic Framework
MRU	Mano River Union
NBA	Niger Basin Authority
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Programme
NEPAD	New Partnership for African Development
NORAD	Norwegian Agency for Development Cooperation
NSAS	Nubian Aquifer System
NWSAS	North West Sahara Aquifer System
OAU	Organization of African Unity
ODA	Overseas Development Aid
OKACOM	Permanent Okavango River Basin Water Commission
OMVS	Organisation pour la Mise en Valeur du Fleuve Sénégal (Senegal River Basin Organization)
ORASECOM	Orange-Senqu River Commission
PFCM	Permanent Framework for Co-ordination and Monitoring of Integrated Water Resources Management (of ECOWAS)
PRSP	Poverty Reduction Strategy Paper
PWC	Permanent Water Commission
RASP	Regional Assistance Strategy Paper
RBO	River Basin Organization
RCCWR	Regional Council for Consultation on Water Resources (of ECOWAS)
REC	Regional Economic Community
RISDP	Regional Indicative Strategic Development Plan (of SADC)
RSAP	Regional Strategic Action Plan (of SADC)

RSWIDP	Regional Strategic Water Infrastructure Development Programme (of SADC)
RWP	Regional Water Policy (of SADC)
RWS	Regional Water Strategy (of SADC)
RWSSI	Rural Water Supply and Sanitation Initiative
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAP	Strategic Action Programme
SAPP	Southern African Power Pool
SDAP	Sustainable Development Action Programme
SIDA	Swedish International Development Agency
SLOT	Strengths, Limitations, Opportunities and Threats
SNEC	Société National d'Eau du Cameroun (Cameroon National Water Company)
SOGED	Diama Dam management and operation agency
SOGEM	Manantali energy management agency
STAP	Short Term Action Plan
STAP TWR	Short-Term Action Plan for Transboundary Water Resources
STEE	Société Tchadienne d'Eau et d'Electricité (Chad Water and Electricity Company)
SVP	Shared Vision Programme
SWCI	Shared Watercourse Institution
TAC	Technical Advisory Committee
TCTA	Trans Caledon Tunnel Authority
TDA	Trans-boundary Diagnostic Analysis
TECCONILE	Technical Cooperation Committee for the Development and Environmental Protection of the Nile Basin
TPTC	Tripartite Permanent Technical Committee
TWR	Trans-boundary Water Resources
TWRM	Trans-boundary Water Resources Management
UDEAC	Central African Customs and Economic Union
UEMOA	West African Economic and Monetary Union (Union Economique et Monétaire Ouest Africaine)
UMA	Union du Maghreb Arabe (Maghreb Arab Union)
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCO-IHP	UNESCO International Hydrological Programme
UNICEF	United Nations Children's Fund
UNOPS	United Nations Office for Projects and Services
UNSO	United nations Office to Combat Desertification
USAID	United States Agency for International Development
VBA	Volta Basin Authority
VNJIS	Vioolsdrift-Noordoewer Joint Irrigation Scheme
WD	Water Division (of SADC)
WHO	World Health Organization
WHYMAP	World Hydrogeological Map
WRCU	Water Resources Coordination Unit (of ECOWAS)
WSSD	World Summit on Sustainable Development
WWF	World Water Forum
ZACPLAN	Zambezi River Action Plan
ZACPRO	Zambezi River Action Plan Project
ZAMCOM	Zambezi River Basin Commission
ZRA	Zambezi River Authority

Units

Length

- 1 km = 1000 m
- 1 mile = 1.56 km

Area

- 1 acre = 4047 m2 = 0.4047 ha
- 1 are = 100 m2 = 0.01 ha
- 1 feddan = 4200 m2 = 0.42 ha
- 1 ha = 10 000 m2
- 1 km2 = 1 000 000 m2 = 100 ha

Volume

- 1 dm3 = 1 litre = 0.001 m3
- 1 hm3 = 1 million m3 = 1 000 000 m3 = 0.001 km3
- 1 km3 = 1 billion m3

Power and Energy

- 1 GW = 1000 MW = 1 000 000 kW
- 1 GWh = 1000 MWh

DEFINITIONS

Below is a list with the definition of some of the key terms/concepts that are used in this report:

- ***Water demand:*** The functional relationship between the value of water (scarcity) and the quantity of water used.
- ***Water requirement:*** Unlike true demand, requirements do not embed scarcity-sensitive parameters. A water requirement is merely a point on a demand curve.
- ***Water withdrawal:*** The amount of water diverted from a source (river, lake or reservoir) or pumped from a groundwater source. This volume does not depend on the water requirement or demand.
- ***Consumption:*** Water withdrawn from a source (river, lake, reservoir or aquifer) and made unavailable for further use (typically downstream) is called consumptive use. Worldwide, irrigated agriculture is by far the largest consumptive use since water is consumed by evapotranspiration for plant growth. Other examples include evaporation losses from reservoirs, contamination/pollution and drainage to a saline sink and incorporation into a product.
- ***Gross water requirement (GWR):*** The volume of water withdrawn from a river, reservoir or aquifer for a particular use. The fraction of this volume that is not consumed by the concerned use will be evaporated while the rest will return to the system (return flow).
- ***Net water requirement (NWR):*** The volume of water for consumptive uses. In the context of irrigation, the net water requirement is the volume of water evapotranspirated by the plants plus the evaporation losses from the distribution system.
- ***Return flow:*** Portion of the withdrawals that will eventually drain back to the river system and thus be available for further use downstream.
- ***Self-Sufficiency Ratio (SSR):*** Expresses the magnitude of production in relation to domestic utilization. SSR is defined by the following equation:

$$SSR\ [\%] = \frac{\text{Production}}{\text{Consumption}} = \frac{\text{Production}}{\text{Production} + \text{Imports} - \text{Exports}} \times 100$$

- ***Internal (surface and groundwater) renewable water resources (IRWR):*** Long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources. In other words, IRWR refer to the water resources resulting from rain falling within the borders of the country (combination of surface water and groundwater resources). Therefore, IRWR are the only quantities that can be added together for regional or continental assessments.
- ***Global (surface and groundwater) renewable water resources (GRWR):*** GRWR are obtained by adding incoming surface water and groundwater flows to the IRWR. GRWR take into account the surface water and groundwater flowing from neighbouring countries and between neighbouring countries (rivers that form the border between countries). As a matter of fact, GRWR cannot be added together for regional of continental assessments.
- ***Natural river discharge:*** The discharge of the river (and groundwater flow) that flows into the sea in natural conditions. In other words, it represents the river discharge before the construction of infrastructure and withdrawals of water.
- ***Level of commitment of a river or lake basin:*** The ratio between water consumption and natural river discharge, on an annual basis.
- ***Blue water:*** The water diverted from a source (river, lake or reservoir) or pumped from a groundwater source.
- ***Green water:*** The rainfall water stored in the soil that can be used by plants.
- ***Rain fed agriculture:*** Pure rain-fed agriculture uses only green water to supply the crop water requirements.
- ***Irrigated agriculture:*** In irrigated agriculture, blue water supplements green water to satisfy the crop water requirements.

1. INTRODUCTION

1.1 Background

Water is of strategic importance to African economies, forming an input to various sectors such as agriculture, industry, mining and power generation. In addition, water resources have the potential to be developed in such a way as to contribute to the achievement of food security and poverty eradication objectives. The efficient and sustainable utilisation of Africa's water resources is therefore a cornerstone for socio-economic development and poverty reduction on the continent. Increasing water and energy demands for growing populations and increased agricultural and industrial production have to be achieved in the forthcoming decades.

The development of water resources use and management options for Africa needs to be carried out in specific climatic, economic and governance conditions. Key aspects in this regard include:

- A high degree of natural climatic variability, i.e. naturally variable rainfall patterns with frequent periods of floods and drought. These are likely to be further exacerbated by the impacts of global climate change
- The need for the construction of large dams and associated inter-basin transfers (IBT) largely as a response to the above point, in order to mitigate the impact of the natural and human induced climatic variability
- Population dynamics on the continent, with most of Africa experiencing significant population growth over the coming decades leading to a commensurate increase in water demand.
- Significant variation in regional integration and governance frameworks for cooperative management of trans-boundary water resources and relative underdevelopment in some regions.

With transboundary water resources constituting nearly 80% of Africa's total freshwater resources, cooperation in the management of shared water resources is critical. In this context, increased regional cooperation and joint planning, development and management of water infrastructure are essential if targets for agricultural and industrial development, food security, energy security, health improvement and others sectors are to be met. With the effects of climate change further exacerbating the highly variable climatic conditions found in most parts of the continent, the informed, strategic selection and implementation of water infrastructure projects will need to be a critical factor for sustainable transboundary water resources management and for achieving the above-mentioned objectives.

1.2 Objectives of the Outlook 2040

The ultimate objective of the PIDA (in the TWR sector) is the selection and prioritization of critical trans-boundary water infrastructure projects and the development of an implementation framework for these projects based on an informed picture of the current situation, realistic estimates of future water requirements and an in-depth assessment of key challenges and gaps that need to be addressed between now and the 2040 time horizon set by the programme.

In order to achieve this, the PIDA Study has been structured into two phases, which can broadly be described as a diagnostic phase (Phase I) and a strategic planning phase (Phase II). This Outlook 2040 Report summarizes the main findings from the diagnostic studies conducted during Phase I of PIDA and forms the basis for the development of the full strategic infrastructure development programme ("Strategic Framework" and "Priority Action Programme" (PAP)) that will form the key output from Phase II of PIDA.

The Outlook 2040 provides policy-makers and strategic planners in regional organisations and national governments alike with an overview of the current situation in the TWR sector as well as the main challenges faced. It also includes a range of options for addressing the identified challenges. The results presented in the Outlook 2040 serve as a basis for the formulation of realistic long-term objectives, to be targeted by policies and programmes at the continental level in order to anchor infrastructure development into regional integration and cooperation in Africa.

1.3 Study scope and report structure

There are about 80 international river and lake basins in Africa (African Water Vision 2025). Most of these rivers and lakes are shared by two to four countries, although some are shared by many more: Congo and Niger (11 countries), Nile (10), and Lake Chad (8), (UNEP, 2005). Furthermore, there are 38 documented trans-boundary aquifers on the continent. Of these, only the Lake Chad basin aquifers are shared by more than four countries (6) while all other aquifers are shared between two and four riparians respectively.

In agreement with the stakeholders, the PIDA Study, and thus the Priority Action Plan (PAP) developed during Phase II, focus on ten selected trans-boundary lake and river basins, namely Lake Chad, Congo, Gambia-Geba-Koliba, Niger, Nile, Okavango, Orange-Senqu, Senegal, Volta and Zambezi. The selected basins straddle, partly or completely, most of the African countries and account for 51.5% of African land area and 80% of the total area of the African international basins.

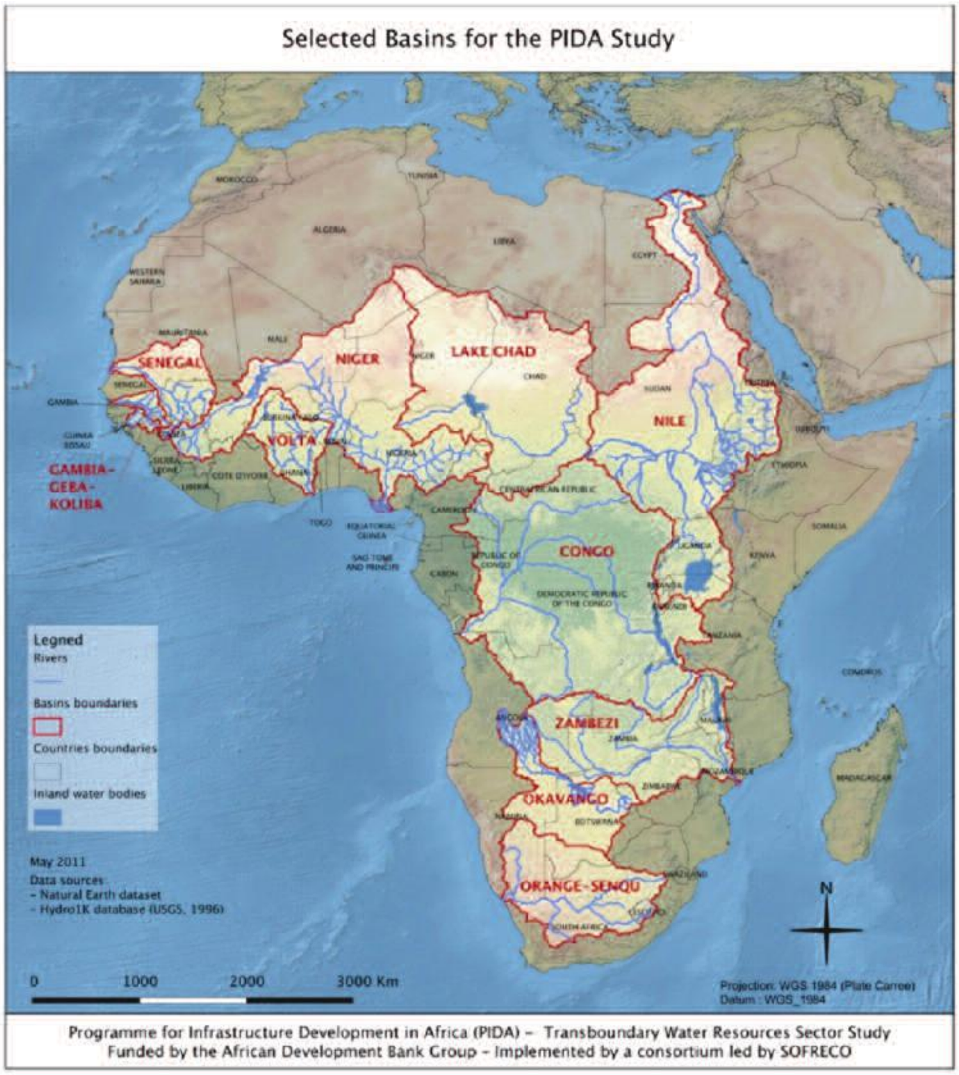
In addition to the ten surface water basins, three trans-boundary aquifers have been selected for inclusion in the PIDA studies and implementation of the PAP, namely the Nubian Sandstone Aquifer System, the North West Sahara Aquifers System and the Iullemeden Aquifer System.

The Outlook 2040 provides an analysis at three levels: continental, country-specific and at the level of the selected target basins and aquifers and is structured as follows:

Key messages for policy-makers and strategic planners are presented in the concluding section of this introductory chapter. This serves to highlight the most important findings emerging from Phase I of PIDA, which will be explained in further details in subsequent chapters of the report.

Chapter 2 provides a brief overview of the macro-economic regional context in which future transboundary water resources development and management take place, focusing on the aspects of expected population growth, food production and food policies as well as economic development patterns.
The current situation in the TWR sector is described in Chapter 3, which describes water resources availability and the state of current infrastructure development at continental and selected basin levels and provides an overview of existing governance frameworks.

Figure 1: Selected surface water basins for the PIDA Study



Chapter 4 describes the results of the detailed modelling and analysis work carried out during the Phase I of the PIDA Study. Following a detailed description of the methodology used for the modelling exercise, it presents the key findings of the water requirement forecast at continental and selected basin levels for the period between now and the year 2040.
Based on the results presented in Chapters 3 and 4, the existing infrastructure gap in the TWR sector for Africa is estimated and described in Chapter 5 of the report.

Chapter 6 presents an overview of the key challenges facing the African TWR sector as well as possible response options. Challenges facing the African TWR sector over the forthcoming three decades until 2040 are presented in generic form. This is followed by a brief description of four key challenges and corresponding response options on which the PIDA programme (in the TWR sector) will focus.
Based on the analysis in Chapters 5 and 6, an overview of investment needs estimates for the TWR sector is presented in Chapter 7, and Chapter 8 concludes the report.

1.4 Key messages

- The population on the African continent is expected to double between now and 2040
- The demand for food (cereals) in Africa is expected to double between now and 2040
- Energy demand in Africa is expected to increase 4-fold by 2040 from current levels
- Africa has the lowest level of water storage capacity and irrigated agriculture globally, and the infrastructure gap for hydropower generation and irrigation is large
- In some African basins, the forecast water demand will soon outstrip available resources if no improvements in management and efficiency of use are made
- The competition between water use sectors and the environment is likely to increase given the growing pressure on freshwater resources
- The annual investment needs in the TWR sector are expected to be around US$ 49 billion per year
- Investments in water infrastructure are highly dependent on integration with transport and energy networks and are only effective if well integrated into coherent, cross-sectoral development strategies and infrastructure investment programmes.

2. MACRO REGIONAL CONTEXT

This section describes the macro-regional context that is likely to determine the trends of regional and continental water demand and thus infrastructure needs, by 2040 in the TWR sector. The analysis focuses on the three primary drivers for increased water demands in the agricultural, industrial and domestic sectors, namely:

- Population growth
- Gross Domestic Production (GDP) growth
- Food policy objectives

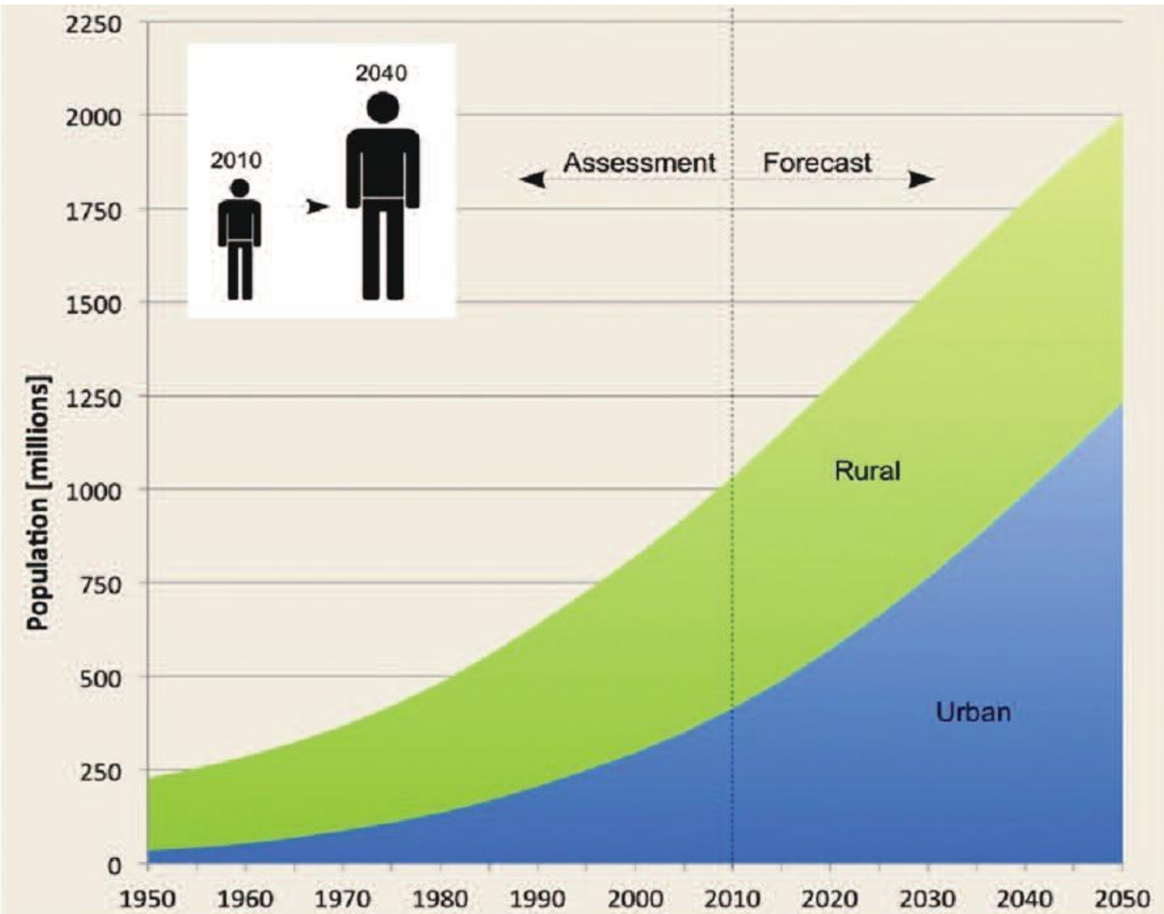
These drivers also form the basis for the continental and basin-wide (water) demand forecasts in Chapter 4 of this Report.

2.1 Population growth

Human population is increasing and, according to United Nations estimates, more than 8.8 billion people will live on Planet Earth in 2040, with most of the global population growth expected to occur in developing countries (United Nations, 2011[1]). As illustrated in Figure 2, the population in Africa is expected to almost double between 2010 and 2040, with a percentage of population living in urban areas rising from 43.8% in 2010 to 60% in 2040.

In the period from 2005 (reference year) to 2040 (planning horizon), the African region with the highest annual population growth rate is Eastern Africa (2.21%), followed by Central Africa (2.15%) and Western Africa (2.03%). Southern Africa is expected to experience a slower annual growth rate of 0.52% (see Figure 3). The average annual population growth rate for the whole African continent is estimated to be around 1.88 %.

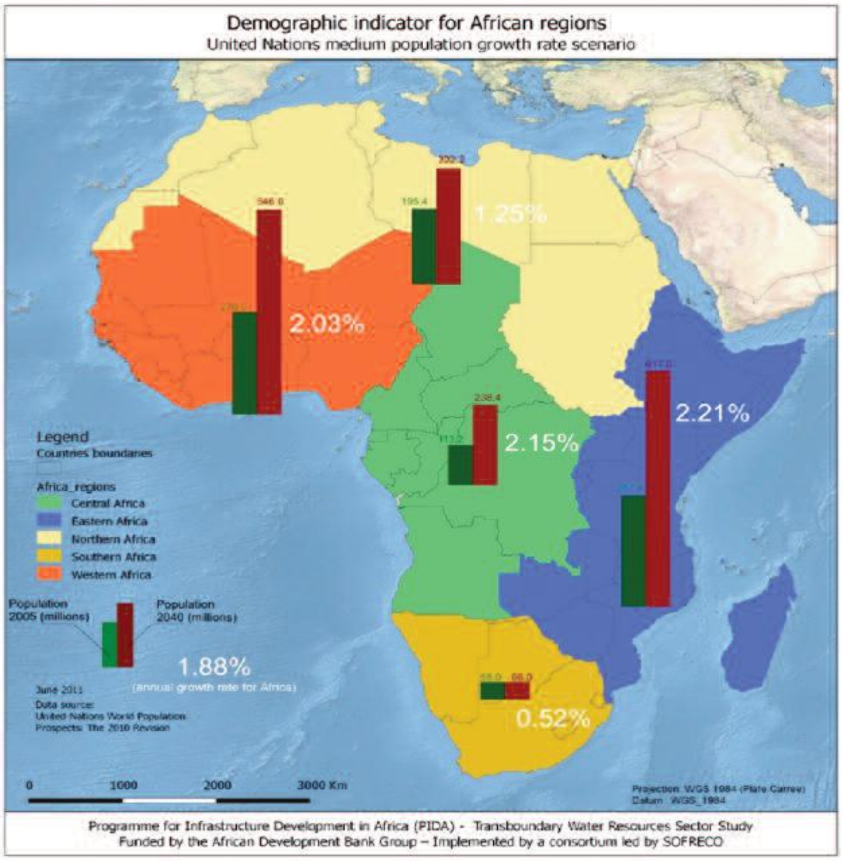
Figure 2: Historical and forecast population in Africa



(Data source: United Nations, World Population Prospects: The 2010 revision).

[1] Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision, http://esa.un.org/unpd/wpp/index.htm

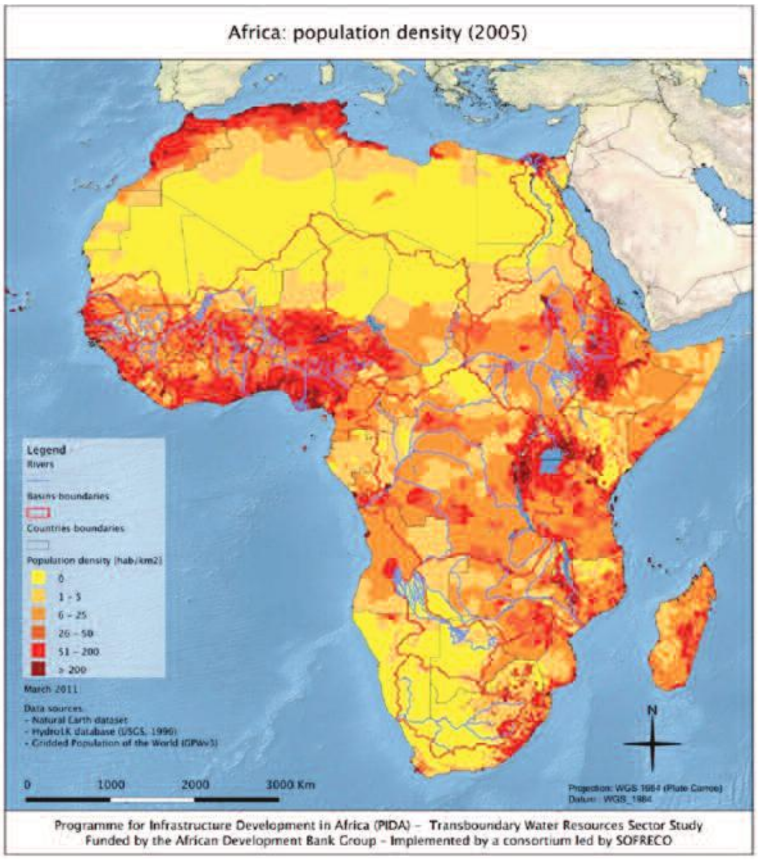
Figure 3: **Map of demographic indicator for African regions**



The population on the African continent is expected to double between now and 2040.

(Data source: United Nations, World Population Prospects: The 2010 Revision, http://esa.un.org/unpd/wpp/index.htm)

Figure 4: **Map of population density in Africa**



Africa (Data source: Gridded Population of the World, GPWv3, 2005).

The overall population distribution in Africa, as is the case globally, is strongly influenced by climate and land cover, with very low population figures in the continent's vast desert and tropical forest areas. High population density occurs in the moderate tropical and sub-tropical climate areas as well as along coastal areas (Figure 4).

In the selected PIDA basins, the population increase follows the continental trend with most of the basins expected to experience a population increase of around 100% (Table 1). The Nile basin will remain the most populated basin in absolute terms, followed by the Niger, and Congo River basins. Combined with forecast higher living standards and GDP growth, population growth will be the major driver for future food and water requirements.

Table 1: Population forecast in the selected basins

Basin	Total population within basins [million]		Percentage of increase [%]
	2005	2040 (medium growth scenario)	
CHAD	38.67	85.02	119.83
CONGO	76.62	162.79	112.46
GAMBIA-GEBA-KOLIBA	2.96	6.61	122.91
NIGER	86.41	189.63	119.47
NILE	192.98	394.20	104.27
OKAVANGO	1.78	3.49	96.07
ORANGE-SENQU	13.14	16.32	24.24
SENEGAL	5.36	10.38	93.63
VOLTA	21.08	47.79	126.66
ZAMBEZI	34.30	70.94	106.81
TOTAL PIDA BASINS	**473.31**	**987.17**	**108.57**

2.2 Food demand and food policy objectives

As a consequence of the expected high population increase, the demand for food will rise significantly between now and 2040. Currently, the consumption of cereals in Africa is around 192 million tons amongst which 73.4% (142 million tons) are produced in Africa (Figure 5). The total cereal import is around 50 million tons while the exports are close to 3 million tons. The food self-sufficiency ratio (SSR) for cereals in Africa was estimated at 73.3 % in 2005. Largely due to the prevailing arid climate, most North African countries have a particularly low SSR, while countries like Chad, Central African Republic, Ethiopia, Guinea, Madagascar, Malawi, Mali, Niger, Nigeria, Sierra Leone, Sudan, Togo, Tanzania, Uganda, Burkina Faso and Zambia have a SSR greater than 85% in terms of cereals (Figure 6).

Figure 5: Cereals consumption in Africa in 2005

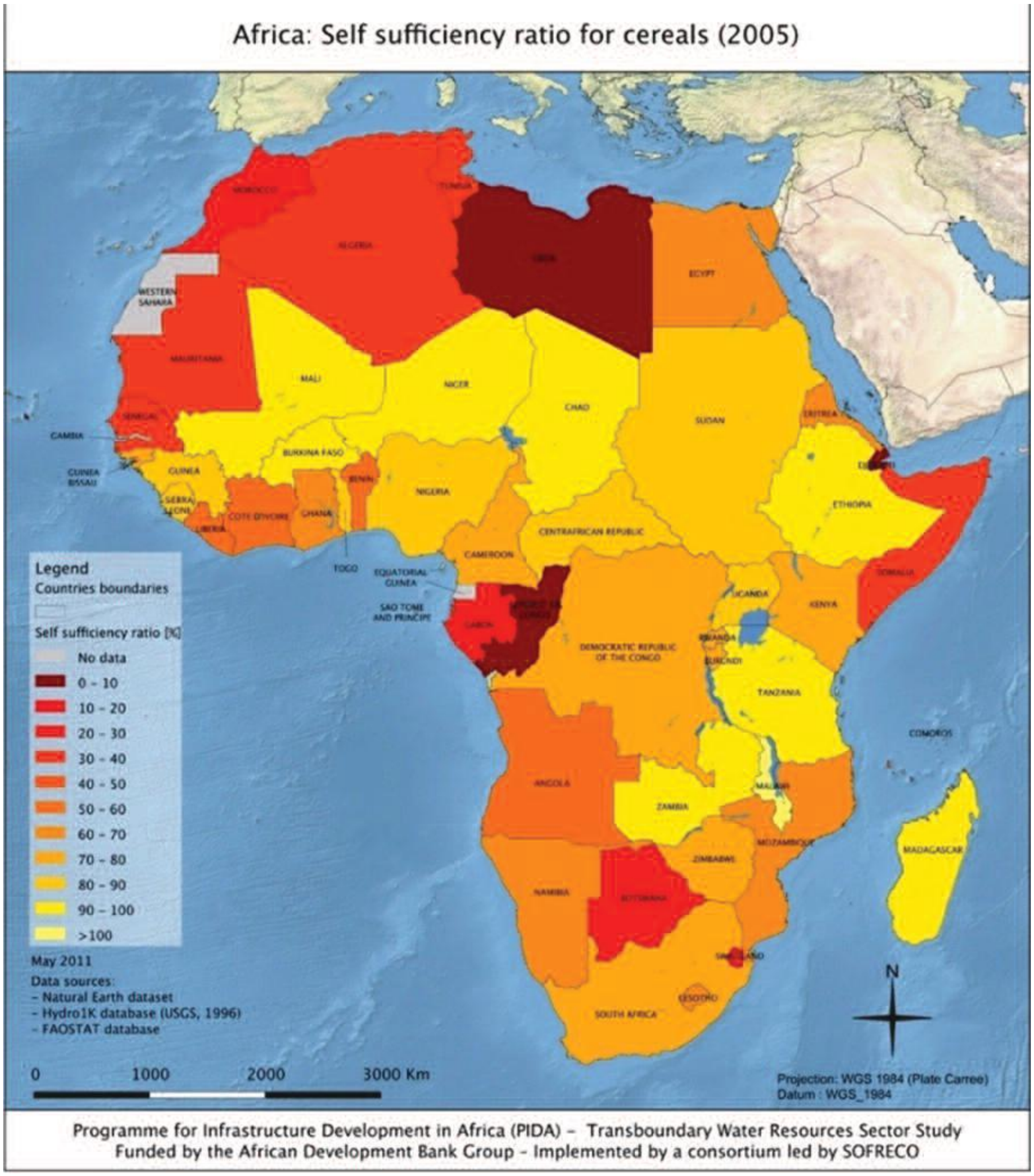
(Data source: FAOSTAT database).

It should be noted that in the context of food security, the SSR is often taken to indicate the extent to which a country relies on its own production resources, i.e. the higher the ratio the greater the self-sufficiency. However, in the context of this analysis, the SSR depicts the overall production level against total cereal demand. Thus, where for example a large part of a country's production of cereals is exported, the SSR may be high but the country may still have to rely heavily on imports of food commodities to feed the population. Therefore, the SSR ration as depicted in Figure 6 is not an indicator for the level of access to food of the population.

Food access remains a significant challenge in Africa with a high number of people considered undernourished (Figure 8). Some of the countries with the highest number of undernourished people are among those with the highest SSR values in terms of total production.

Ensuring increased food production and improving access to food will continue to be a key challenge for the African continent. It is forecast (see Chapter 4 for details) that the increase in total cereal requirements in 2040 in Africa (compared to the current situation) is expected to range between 56% and 78%, depending on the scenario considered (Figure 7). In terms of cereals' quantities, it represents an increase ranging from 106 to 150 million tons (compared to 192 million tons currently).

Figure 6: Map of self-sufficiency ratio (SSR) in terms of cereals for Africa



(Data source: FAOSTAT database).

Figure 7: **Current cereals consumption and forecast requirements for 2040 in Africa.**

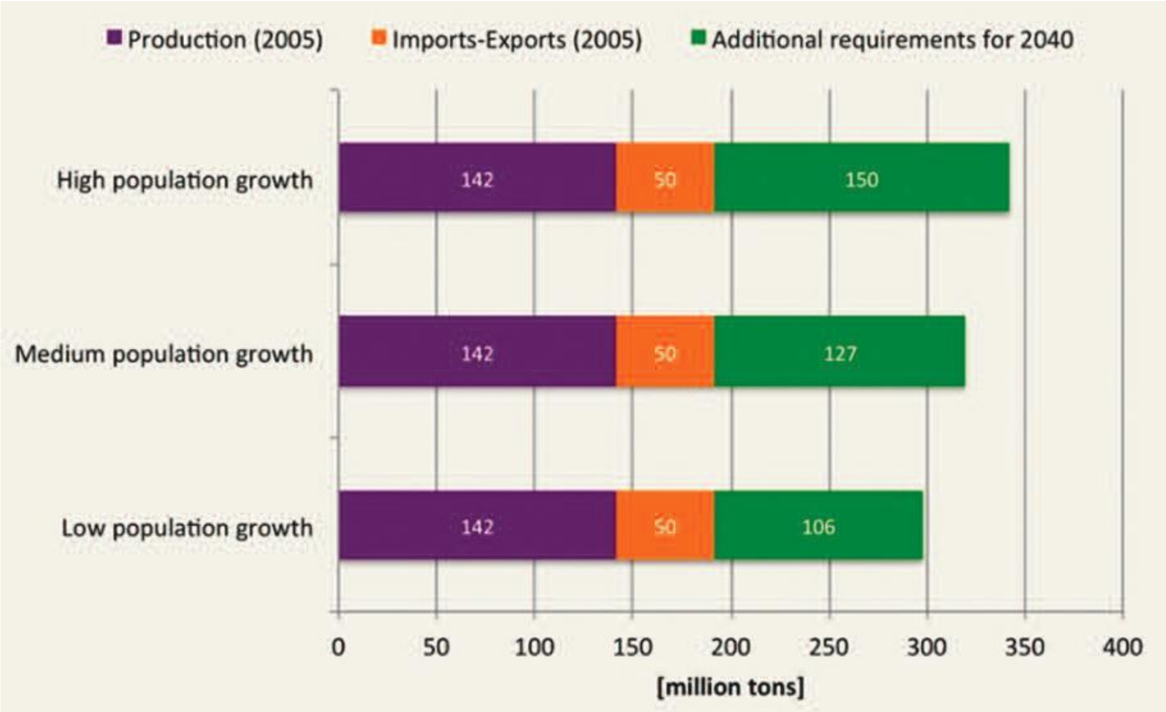
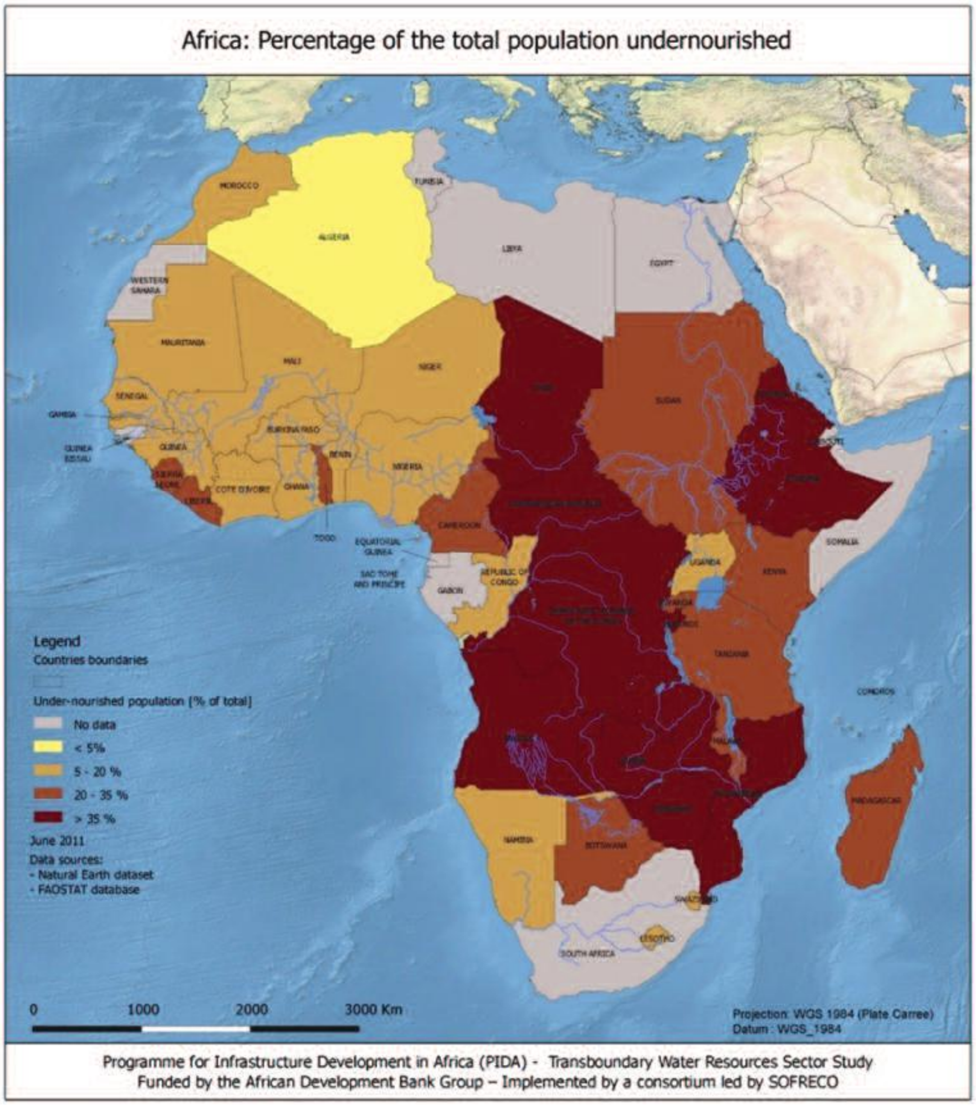


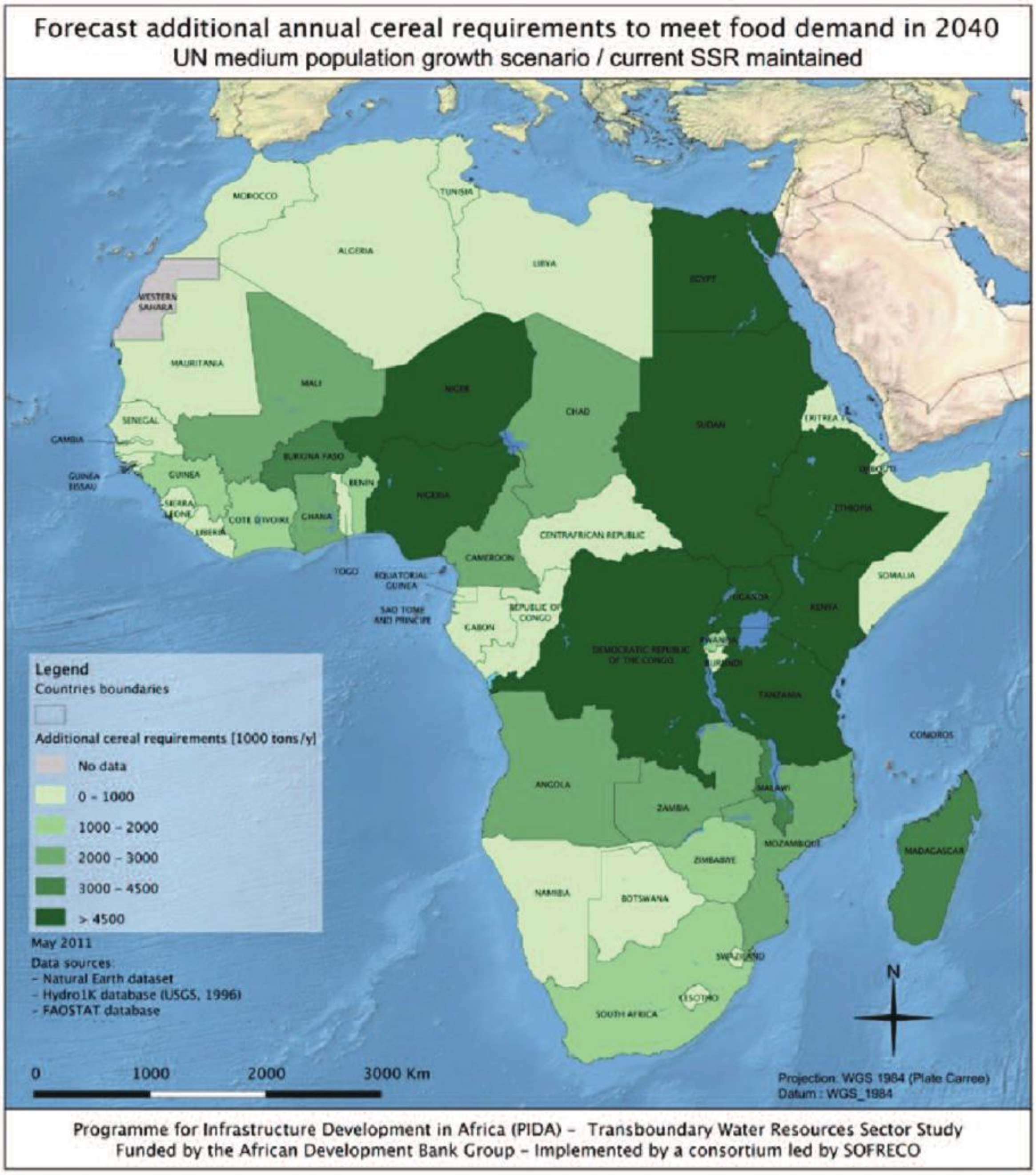
Figure 8: **Map of the percentage of the total population undernourished in Africa (Data source: FAO AQUASTAT database).**



The spatial distribution of these additional food requirements (Figure 9) mirrors the overall population growth trends. In terms of the selected PIDA basins, the Nile, Congo and Niger River basins (and the Zambezi to a lesser extent) are the ones facing the greatest challenge.

In order to meet the increased food demand, countries will have to make clear food policy choices in order to implement long-term measures that guarantee sufficient access to food for the population in the long-run. Commonly two different food policy choices are considered, food self-sufficiency and food security. The former aims at achieving a 100% self-sufficiency ratio of domestic food production, often requiring significant investments in the agricultural sector in order to keep up with increasing domestic food demand. The latter approach includes options to supplement domestic production with food imports in order to meet domestic production shortfalls. Given the expected population increase, it is likely that a combination of investments in irrigated agriculture to increase domestic production and trade-based food security options needs to be pursued by most countries in parallel. With some African countries having the potential of becoming large-scale net cereal exporters, regional investment and trade options should be promoted (see further discussion in Chapter 7).

Figure 9: Additional annual cereal requirements to meet food demand by 2040.



2.3 GDP growth

Detailed macro-economic analyses and forecasts carried out by the PIDA macro-economic expert team expect a relatively high economic growth rate for Africa between now and 2040, estimated to be at 6% per year.

Around 40 countries out of the 53 are expected to exhibit a growth rate higher than 5% per year on average for the period 2008-2040 and 20 African countries are forecast to experience an average growth higher than the continental growth rate of 6%. Nigeria, already one of Africa's largest economies, with an estimated growth rate of 7.9% per year for the period 2008-2040 is among the countries with a growth rate higher than (continental) average, alongside economies such as Angola, Benin, Gambia and Malawi.

Twenty countries are forecast to experience an average growth rate of around 5 to 6% per year and growth in South Africa, the continent's largest (non-oil) economy is expected to be at 4.9 % per year. Only ten countries are expected to have growth rates lower than the continental average.

The forecast high overall GDP growth rate will have significant impacts on industrial water requirements since water is a production factor of nearly all economic goods. Likewise, with increased economic growth, energy consumption will rise and increase the water requirements for the cooling of thermal power plants. Higher GDP also results in higher living standards with a commensurate increase in water requirement for domestic uses by urban and rural populations.

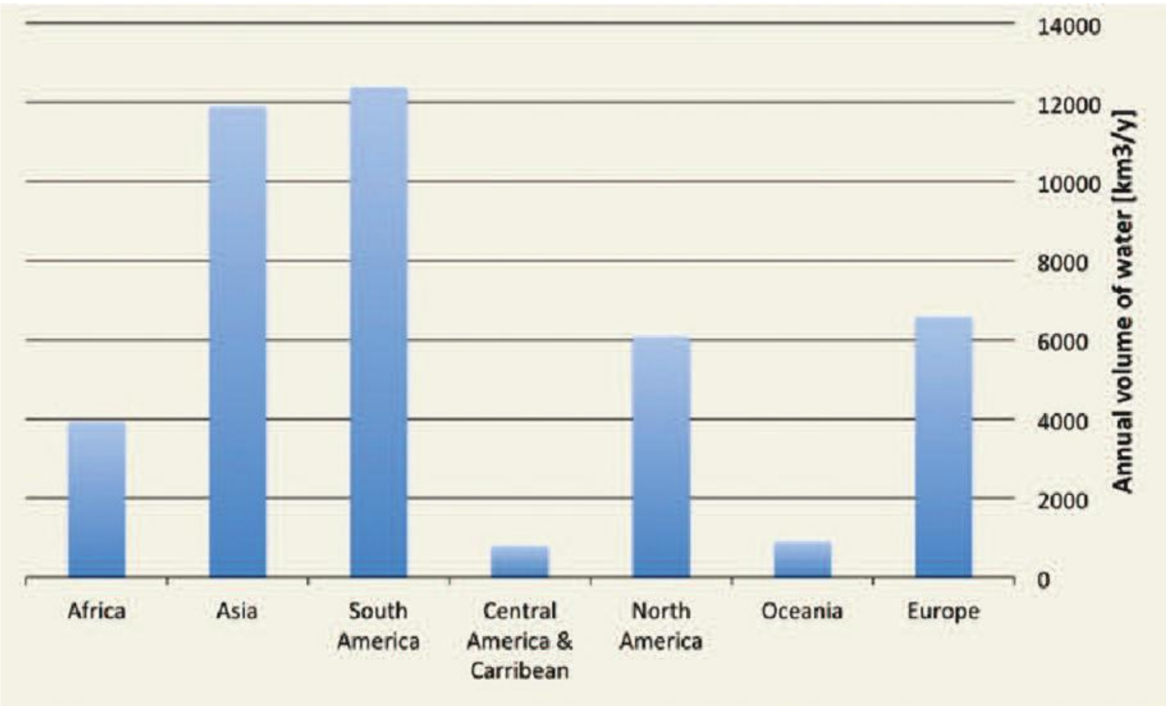
3. BASELINE: CURRENT SITUATION IN THE TRANSBOUNDARY WATER RESOURCES SECTOR

This chapter provides an overview of the current baseline (at the continental and selected basin levels) in terms of available water resources, existing infrastructure and TWR governance frameworks. The baseline assessment provides a basis for the (water resources) demand forecast presented in Chapter 4 of this report as well as the development of the strategic framework and selection of PIDA projects in Phase II.

3.1 Surface and groundwater resources availability

This water resources availability overview is based on the concept of internal renewable water resource (IRWR), which is the long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. While IRWR exhibits large regional disparities, in Africa as a whole, the IRWR is estimated at 3931 km3 per year. Africa represents 9.2 percent of the world IRWR, compared to 28% in Asia and 29.1% in South America respectively (Figure 10 and Table 2). The IRWR in Africa is distributed between surface water (3833.63 km3 per year) and groundwater (1419.28 km3 per year) with an overlap of 1324.19 km3 per year.

Figure 10: **Comparison of internal renewable freshwater resources by world regions**



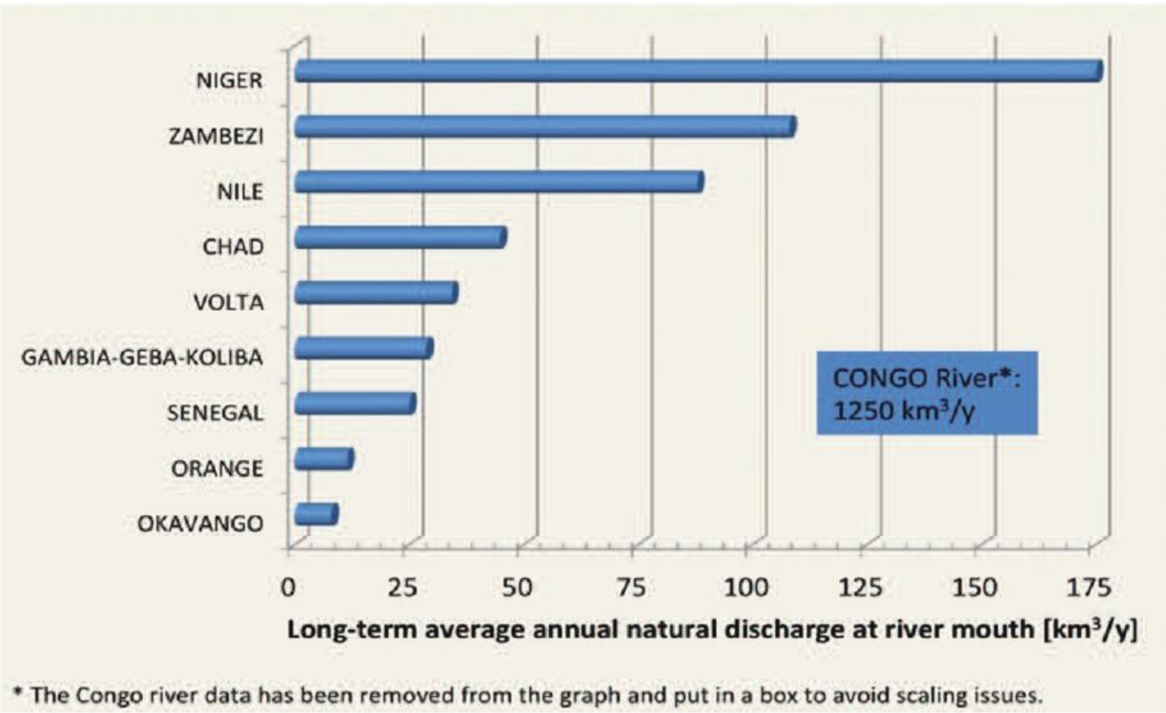
(Data source: FAO AQUASTAT)

Table 2: **Comparison of IRWR by world regions (Data source: FAO AQUASTAT)**

Region	Annual volume of water [km3/y]	Percentage of World IRWR	IRWR per capita (2008) [m3/cap/y]
WORLD	**42517**	**100.0**	**103578**
Africa	3931	9.2	4007
Asia	11886	28.0	2913
South America	12380	29.1	32165
Central America & Caribbean	781	1.8	9613
North America	6077	14.3	13401
Oceania	892	2.1	32510
Europe	6569	15.5	8969

At the lake or river basin levels, the renewable water resources available are defined as the natural discharge of the river (and groundwater flow) that flows into the sea (or inner lake) in natural conditions. In other words, it represents the river discharge before the construction of infrastructure and withdrawals of water. While in a river (or lake) basin, the water availability exhibits seasonal and inter-annual variability, Figure 11 presents the natural discharge by considering only long-term average annual values calculated with historical records that were available (Global Runoff Data Centre[2], Global River Discharge Database[3] or data provided by the L/RBO's).

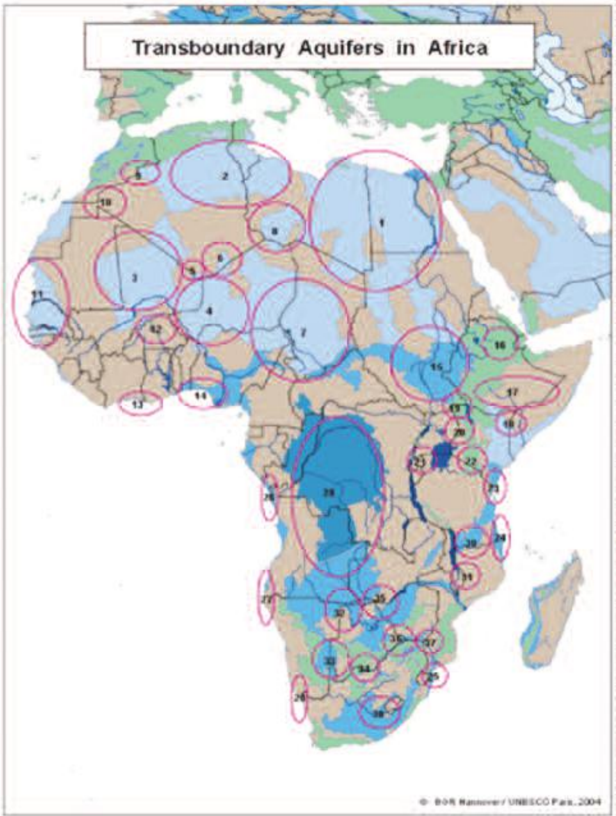
Figure 11: **Long-term average annual natural discharge at river mouth.**



The disparities amongst the selected river basins are significant. The river basin with the highest natural discharge is the Congo, with a long-term average natural flow around 1250 km3 per year, which represents around 7 and 14.5 times the value for the two next biggest basins: the Niger and Zambezi River basins respectively. The aggregated annual natural discharge in the ten selected basins is around 1773 km3/y, which represents 46.3 % of total renewable water resources in Africa and around 80% of the renewable water resources in the continent's international basins. There are 38 documented trans-boundary aquifers on the African continent. Tanzania and Mozambique each have seven trans-boundary aquifers that they share with their neighbours. The largest number of riparians, six, are found in the Lake Chad basin aquifers. Figure 12 shows the geographical distribution of the aquifers alongside the key number of indicative aquifers shown on the map.

[2] http://www.bafg.de/GRDC/EN/Home/homepage__node.html
[3] http://www.rivdis.sr.unh.edu/

Figure 12: **Map inventory of trans-boundary aquifers of Africa (Source: UNESCO-IAH ISARM).**



No	Aquifer Name	Countries
1	Nubian Sandstone Aquifer System	Chad, Egypt, Libya, Sudan
2	Northwest Sahara Aquifer System	Algeria, Libya, Tunisia
3	Taoudeni Basin	Algeria, Mali, Mauritania
4	Irhazer – Iullemeden Basin	Mali, Niger, Nigeria
5	Air Cristalline Aquifer	Algeria, Mali, Niger
6	Tin –Serinne Basin	Algeria, Niger
7	Chad Basin	Central African Republic, Chad, Cameroon, Niger,Nigeria
8	Mourzouk – Djado Basin	Chad, Libya, Niger
9	Errachidia Basin	Algeria, Morocco
10	Tindouf Aquifer	Algeria, Morocco
11	Senegalo – Mauritanian Basin	Gambia, Guinea – Bissau, Mauritania, Senegal
12	Liptako – Gourma Aquifer	Burkina Faso, Niger
13	Coastal Sedimentary Aquifer	Ghana, Ivory Coast
14	Coastal Sedimentary Aquifer	Benin, Nigeria, Togo
15	Upper Nile Basin	Ethiopia, Sudan
16	Awash Valley Aquifer	Djibouti, Ethiopia
17	Ogaden – Juba Aquifer	Ethiopia, Kenya, Somalia
18	Merti Aquifer	Kenya, Somalia
19	Rift Aquifers	Kenya, Tanzania, Uganda
20	Mount Elgon Aquifer	Kenya, Uganda
21	Kagera Aquifer	Tanzania, Uganda
22	Kilimanjaro Aquifer	Kenya, Tanzania
23	Coastal Sedimentary Basin	Kenya, Tanzania
24	Coastal Sedimentary Basin	Mozambique, Tanzania
25	Limpopo Basin	Mozambique, Swaziland
26	Coastal Sedimentary Basin	DR of Congo, Angola
27	Coastal Sedimentary Basin	Angola, Namibia
28	Coastal Sedimentary Basin	Namibia, South Africa
29	Congo Intra- cratonic Basin	DR of Congo, Angola
30	Karoo Sandstone Aquifer	Mozambique, Tanzania
31	Shire Valley Alluvial Aquifer	Malawi, Mozambique
32	Northern Kalahari/Karoo Basin	Angola, Botswana, Namibia, Zambia
33	SE Kalahari/Karoo Basin	Botswana, Namibia, South Afrika
34	Ramotswa Dolomite Basin	Botswana, South Afrika
35	Nata Karoo Sud- basin	Botswana, Namibia, Zimbabwe
36	Tuli Karoo Sud-basin	Botswana, South Afrika, Zimbabwe
37	Medium Zambezi Aquifer	Botswana, Mozambique, South afrika, Zimbabwe
38	Karoo Sedimentary Aquifer	Lesotho, South Afrika

As illustrated in Figure 13, water resources are unevenly distributed within Africa, due to physical and climatic conditions. Most of the IRWR are located in the central region, mainly in the Congo River basin and the upper (Guinea) and lower (Nigeria) part of the Niger River basin. North Africa is particularly poorly served in terms of internal renewable water resources, of which most are groundwater resources. While absolute IRWR figures are of indicative value, the concept of IRWR per capita is of greater relevance for strategic planning as this depicts more accurately the degree of water availability for the various users and uses. Figure 14 illustrates predicted IRWR per capita in 2040, considering a medium population growth scenario, compared to the 2005 situation depicted on the right part of the figure. It is based on a water stress index where the water scarcity of countries is ranked within four categories, depending on the annual internal renewable water availability per capita:

- Below 1000 cubic meters per person per annum (pp/pa), a country or region is said to experience "water scarcity";
- Between 1000 and 1700 cubic meters pp/pa, a country or region faces water stress and periodic or limited water shortage can be expected;
- Between 1700 and 2500 cubic meters pp/pa a country or region is in a situation of vulnerability regarding its water security;
- Beyond 2500 cubic meters pp/pa, the country or region would not experience any water stress.

Figure 13: **Map of internal renewable surface and groundwater resources in Africa**

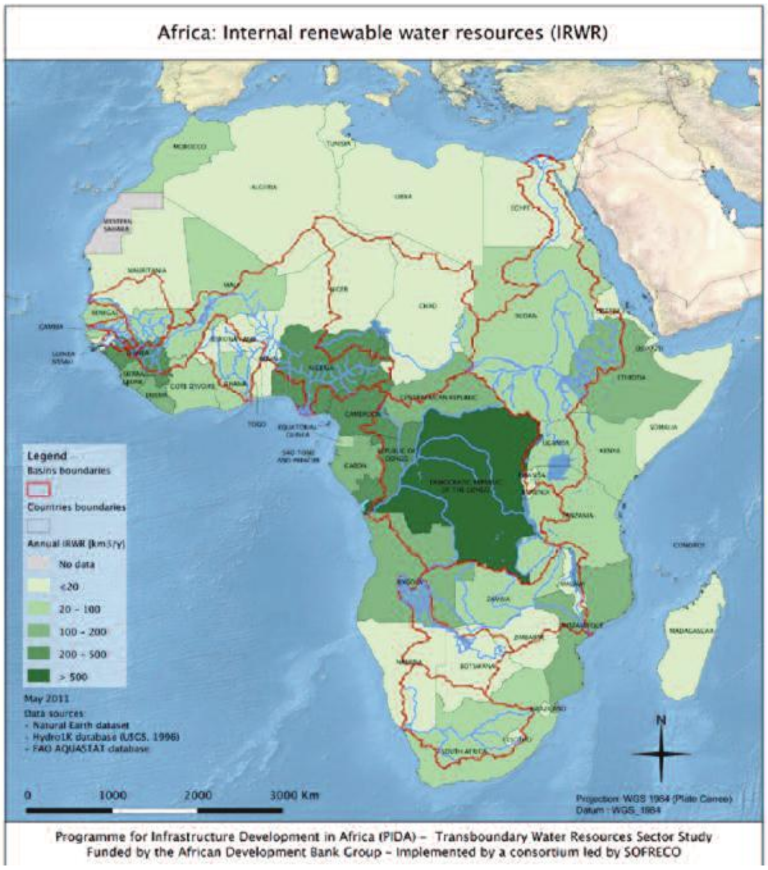
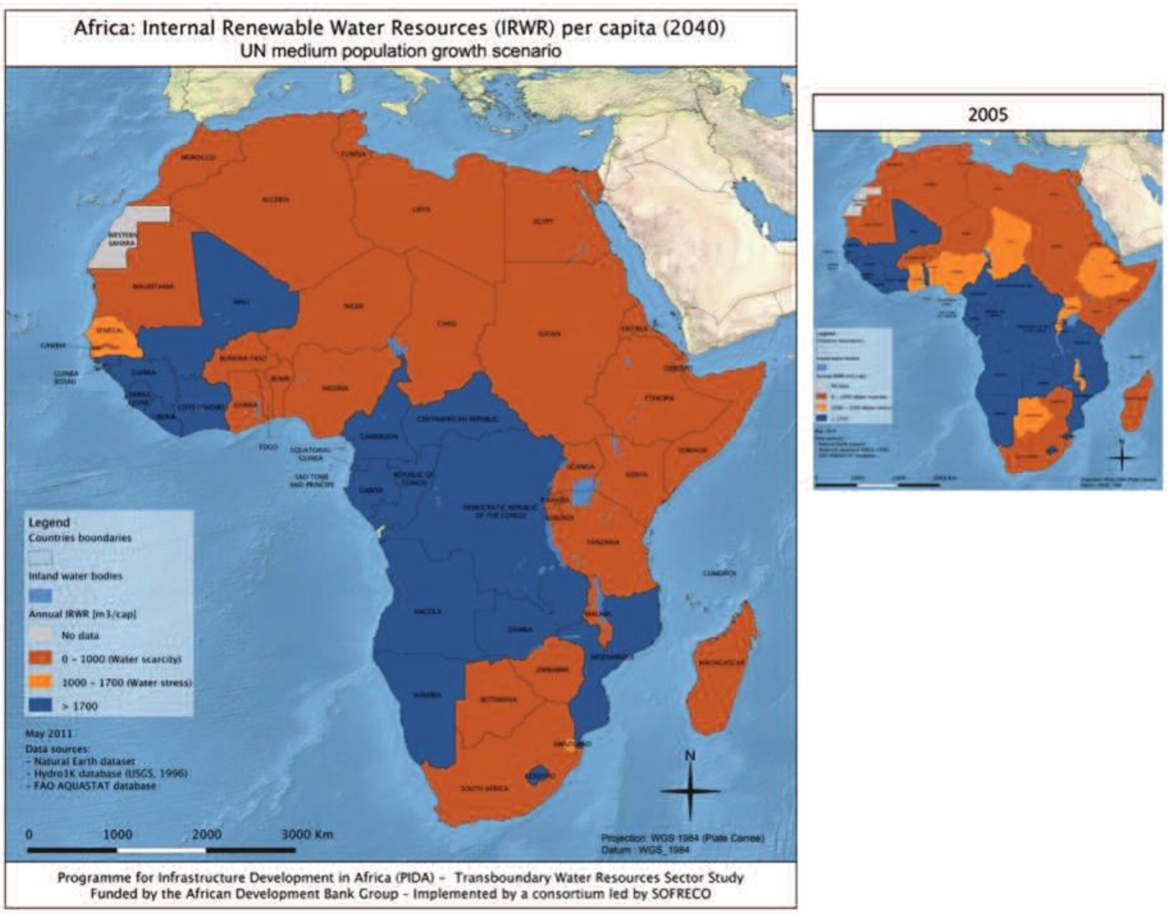


Figure 14: **Map of Internal renewable surface and groundwater resources per capita in Africa. Comparison between the reference year and the situation in 2040 for a medium population growth scenario (Data sources: FAO AQUASTAT database and UN World Population Prospects).**



At present, about half the African continent faces some sort of water stress or water scarcity. The situation is predicted to become significantly more aggravated by 2040. The only regions where the IRWR per capita is considered as sufficient are the Congo River basin, Guinea, Guinea Bissau, Sierra Leone and Liberia. Several countries that were in a situation of vulnerability in 2005 will become water-stressed or water-scarce in 2040. It is also interesting to notice that the majority of the countries sharing international river basins (except Congo) would have to face severe water scarcity challenges in 2040.

While these predictions of water scarcity are calculated on an average annual basis, seasonal and/or inter-annual distribution of water availability and requirements are common in African basins and have to be taken into consideration in the context of basin management and infrastructure planning.

Non-conventional sources of water

Non-conventional sources of water are desalinated water and reused treated wastewater.
According to the FAO AQUASTAT database, data on non-conventional sources of water are only available for 15 countries. These countries are located in areas where the internal water resources are limited: Northern and to a lesser extend Southern region. It is estimated by FAO that, for Africa, 177.8 million m3 of water are desalinated annually (amongst which 155.2 million m3 in the Northern region) and 3032.7 million m3 of wastewater are treated and reused (amongst which 3032 million m3 in the Northern region).

3.2 Infrastructure

3.2.1 Reservoirs and hydropower plants

This section presents an overview of the major existing and planned hydraulic infrastructure with regional significance in the 10 selected river basins. It is based on the FAO African dams database (FAO, 2006), the World Bank Africa Infrastructure Country Diagnostic (AICD, 2008) database as well as other specific reports collected in the various L/RBOs. The spatial location of existing infrastructure is shown in Figures 15 and 16.

Figure 15: **Map of the existing dams in the selected basins. Points are proportional to the total storage capacity of the dam.**

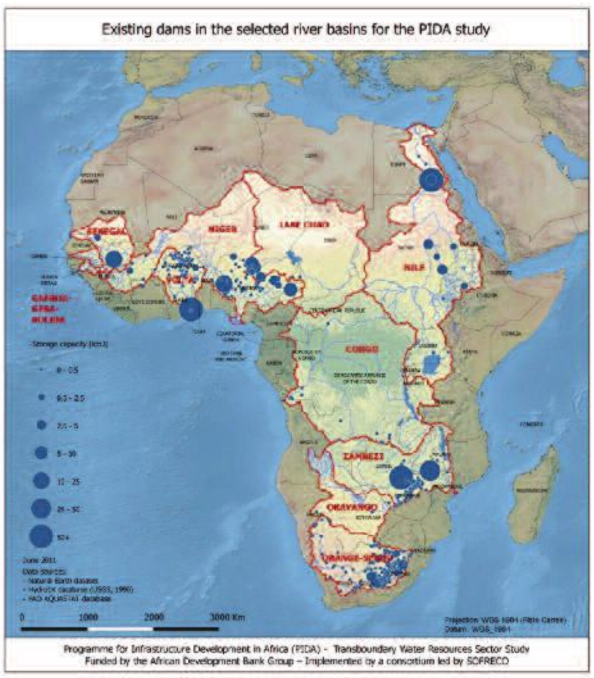
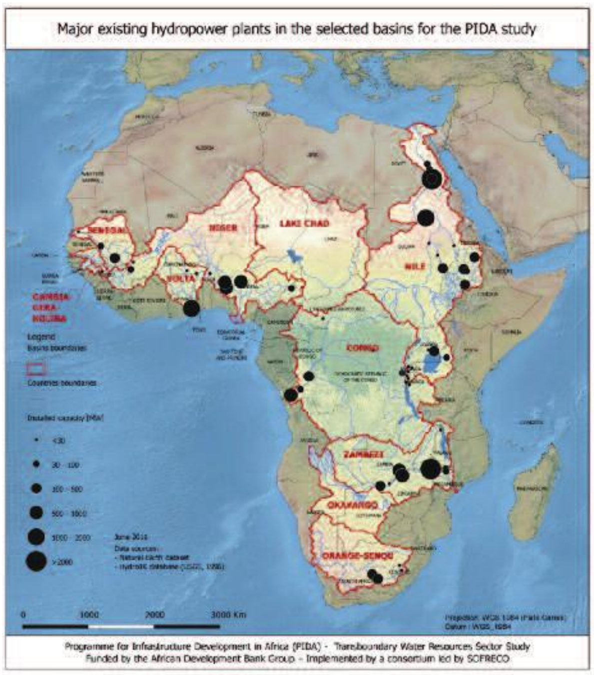


Figure 16: **Map of the major existing hydropower plants in the selected basins. Points are proportional to the installed capacity of the hydropower plant.**



It is worth mentioning that most of the dams in Africa have been built before 1988 with only a few completed in the last two decades (the Lesotho Highlands Water Project (Katse and Mohale dams and associated transfer tunnels) and Tekeze dam (TK-5) in Ethiopia arguably being the most significant ones). While a number of pre-investments are ongoing, at present only a few projects are at the stage of detailed design.

Whereas multi-purpose dams are increasingly being conceptualized, most of Africa's dam infrastructure in the past has been built with hydropower generation as a primary purpose (followed by irrigation water supply). Nonetheless, at present, only 8.4% of the total estimated hydropower potential (see Table 3 below) in the ten PIDA basins are exploited with the total installed capacity at around 15 756 MW. Of this more than 60% are located in the Nile and Zambezi River basins with 5407 MW (34.31%) and 4904 MW (31.15%) installed capacity respectively and a further 27% of installed capacity is found in the Niger (2068 MW or 13.12%) and Volta river basins (1511 MW or 9.59%). Thus, a total of 84% of currently installed capacity is concentrated in these four river basins. Despite these basins having the highest installed capacity (in terms of absolute capacity), the bulk of the estimated (and currently unexploited potential) is also located in these basins, with only a small percentage of estimated potential in the remaining PIDA target basins. While hydropower projects in other basins are possible, the future increase in the utilization of the existing (continental scale) hydropower potential would have to target these four basins primarily.

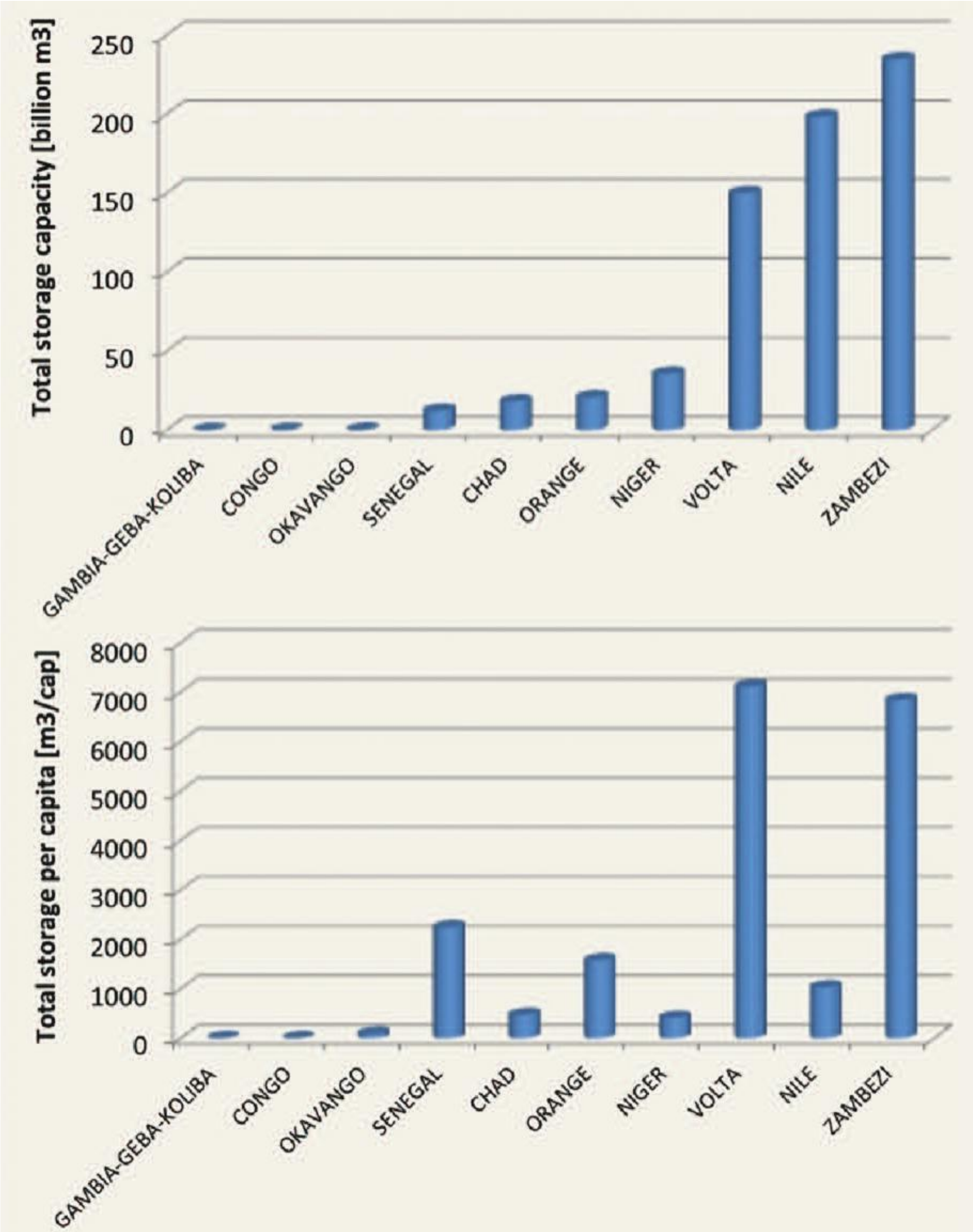
Similar to the situation described for installed hydropower capacity, the bulk of the currently existing storage capacity is concentrated in only a few basins. Of the total storage capacity in the PIDA basins of 669 billion m3, 66% is in the Kariba, Cahora Bassa (both Zambezi basin), Akosombo (Volta basin) and High Aswan dams (Nile basin) as illustrated in Table 3. Despite the comparatively low storage capacity in absolute terms (given the relatively small total annual run-off) the Orange-Senqu River basin is noteworthy in that it is one of the most developed river basins in the world, with several large dams and the world's largest international inter-basin-transfer managed as a single system.

Table 3: Comparison of IRWR by world regions (Data source: FAO AQUASTAT)

BASIN	Installed capacity [MW]				Reservoir storage capacity	
	Operational	Under Construction	Planned	Potential	Current total capacity	Current total storage capacity per capita [m^3/cap]
LAKE CHAD	0	0	75		18.12	468.8
CONGO	840	0	46 957	123600	0.064	0.8
NIGER	2 068	0	1054	6000	35.56	411.5
NILE	5 407	185	13 404	45000	198.19	1026.9
OKAVANGO	0	0	0	400	0.15	84.3
ORANGE	625	0	77		20.67	1573.2
SENEGAL	216	0	609	2000	12.02	2241.6
VOLTA	1 511	0	538	2500	149.91	7110.7
ZAMBEZI	4 904	0	9729	16000	234.54	6837.6
GAMBIA-GEBA-KOLIBA	0	0	120	4000	0	0
TOTAL PIDA BASINS	***15 571***	***185***	***72 563***	***199 500***	***669***	

In terms of storage capacity per capita (Figure 17), the Congo River basin has the capacity to store less than one cubic meter per capita while this ratio is around 7100 m3/cap in the Volta river basin, 6840 m3/cap and 1000 m3/cap in the Zambezi and Nile basins respectively. Based on the level of the ten river basins considered, the ratio is around 1413.9 m3/cap and can be considered as relatively low compared to the 6000 m3/cap and 2200 m3/cap in the USA and China respectively. While water storage per capita can be used as an indicator for water security in arid and semi-arid regions (as rainfall is limited), this is not the case for high rainfall basins (e.g. Congo). For instance, for the Congo basin as well as some (upper) parts of the Nile, the storage will be mainly for hydro-power and not to provide seasonal storage for irrigation purposes. Water storage requirements are site-specific: more storage is needed in arid and semi-arid regions with high climatic variability than in temperate and humid regions.

Figure 17: **Current total storage capacity and per capita total storage in the selected basins**[4]**.**

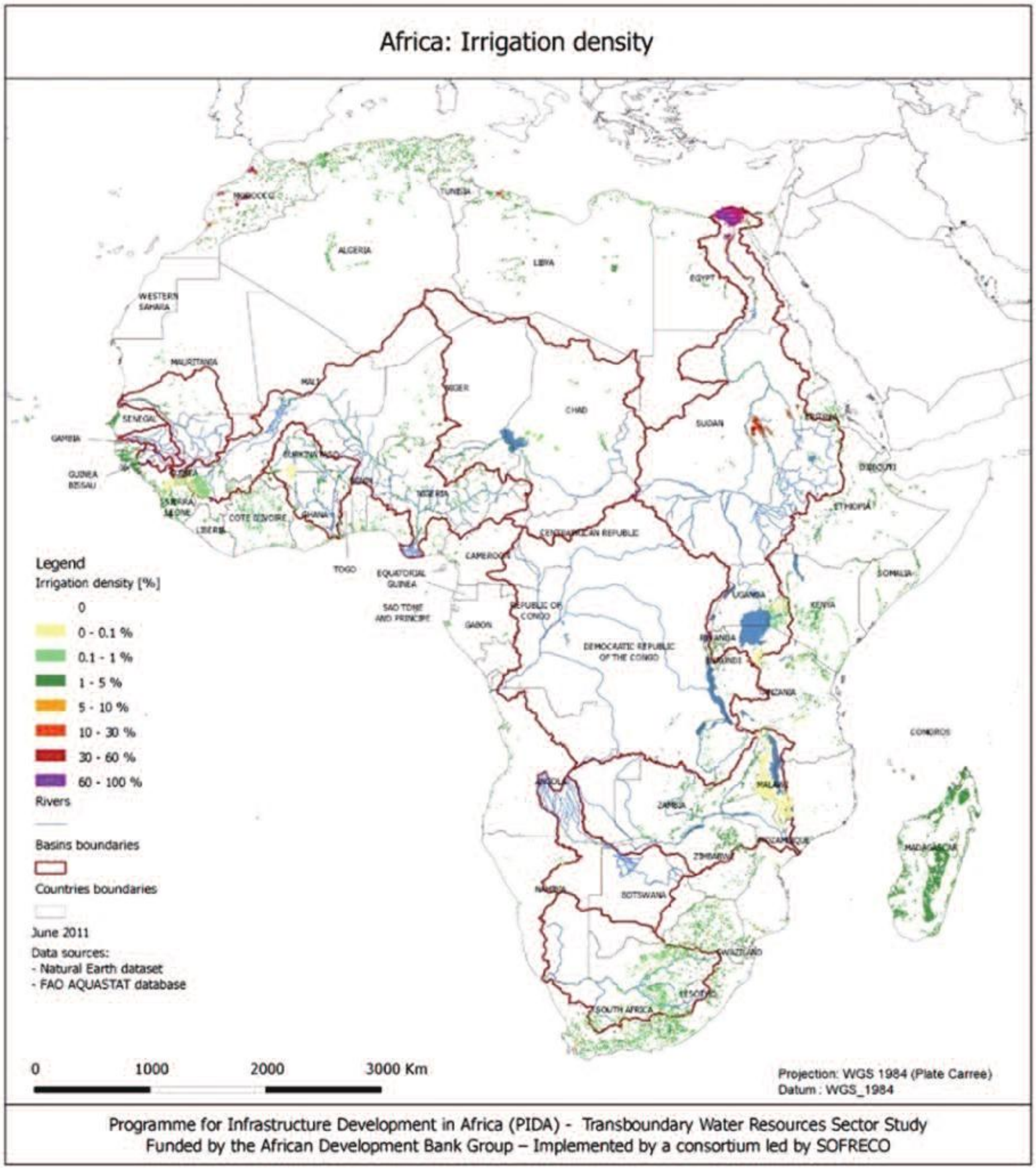


3.2.2 Irrigated areas

Irrigation schemes (Figure 18) are usually at national infrastructure levels and very few joint trans-boundary irrigation schemes exist (the Noordoewer-Vioolsdrift Joint Irrigation Scheme between Namibia and South Africa on the Orange-Senqu River being one such joint scheme). In the selected PIDA basins, the area currently equipped for irrigation stands at around 6.2 million hectares, which represents around 20% of the estimated potential in these basins (see table 4 below and Figure 19). At the continental level, the irrigation potential in Africa has been estimated by FAO at more than 42.5 million ha, of which 30.6 million ha are located in the selected basins for the PIDA study. Almost one third of this potential is located in only two humid countries: Democratic Republic of the Congo and Angola.

[4] Although efforts have been made to ensure consistency of data use across PIDA sectors, some figures presented in the table may differ from the ones used in the Energy Outlook due to different spatial levels of analysis (RECs/Power Pools for the energy, transboundary river basins for TWR).

Figure 18: **Map of the irrigation density in Africa**



(Data source: FAO AQUASTAT, 2002).

It should be noted however, that according to the FAO, the irrigation potential is an estimation of both land suitable for irrigation and available renewable water resources. The irrigation potential can therefore be overestimated in some basins. Likewise, this does not take into account the financial viability of irrigation schemes related to factors such as market access, availability of technical skills and other factors.

Critically, the biggest challenge for the expansion of agricultural production in Africa (both irrigation and rain-fed) is the low efficiency of production. Thus, in addition to increasing the area under production, significant investments need to be made in improving production efficiency if food production targets for 2040 are to be met.

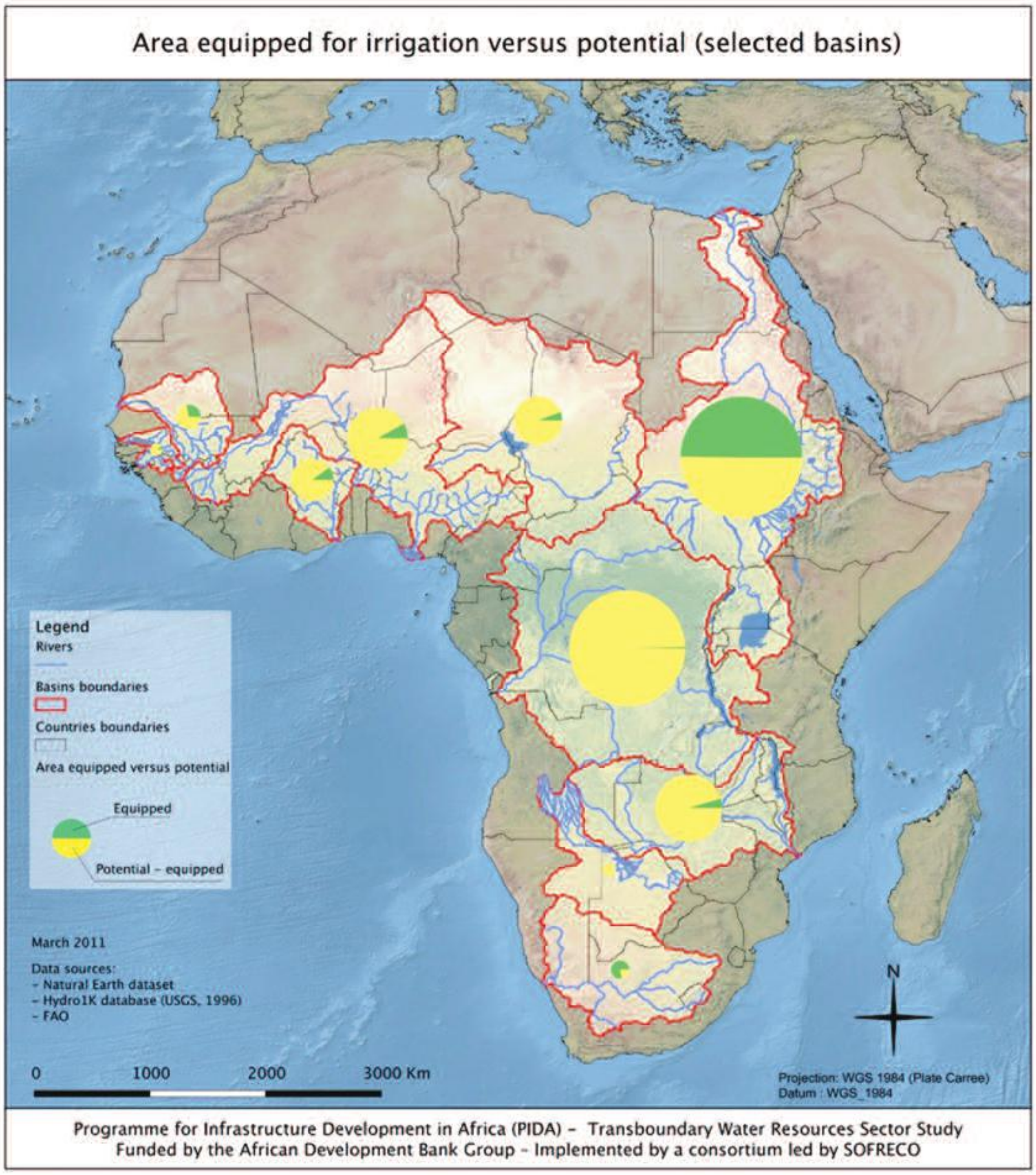
Irrigation efficiency is probably the most challenging issue for African irrigated agriculture. It is defined as the ratio between the water consumed by the plants through evapotranspiration and the quantity of water withdrawn from the river or reservoir. This ratio is often less than 0.5, which means that the volume of water withdrawn from the river, lake or reservoir is twice the volume which is actually consumed (evapotranspirated) by the crops. African countries suffering from severe water scarcity (e.g. Morocco) are subsidizing the provision of efficient irrigation technologies. This should be the approach in many other countries since more than one third of Africa's population suffers from water scarcity and half of the African countries will suffer from "water stress" by 2025.

Table 4: Current and potential irrigated areas in the selected basins

River Basin	Irrigated area [ha]	Irrigation potential* [ha]
Okavango	0	208 060
Gambia-Geba-Koliba	10 000**	115 000
Lake Chad	113 296	1 989 000
Senegal	118 150	434 400
Zambezi	146 869	3 160 380
Volta	150 000**	1 487 000
Niger	228 240	2 816 510
Orange	302 722	390 000
Congo	35 767	9 800 000
Nile	5 078 604	10 192 000
Total 10 basins	*6 183 648*	*30 592 350*

*upper limits estimated by FAO in 1999; ** Author's rough estimation (not validated)

Figure 19: Map showing the areas under irrigation versus the irrigation potential in the selected basins



3.2.3 Rivers and lakes transport infrastructure

The main regional inland waterways in Africa are limited to five rivers, the Nile, the Congo, the Niger, the Senegal and the lower Zambezi Rivers, and three lakes, Lake Victoria, Lake Tanganyika and Lake Malawi. These international inland waterways are important, being a source of livelihood for millions of people using them as traditional channels of trade and communication. To foster integration with lake and river shipping, it is essential to link them with multimodal transport through modern trans-shipment stations to road and rail networks — increased use could be made of the African rivers by integrating transport networks across the continent. Below is a brief overview of the major existing and planned transport infrastructure in the selected basins.

Currently, river and lake transport serve essentially only the people living directly along rivers while river and lake based long haul traffic has practically completely disappeared. The main reason is that the rivers and lakes are neither maintained appropriately nor maintained for navigation and transport purposes. For example, dredging is not carried out, the navigation systems are not correctly maintained and the fleets are old and in very poor condition.

Lake ports have serious infrastructure problems, with the exception of Bujumbura on the Lake Tanganyika. On Lake Victoria, the rail links at each of the ports are relatively well maintained except for Jinja. But, with the exception of Mwanza, none of the ports is equipped to effectively handle increased volumes of general and container traffic.

In the Senegal River basin, the OMVS, with support from the World Bank, is preparing a Senegal River Basin Integrated Multimodal Transport system. The objective is to restore the river transport system of the Senegal River and to enhance it by connecting it to a system that integrates it to land-based ground transportation. In the Zambezi River basin, plans exist to re-open the Shire–Zambezi waterway from Nsanje, in Southern Malawi, to the Indian Ocean port of Chinde, in Mozambique. This will enable barges and medium-sized seagoing vessels direct waterway access to the Indian Ocean. In the Congo River basin, the International Commission of the Congo-Oubangui-Sangha Bassin (CICOS) aims to develop intergovernmental cooperation to enhance interior navigation and is currently preparing a strategic plan to improve the transport along the Congo and its tributaries. Also, the potential of the Niger River must be highlighted: more than three-fourths of its total length could be used by commercial shipping.

3.3 TWR governance

3.3.1 Africa Water Vision and related declarations

The central water related policy instrument for the continent is the African Water Vision 2025, which aims for «an Africa where there is an equitable and sustainable use and management of water resources for poverty alleviation, socioeconomic development, regional cooperation, and the environment.»

The Vision was created by the United Nations Economic Commision for Africa, and designed to aid in the development of a future where the full potential of Africa's water resources can be readily unleashed to stimulate and sustain growth in the region's economic development and social well-being. The Africa Water Vision 2025 is supported by a series of high-level policy statements such as the:

- Abuja Ministerial Declaration on Water: A Key to Sustainable Development in Africa (2002)
- Sirte Declaration on the challenges of implementing integrated and sustainable development on agriculture and water in Africa (2004)
- Declaration of Water and Energy Ministers of Johannesburg (2006)
- Ministerial Declaration of Tunis ending the First African Water Week (2008)
- Sharm El Sheikh Declaration on Water and Sanitation (2008)

These declarations underscore the commitment of African leaders to water resources development for improved and optimized use of the continent's water resources for social and economic development on the continent. At the same time, these high-level declarations create awareness, symbolize political commitment and aim at ensuring an enabling regulatory and institutional framework within regions and AU Member States in the management of water resources.

3.3.2 Policy, legal and institutional frameworks for surface water management

The PIDA governance review found that generally there is a high degree of commonality between policy objectives across the continent and water is recognized throughout as a key driver for achieving economic growth and improved social conditions.

In terms of the legal framework, there are numerous bilateral and multilateral basin-specific agreements but few regionally agreed rules for TWRM in the form of regional (framework) agreements. Currently, only the SADC region has adopted a regional framework agreement (Revised SADC Protocol on Shared Watercourses) and no other African REC has adopted a similar regional legal framework. However, ECOWAS has put in place a strong policy framework for Integrated Water Resources Management and is finalizing a legal framework for trans-boundary water resources. It is believed that doing so would greatly facilitate the achievement of regional policy objectives through the implementation of regional trans-boundary water management programmes. With the UN Convention on the Law of the Non-Navigational Uses of International Watercourses, a state of the art global agreement is readily available on which future regional agreements at the REC level can be based.

The institutional architecture for TWRM can broadly be categorized into three levels, namely the continental, regional (REC) and Lake/River Basin levels (L/RBO).
At the continental level, the African Union Commission (AUC), the principal executive organ of the AU is tasked with, among other things, the preparation of strategic plans and studies for the consideration of the Executive Council. The AUC further elaborates, promotes, coordinates and harmonizes the programs and policies of the Union with those of the RECs. The African Ministers' Council on Water (AMCOW) was formed by the AU in 2002 with the objective of promoting cooperation, security, social and economic development and poverty eradication among Member States through the management of water resources and the provision of water supply services. AMCOW is now a recognized specialized Technical Committee for Water and Sanitation at the AU Summit in Sharm el Sheikh and in 2008 it was designated as the responsible authority for the implementation of the «African Water Vision 2025».

AMCOW maintains a number of key initiatives driving water related development in Africa, such as:

- The African Water Facility
- The African Ministers' Initiative on Water, Sanitation and Hygiene (AMIWASH)
- Rural Water Supply and Sanitation Initiative (RWSSI), and
- The African Water Sector Monitoring and Evaluation

A key initiative of the African Union is the New Partnership for Africa's Development (NEPAD). The initiative is organized in a number of thematic areas, of which "Climate Change and Natural Resource Management" and "Regional Integration and Infrastructure" have a direct bearing for trans-boundary water management. NEPAD maintains a sector programme for water which was developed to address the many challenges in managing water resources on the continent. Among these are the threats posed by drought, floods and climate change. NEPAD's water programme is complemented by its sector programme for energy, which also relates to issues of trans-boundary water management, particularly the generation of hydropower.

At the regional level, the Regional Economic Communities (RECs) are the centre of the TWRM institutional framework. While originally the objective of the RECs is the facilitation of greater regional integration and trade through the creation of Free-Trade Areas, most RECs have since expanded beyond a narrower trade focus and adopted a strong regional development mandate including areas of trade, transport, energy, natural resources management and development to name but a few. The degree to which they deal with trans-boundary water management differs considerably between the eight recognised RECs. Whereas some do not engage strongly (or at all) with trans-boundary water matters, other RECs have created a strong policy, legal and institutional framework for trans-boundary water management in their region. As noted above, the Southern African Development Community (SADC) arguably currently has the strongest framework and is the most active driver of trans-boundary water resources management and development, but other RECs are increasingly taking on a stronger role.

At the basin level, L/RBOs play a central role in TWRM. While some RBOs have already been established many decades ago (e.g. OMVS for the Senegal River), the last two decades have seen a proliferation of RBOs so that today nearly all major shared basins on the continent have one or more established L/RBOs showing that they are increasingly seen as institutions for advancing regional integration agendas. However, at present only very few L/RBOs have a mandate for infrastructure management and operation while the majority of L/RBOs are focused on determining an overall management system for the basin that balances socio-economic development needs, with the need for protecting the basin's biodiversity and the environmental services the basin provides to its population.

3.3.3 Policy, legal and institutional frameworks for groundwater management

The governance framework for the management of trans-boundary groundwater is comparatively less developed. However, efforts are increasingly made to strengthen the management architecture for shared groundwater.

At present, groundwater is considered only to a very limited extent in continental or regional policies and designated policies for the management and development of shared groundwater do not exist. Likewise, regional legal frameworks for the management of shared aquifers do not exist on the continent, with the exception of the Revised SADC Water Protocol on Shared Watercourses. However, it should be noted that the SADC Revised Protocol covers only aquifers that are connected to surface water resources and not so-called confined aquifers.

The development of continental or regional legal frameworks for the management of shared aquifers would considerably strengthen the management frameworks for shared aquifers in Africa. The UN International Law Commission's Draft Articles on the Law of Trans-boundary Aquifers and Aquifer Systems might provide valuable guidance in this regard.

In terms of the institutional framework, AMCOW has established an Africa Groundwater Commission at the continental level. Its main objective is to generate ongoing political buy-in and support in a roll-out of the AMCOW Brazzaville decisions towards the vision of "An Africa where groundwater resources are valued and utilized sustainably by empowered stakeholders." The Commission's work includes acting as a sounding board for implementing decisions by AMCOW and by other Multi-stakeholder Consultations in order to provide strategic advice on collaborative aspects on groundwater resources management in Africa.

At the regional level, the SADC, ECOWAS, IGAD have been involved in the development or the management of trans-boundary aquifers. While their policies are not necessarily consistent as they each have different operational objectives, they have demonstrated an interest that is motivated by their Member States. These policies are increasingly addressing issues concerning trans-boundary groundwater management.

In addition, non-REC regional organisations such as CEDARE and OSS contribute to capacity development and the conduct of pre-feasibility assessments for shared aquifer development.

At the shared aquifer system level–analogous to lake/river basin for surface water–only three cooperative structures for the management of trans-boundary aquifers exist, and are at various stages of their development. Additional structures are currently being set up for some aquifer systems in Southern and West Africa. A key gap is the current lack of management arrangements for the conjunctive use of trans-boundary surface and groundwater resources. Efforts in this regard are only being made, for example the Orange-Senqu River Commission (ORASECOM) has, in recent years, set up a groundwater task team that, among other things, is exploring conjunctive use and management options. Among the selected PIDA basins, important trans-boundary aquifer systems underlie the Lake Chad, Niger and Nile basins and the respective basin commissions are increasingly looking to include the management of these aquifers in their scope of work in conjunction with the management of the basin's surface water resources.

4. FORECAST WATER REQUIREMENTS – OUTLOOK 2040

This chapter provides an overview of forecast water requirements for the 2040 horizon. After a description of the methodology and assumptions that were used for modeling purposes, the results are presented at the continental and country levels as well as at the basin level for the selected PIDA basins.

4.1 Methodology and assumptions

The methodology addresses both sides of the water balance – supply and demand - and consequently assumptions and parameters are required to assess both sides of the equation. The assumptions and parameters used reflect the predominant factors that are likely to determine the trends of regional and continental infrastructure supply and demand over the period until 2040.

As noted, water requirements are likely to increase by 2040 due to population and economic growth, urbanization, and possible climate change. Projections of water requirements are derived for major consumptive uses of which the following have been included in the model: irrigated agriculture, domestic and industrial use and evaporation from reservoirs.

Future water requirements for non-consumptive uses such as hydropower generation, navigation, recreation and environmental flows are not included in the present analysis, given the coarse spatial and temporal resolution of the model used for this study.

The forecast focuses on water quantity. Water quality is not considered in the model as this would require a level of analysis that is beyond the scope of this study. However, it is here emphasized that ensuring the availability of adequate quality water for the respective uses as well as water quantity are critical issues that will pose increased challenges over the years until 2040.

4.1.1 Reference year

For consistency purposes, the year 2005 was used as the reference year for data inputs wherever possible. The selected reference year appeared to be the most recent year in common for all databases that were used to carry out the analysis. Nevertheless, some data was unavailable for the year 2005, in which case the most coherent data was used.

4.1.2 Domestic requirements

For domestic water uses, the following data sources are used and assumptions made:

- The population forecast for 2040 was taken from the World Population Prospects database[5] weighted by the population density of the country's land area in the basin. The spatial distribution of the population is taken from the Gridded Population of the World (GPWv3) database[6] and is illustrated in Figure 4. Starting from the 2005 reference year, the calculated percentage of countries' total population living within basins' boundaries is assumed to remain constant until 2040.
- For the percentage of population residing in urban areas, the United Nations World Urbanization Prospects for the period 2040-2045 were used. The ratio is illustrated in Figure 2.
- There is no seasonal variation
- Per capita water consumption in rural areas = 60 litres per day
- Per capita water consumption in urban areas = 200 litres per day
- System efficiency (□)= 60%

It is recognized that the assumed water requirements for rural and domestic areas are relatively high compared to current level but they take into account the expected high increase of living standards of the African continent in the coming 30 years.

4.1.3 Industrial requirements

Water is a key input for virtually all industrial production processes. By far the largest share of industrial water intake is used for cooling and condensation, particularly in steam-electric power plants as well as in almost all manufacturing and refining operations. Likewise, water is used for the washing of raw materials and equipment, to convey production inputs, and can be part of the product itself. For macro-level forecast purposes, these uses are not distinguished but rather aggregated into a single use for which the following assumptions apply:

- For countries' water withdrawals for industrial purposes, the data from the FAO-AQUASTAT online database[7] reference year 2005 was used;
- The increase in countries' GDP is the main driver

[5] http://www.un.org/esa/population/unpop.htm
[6] http://sedac.ciesin.columbia.edu/gpw/global.jsp
[7] http://www.fao.org/nr/water/aquastat/main/index.stm

of the increase in water requirements for industrial purposes;

- The relationship between GDP and industrial water requirements is extrapolated from UNESCO data[8] for 5 regions in Africa (North, South, East, West and Central);
- Industrial water withdrawals are weighted by the percentage of the countries' population within the basin. The spatial distribution of the population is taken from the Gridded Population of the World (GPWv3) database and is illustrated in Figure 4. The calculated percentage of countries' total population living within basins boundaries is expected to remain constant from the 2005 reference year until 2040;
- Countries' projected GDP for the period until 2040 was forecast by the PIDA macro-economic team and is used by all sectors;
- There is no recycling of wastewater;
- The ratio between water withdrawals and consumption is estimated to range from 8% to 16 % depending on the region in Africa (North, South, East, West and Central), according to UNESCO data[9].

4.1.4 Evaporation from reservoirs

Evaporation losses from large man-made reservoirs can be significant and must be included in the water balance equation. Where the data was available, evaporation losses from planned reservoirs were extrapolated from the losses from neighbouring reservoirs using the ratio between the areas at full supply elevation (FSL).

4.1.5 Food and agricultural requirements

For an estimate of the amount of food that has to be cultivated by 2040, the following assumptions are used:

- Food production will be targeted at closing the gap between domestic production and demand in terms of total cereals (e.g. wheat, maize, rice). The self-sufficiency ratio (SSR) is expected to remain constant[10] for the forecasted population in the selected basins. This last assumption can be considered as relatively cautious as the FAO[11] forecasts a slight decrease in SSR by 2030 and 2050.
- This study forecasts a caloric requirement of 1900 calories/day and a typical caloric content of 3600 calories per kilogram of grain. This leads to an annual caloric cereal requirement (CCR) expected to be 190 kg/cap/year[12].
- The population forecast for 2040 was taken from the World Population Prospects database[13] weighted by the population density of the country's land area in the basin. The spatial distribution of the population is taken from the Gridded Population of the World (GPWv3) database[14] and is illustrated in Figure 4. Starting from the 2005 reference year, the calculated percentage of countries' population living within basin boundaries is expected to remain constant until 2040.

In order to translate this amount of food into the equivalent water requirement for agriculture, the following information is required:

- Average cereal yields (T/ha) in 2040 for each irrigated area
- Crop water requirements (m3/ha/year) in each irrigated area
- Overall irrigation system efficiency
- Percentage of return flows that will drain back to the river system
- The ratio between irrigated and rain-fed area for cereals: pure rain-fed agriculture uses only green[15] water to supply the crop water requirements while in irrigated agriculture, blue[16] water supplements green water to satisfy the crop water requirements.

In order to avoid a biased forecast (due to unrealistic ratio between rain-fed and irrigated area), the approach used was to estimate the maximum amount of irrigation that might have to be developed by 2040 by considering that irrigation expansion will be targeted at closing the gap between domestic production and demand in terms of cereals (e.g. wheat, maize, rice). The self-sufficiency ratio (SSR) is expected to remain constant[17] for the forecasted population in the selected basins as illustrated in Figure 6. It is understood that the assumption of considering irrigation as the only source for improving food security is unrealistic in practice. However, this assumption is of analytical interest, as it is used here to help bracket the range and scope of the analysis and to provide reference points. This scenario will provide an estimated upper limit on projected water requirement for agriculture and is commonly used, including recently by the World Bank,

[8] Shiklomanov, I. A., World Water Resources and their Use Database. A Joint SHI/UNESCO-IHP product, available at http://webworld.unesco.org/water/ihp/db/shiklomanov/, 1999

[9] Shiklomanov, I. A., World Water Resources and their Use Database. A Joint SHI/UNESCO-IHP product, available at http://webworld.unesco.org/water/ihp/db/shiklomanov/, 1999

[10] SSR close to current situation will be estimated from the data available in the FAOstat database (http://faostat.fao.org/)

[11] FAO (2006), World agriculture: towards 2030/2050 – Interim report, Rome.

[12] C. Funk and M. Brown, Food Security Volume 1, Number 3, 271-289, DOI: 10.1007/s12571-009-0026-y

[13] http://www.un.org/esa/population/unpop.htm

[14] http://sedac.ciesin.columbia.edu/gpw/global.jsp

[15] Green water. It corresponds to the rainfall water stored in the soil that can be used by plants.

[16] Blue water. It corresponds to the water diverted from a source (river, lake or reservoir) or pumped from a groundwater source.

[17] SSR close to current situation will be estimated from the data available in the FAOstat database (http://faostat.fao.org/)

in its analysis of the development opportunities in the Zambezi River basin[18].

To estimate the maximum amount of irrigation that might have to be developed by 2040, the following assumptions have been used:

- Average cereal yields (T/ha) in 2040 come from the FAO report "Demand for products of irrigated agriculture in Sub-Saharan Africa" published in 2006.
- Crop water requirements (m3/ha/year) in each country are taken from the following reference: Irrigation Potential in Africa: a basin approach, FAO Land and Water Bulletin 4, 1997.
- The overall irrigation system efficiency is expected to be 50%.
- The percentage of return flows is expected to be 50%.
- Irrigation expansion will be targeted at closing the gap between domestic production and demand in terms of cereals (e.g. wheat, maize, rice).

4.1.6 Seasonality, climate change and future water availability

Temporal resolution: water availability in a river basin exhibits seasonal and inter-annual variation. Given the macro-level nature of the analysis and data available, a yearly time step is adopted for the analysis and the seasonal variability of water availability in the system (river discharge) is not considered. Likewise the assumption is made that historical weather patterns are representative of possible future conditions (see further explanation under climate change impacts below).

Possible impacts of climate change: According to the IPPC[19], (2007), the observed increase in global average temperature would very likely be due to the increase in green house gas concentrations in the atmosphere. Also, *"it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica),* (IPPC, 2007[20])", as illustrated in Figure 20.

In the future, beside the impacts on water availability (both in quantity and seasonality), Africa would be affected by an increase in temperature that can impact the crop water requirements and crop yields: higher air temperatures induce higher evapotranspiration rates and therefore higher crop water requirements.

It is worth mentioning that the continental trend highlighted in Figure 20 can vary regionally: some regions could be affected by an increase in rainfall or temperature while others could be affected by a decrease.

It is now widely accepted by the international community that climate change will affect the hydrology of rivers and lakes and thus overall, freshwater resources availability. Making use of Global Circulation Models (GCM) results could be useful to assess the impact of global change on future water availability[21]. However, GCM provides results in terms of rainfall (depending on the region) and not in terms of river discharge and groundwater recharge. To obtain valuable information for the present PIDA study, it would require the implementation of spatially distributed hydrological models (transformation of rainfall into run-off), for the ten selected basins. Although it is valuable, this is a very complex scientific exercise and is well beyond the scope of the PIDA Study. It is therefore necessary to make use of the above-stated assumption (see under temporal resolution).

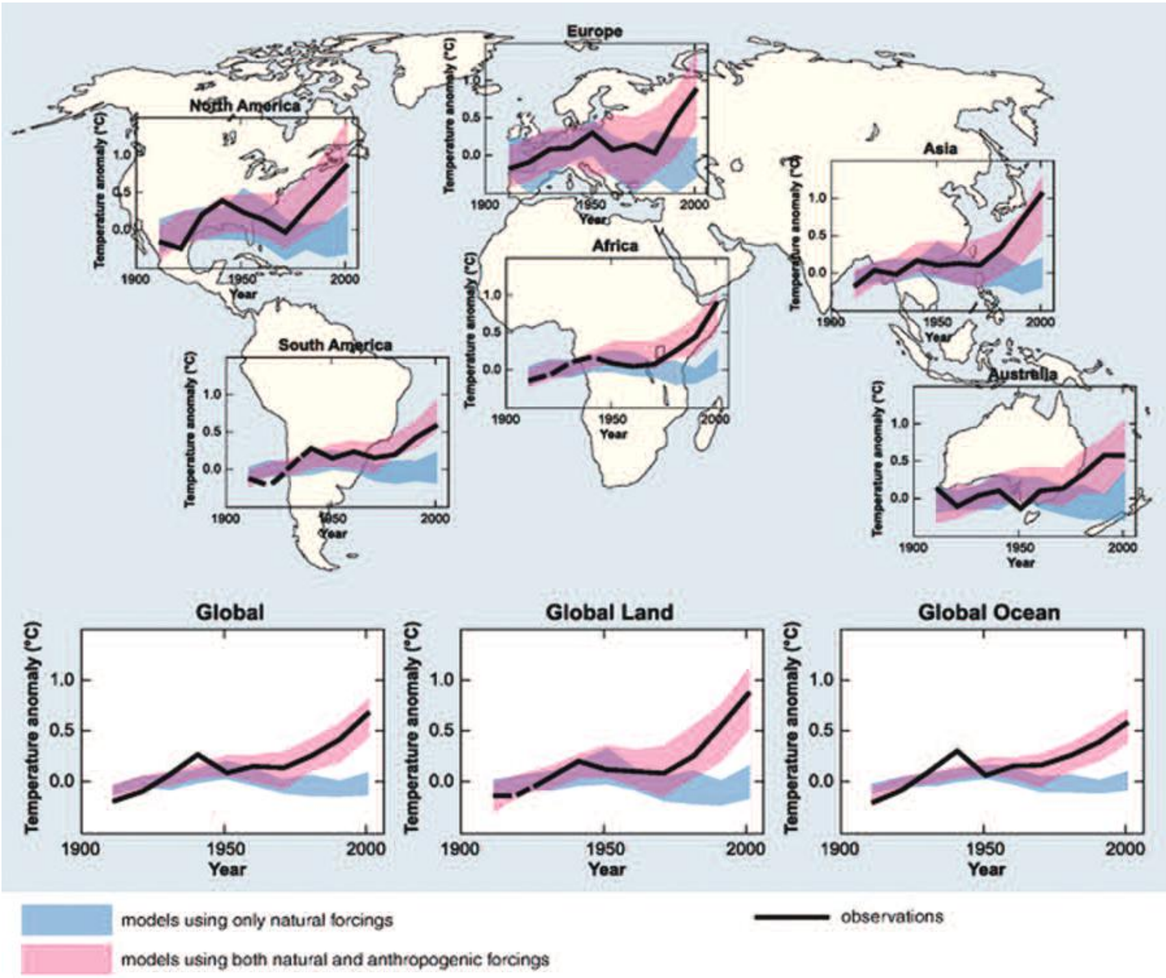
[18] The Zambezi River Basin, A Multi-Sector Investment Opportunities Analysis. World Bank, June 2010.

[19] IPCC Fourth Assessment Report: Climate Change 2007 http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains2-4.html)

[20] IPCC Fourth Assessment Report: Climate Change 2007 (http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains2-4.html)

[21] Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom, 2007

Figure 20: **Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings**



Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. (Source: IPPC, 2007).

4.1.7 Scenarios

As indicated in the assumptions presented in the methodology section, projected water requirements depend on the values taken for both endogenous and exogenous factors like population and economic growth, the level of regional integration and cooperation, food policy, environmental policy and other similar factors. Since those values are uncertain, alternative development scenarios have been formulated and modelled for the purposes of this analysis as follows:

- ***Population growth rate:*** The “Low”, “Medium”, and “High” variants of the World Population Prospects database were analyzed[22] and the corresponding needs in terms of irrigation and domestic water uses assessed.
- ***Irrigation development policy:*** In order to estimate the future water withdrawals in the irrigation sector by 2040, several scenarios were analyzed to define possible trends:
  - In the first scenario (status-quo), the assumption is made that the current situation in the irrigation sector remains unchanged by 2040 (in terms of irrigated area, irrigation system efficiency, irrigation technologies, crop water requirements etc.)
  - The second scenario (business as usual) assumes that the growth rate of irrigated area during the past 30 years (from 1978 to 2008) will remain constant until 2040. Other parameters (crop yields, irrigation system efficiency, technology, etc.) remain unchanged.
  - The third scenario (accelerated irrigation expansion) is identical to the second in all respects, except that it assumes that the growth rate of irrigation area experienced during the past 30 years (from 1978 to 2008) is doubled in the forthcoming 30 years until 2040

[22] (http://esa.un.org/unpp/index.asp?panel=3)

(thus assuming political choices oriented towards accelerated irrigation expansion).

- In the last scenario (full irrigation), it is assumed that irrigated agriculture expansion will be the only source of food to bridge the gap between the food requirement in 2040 and the current situation. This unrealistic assumption is of analytical interest, rather than for practical application. This scenario will provide an estimated upper bound on projected water requirement for agriculture. In this scenario, it is also assumed that the current crop yields will remain unchanged in the future.

In combining the above factors and scenarios, a total of 12 scenarios were modelled and analyzed.

Table 5: Scenario overview

	Population Growth	Irrigation development policy
Scenario 1	Low	Status-quo (lower bound)
Scenario 2	Medium	Status-quo (lower bound)
Scenario 3	High	Status-quo (lower bound)
Scenario 4	Low	Business as usual
Scenario 5	Medium	Business as usual
Scenario 6	High	Business as usual
Scenario 7	Low	Accelerated Irrigation expansion
Scenario 8	Medium	Accelerated Irrigation expansion
Scenario 9	High	Accelerated Irrigation expansion
Scenario 10	Low	Full irrigation (upper bound)
Scenario 11	Medium	Full irrigation (upper bound)
Scenario 12	High	Full irrigation (upper bound)

4.1.8 Modelling of the water balance

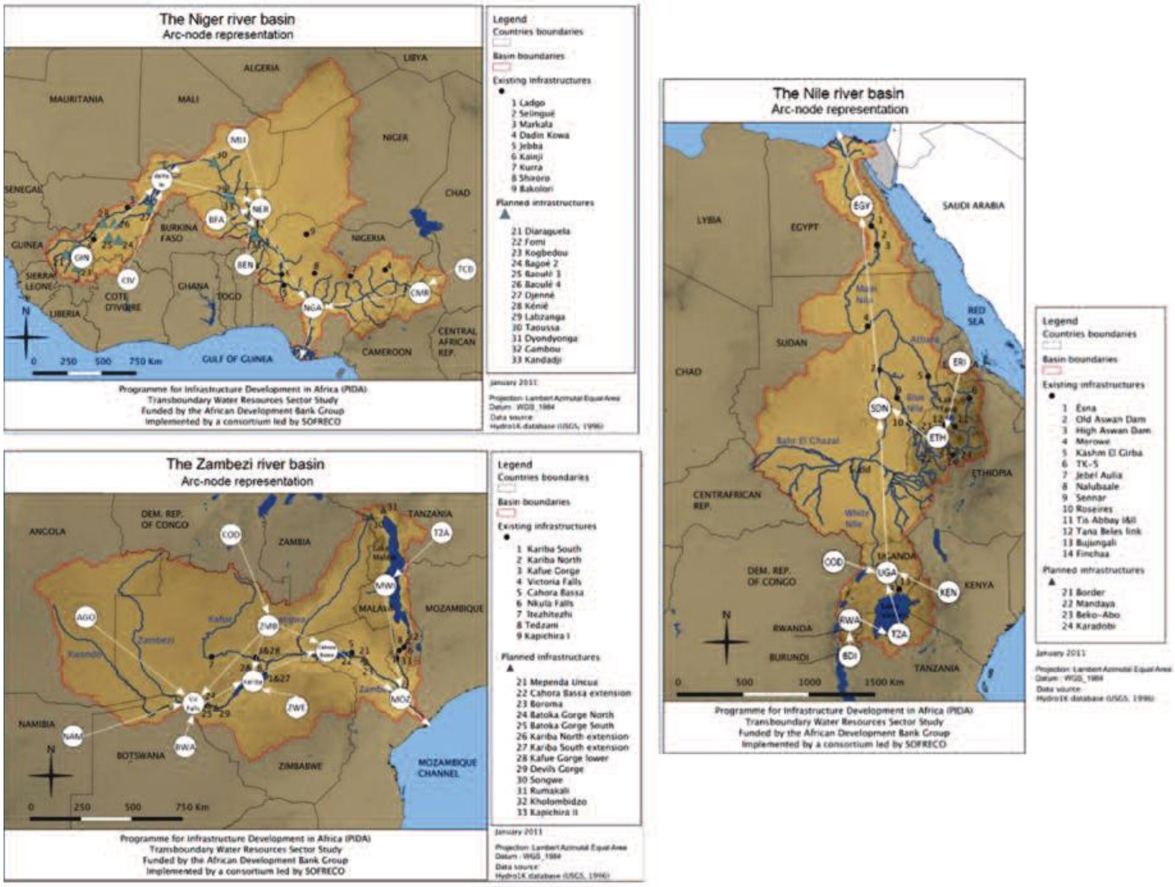
Since water is a mobile resource, and due to the importance of return flows (especially in irrigated agriculture), the comparison between demand and supply at the basin level requires the consideration of the topology. Moreover, since most of the data needed to assess future requirements is available at the country level, the distinction between upstream and downstream countries is critical when matching supply with demand.

To address this issue in three largest and heavily committed river basins (Nile, Niger and Zambezi), water availabilities are assessed through an arc-node representation of the system. Nodes represent demand sites (here countries) whereas the arcs represent the hydraulic connectivity between neighbouring nodes.

Considering the coarse spatial resolution of these arc-node models, localized water scarcity problems within a country are not considered. Figure 21 shows the arc-node representations of the Nile, Niger and Zambezi basins where circles and arrows represent nodes and arcs respectively.

For the other basins, the comparison at the level of the whole basin remains acceptable within the scope of the TWR PIDA Study. For the river basins whose geographical area is predominantly located in one country with a limited percentage of the basin area in other countries (e.g. Congo, Orange), or with currently limited development (e.g. Congo, Okavango), this approximation is not that critical: considering detailed arc-node models in such basins would not affect the major conclusions of the study. In order to refine this preliminary analysis, more detailed studies are needed.

Figure 21: Map of the arc-node models for the Nile, Niger and Zambezi River basins.



With the above assumptions and data sources, projections of future water requirements in Africa were calculated for the different scenarios presented in Table 5. The results are first presented at the continental level and subsequently at the selected PIDA basins level. These water requirements are the volume of water needed to meet the needs of the domestic, agricultural and industrial sectors (including evaporation losses from reservoirs where data was available) should there be no limit on water and financial resources.

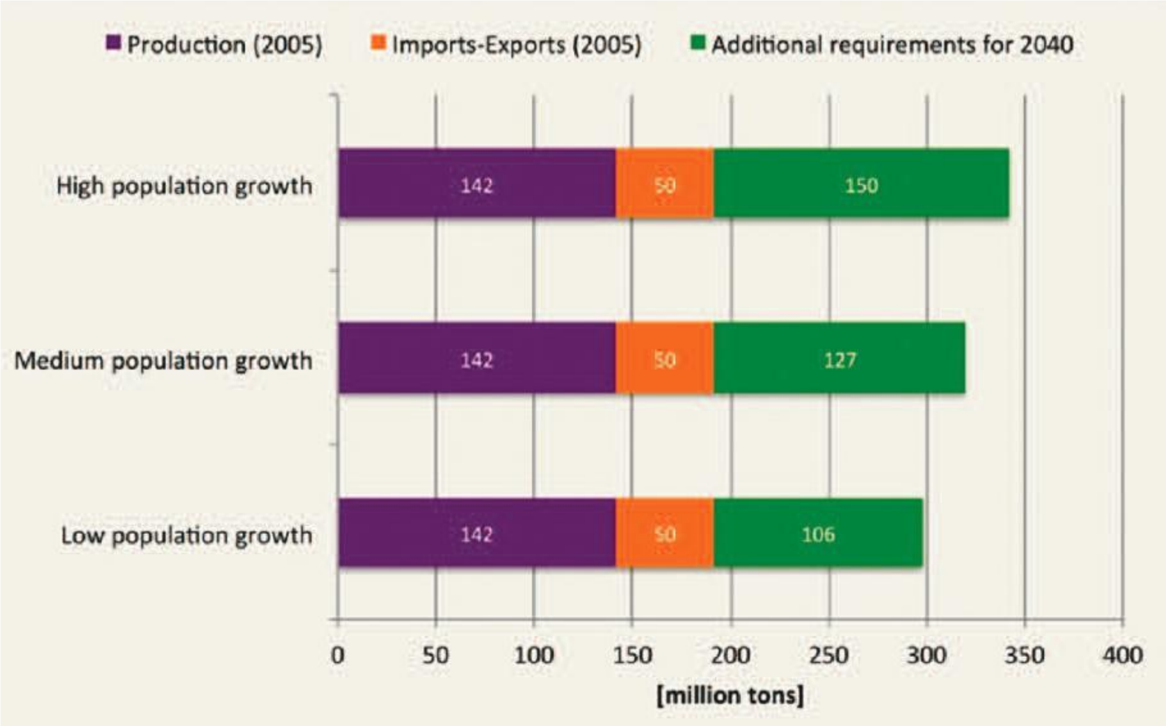
4.2 Current and forecast water resources withdrawals and requirements at continental level

As indicated in the previous sections, water requirements are expected to increase significantly by 2040, with food production through irrigated agriculture representing, by far the largest consumption. This section gives an overview of the difference between the water requirements and the volume of water available at the continental level.

4.2.1 Analysis of food requirements (cereals)

As illustrated above, the projection of food requirement for the 2040 horizon is based on the assumption that production increases in irrigated agriculture will be targeted at closing the gap between domestic production and demand in terms of cereals (e.g. wheat, maize, rice). Considering a caloric cereal requirement of 190 kg/cap/year, the forecast additional food demand, in terms of cereals, was estimated for each scenario considered in Table 5. The future food requirement will only vary depending on the population growth scenario i.e. low, medium and high as other factors taken into account do not impact the forecast food demand. The results are presented in Figure 22 where the current cereal consumption and forecast cereal requirements in Africa (for the various scenarios) are illustrated.

Figure 22: **Current cereals consumption and forecast requirements for 2040 in Africa.**



The current cereal consumption is estimated by the sum of the current production and imports minus exports[23]. It is shown in the figure that:

- Currently, the consumption of cereals in Africa is around 192 million tons of which 73.4% (142 million tons) are produced in Africa. The total cereal export is around 3 million tons while the imports are close to 53 million tons.
- The increase in total cereal requirements in Africa (compared to the current situation) is expected to range between 56% and 78% depending on the scenario considered. In terms of cereals quantities, it represents an increase ranging from 106 to 150 million tons (compared to 192 million tons currently).

As mentioned in Chapter 2, the spatial distribution of these additional food requirements is illustrated in Figure 9. Not surprisingly, these requirements closely mirror the predicted population distribution. The Nile, Congo and Niger River basins (and the Zambezi to a lesser extent), face the highest increased in food requirements.

4.2.2 Analysis of gross water requirements

Continental figures and sector's contributions

Figure 23 shows the total forecast (2040) annual gross water requirements for the twelve scenarios at the continental level. This is the volume of water that must be withdrawn from the river system for domestic, industrial and agricultural uses. Evaporation losses from the large man-made reservoirs are also included where data was available. The total water withdrawals for the reference year 2005 are shown for comparative purposes.

In 2005, the volume of water withdrawn from the river systems across Africa was about 265 km3 (or billion m3) per year of which 66 km3 per year lost by evaporation losses from man-made reservoirs, 9 km3/y for industrial uses, 21 km3 per year for domestic uses and 170 km3 for the agricultural sector.

It is estimated that by 2040, the gross water requirement for domestic uses will range between 135-161 km3 per year, depending on the population growth rate scenario. In other words, the impact of the future population growth rate on the gross water requirements can be as high as 20%. According to the estimated future annual GDP growth rate of 6%, industrial gross water requirements will total around 35 km3 per year. Finally, evaporation losses from man-made reservoirs will represent a significant part of the requirements, with a total of around 77 km3 per year, more than twice the gross water requirement for industrial uses.

For the agricultural sector, the water withdrawals in 2040 will vary depending on a series of economical, technical, climatic and political conditions, and factors that are difficult (if not impossible) to predict. However, modelling the four scenarios (for irrigated agriculture development) described above provides a good indication of the expected order of magnitude of the future withdrawals for the irrigation sector:

Status-quo scenario: If the current situation in the irrigation sector remains unchanged at the 2040

[23] Total cereals production, imports and exports are available for each country in the FAOSTAT online database

horizon (in terms of irrigated area, irrigation system efficiency, irrigation technologies, crop water requirements etc.), the withdrawals will remain unchanged. If this status-quo remains consistent, the gross water requirements for irrigation will be around 170 km3 per year in 2040.

Business as usual scenario: If the irrigated area growth rate of the past 30 years (from 1978 to 2008), estimated at 0.15 million ha per year, remains constant until 2040, the irrigated area will increase by around 35% in 2040. This represents an additional annual irrigation withdrawal of 55 km3 per year in 2040. In this scenario, the total withdrawals for the irrigation sector would be 225 km3 per year (170 km3 + 55 km3).

Accelerated irrigation expansion scenario: a doubling of the growth rate for the expansion of irrigation areas over the next three decades (compared to the previous 30 years from 1978 to 2008) would lead to continental gross water requirements for the irrigation sector of around 280 km3 per year.

Upper bound scenario: In the theoretical upper bound scenario, where it is assumed that irrigation expansion will be the only contributor to sources of food supply to bridge the gap between future food requirements and the current situation, the estimated additional withdrawals for the irrigation sector range from 400 km^3 to 580 km^3.
In the case of the three first irrigation scenarios (status-quo, business as usual and irrigation expansion), it is worth mentioning that the gap between the food production and the demand will be met by either rain-fed agriculture or international imports. The importance and potential development of rain-fed agriculture will be highlighted in the section addressing the choices and options to meet the future challenge in Africa.

Figure 23: **Projections of annual gross water requirements in Africa in 2040 as compared to current withdrawals in 2005.**

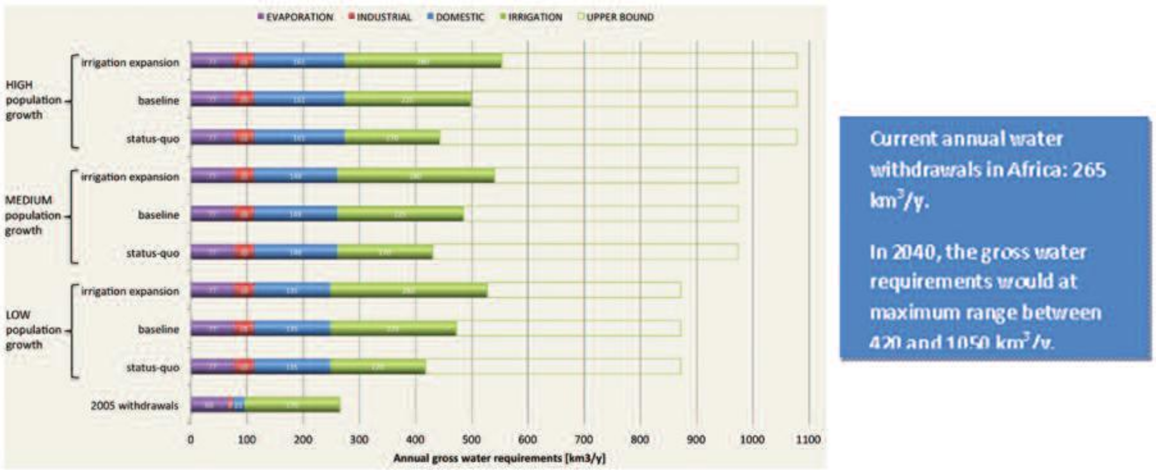
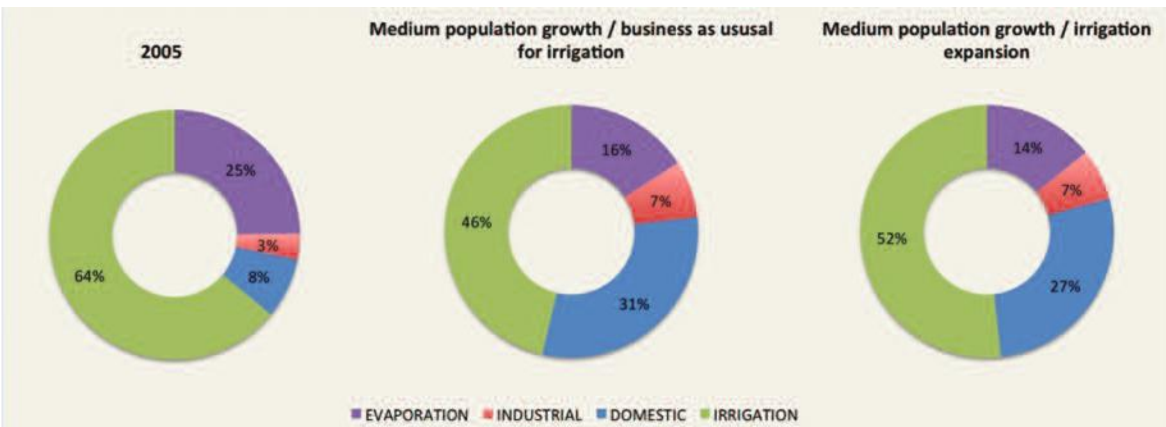


Figure 24 presents the ratios of the different uses in percentage of total gross requirements. In 2005, the distribution amongst the different sectors was as follow: 8% (domestic), 3% (industrial), 64.1% (irrigation) and 25% (evaporation). The figure illustrates that by 2040, irrigation will remain the major water user in Africa. However, its share of the gross water requirement would decrease while the percentage share of the domestic and industrial sectors will be likely to triple and double respectively.

Figure 24: **Sector's contribution to annual gross water requirements (Africa).**



Country scale figures

The annual water withdrawals (in 2005) for each African country are depicted in Figure 25 while the same information, per capita, is illustrated in Figure 26. These values correspond to the FAO AQUASTAT estimated water quantity that is withdrawn from the river system, for each country, for agricultural, industrial and domestic uses. A fraction of this volume is consumed while the remaining returns to the river system.

Figure 25: **Africa: map of annual withdrawals (2005).**

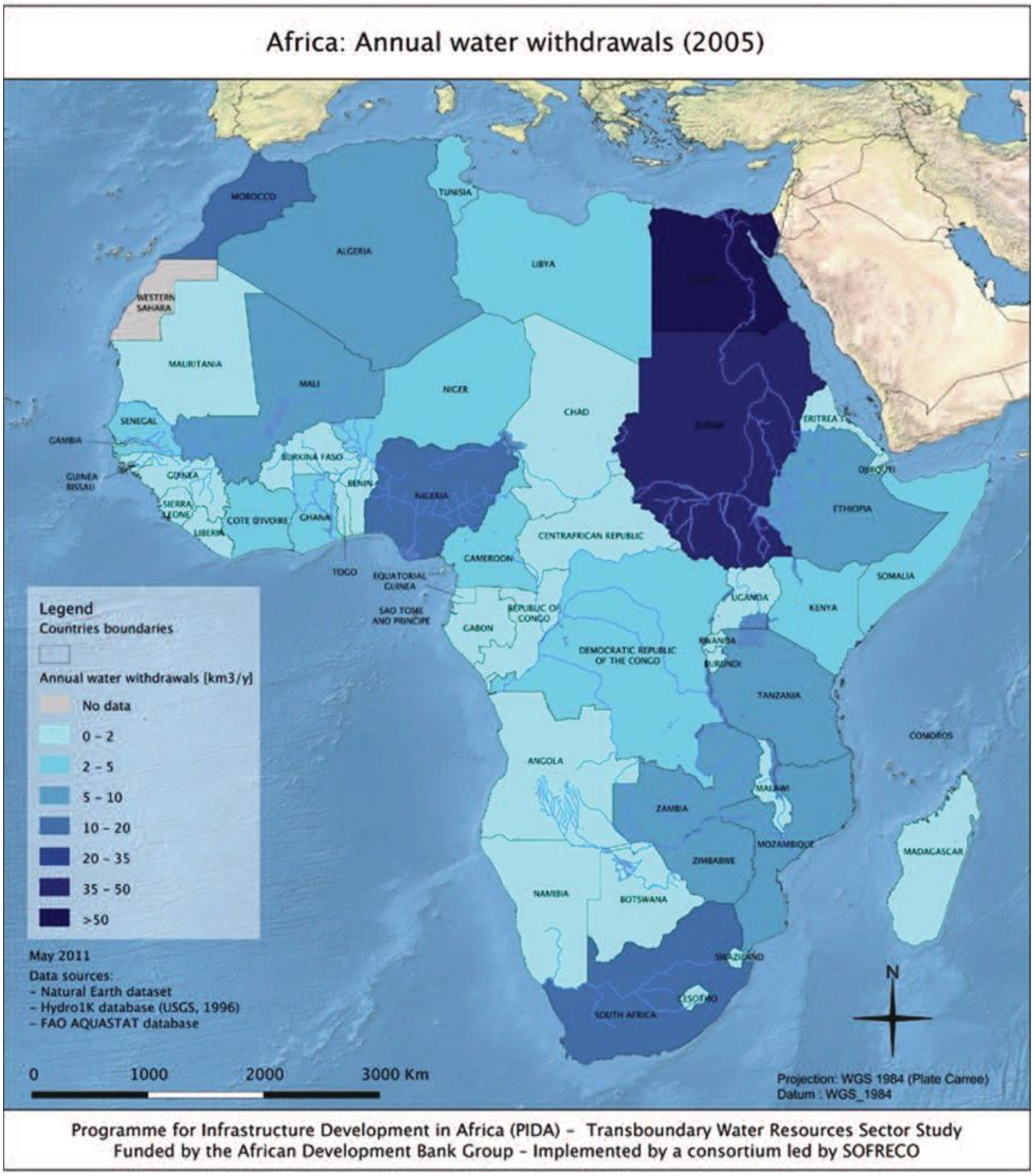


Figure 26: **Map of annual water withdrawals per capita (2005).**

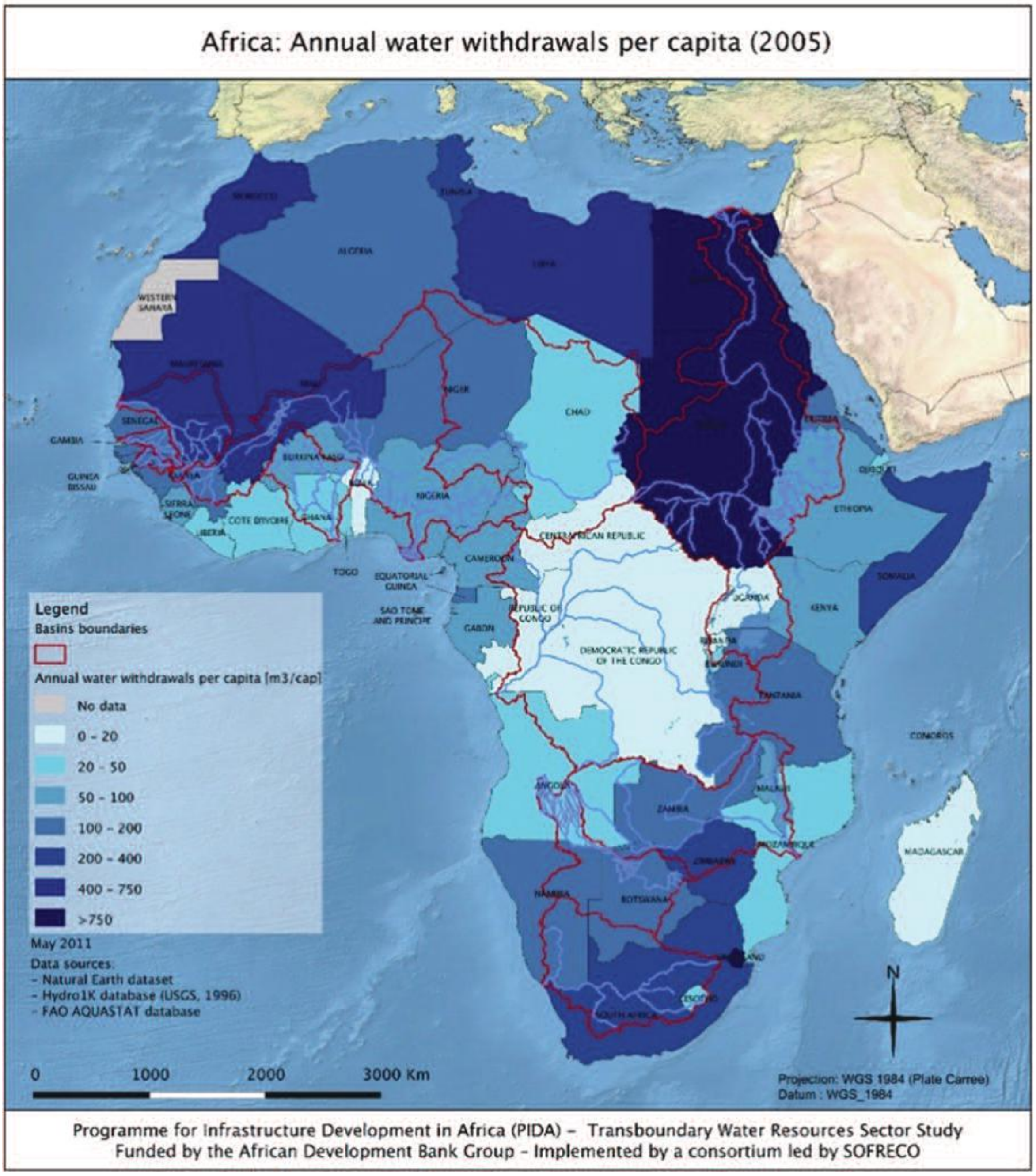
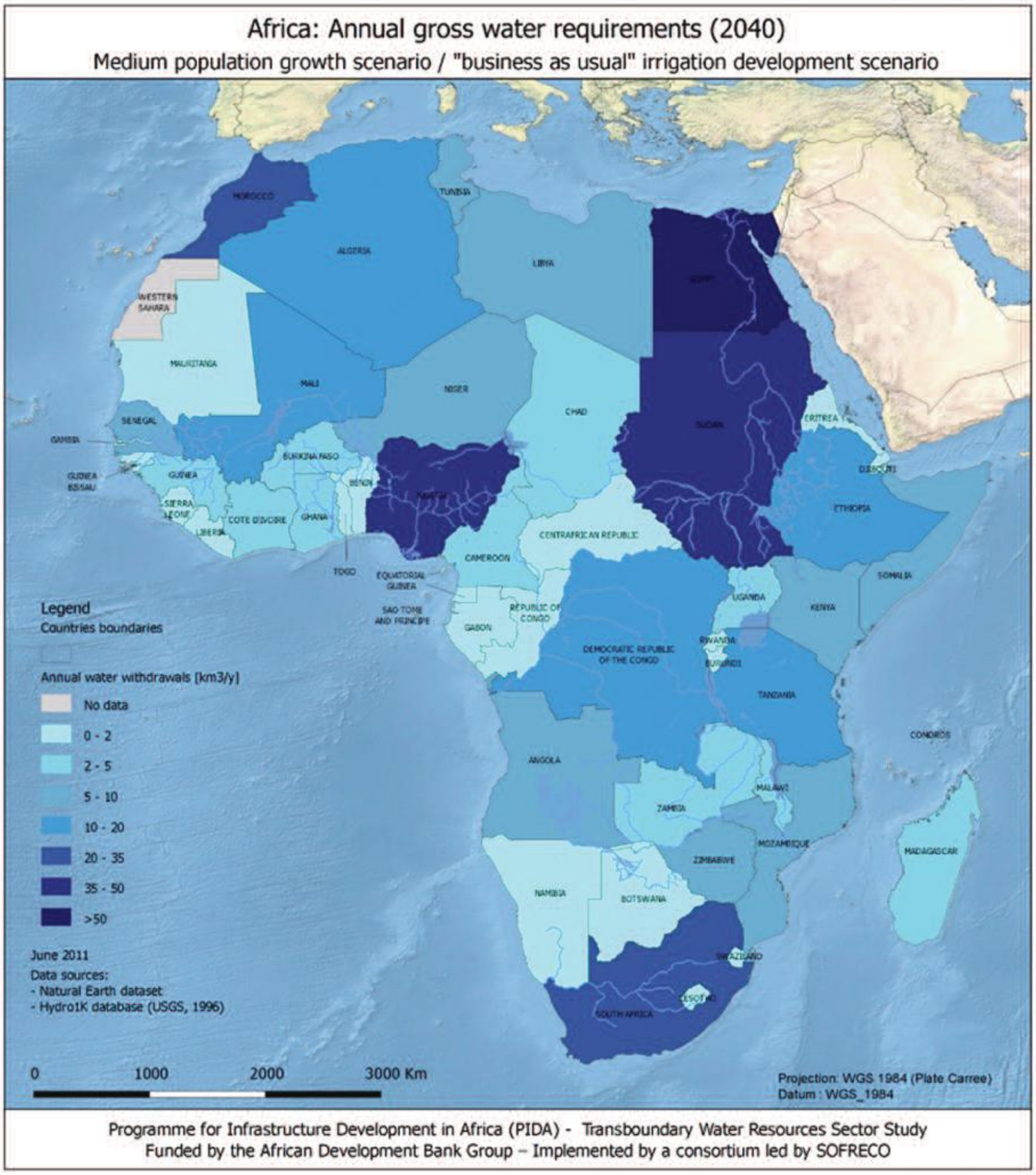


Figure 27 shows countries' annual gross water requirements for the year 2040 considering a medium population growth rate and business as usual irrigation development scenario (irrigated area growth rate of the past 30 years remains constant until 2040, all other parameters remain unchanged).The map illustrates that:

- In 2040, most of the countries in the Nile basin will have a high gross water requirement for water (> 50 km3/y)
- The pressure on the water resources in the Niger and Orange Rivers is also likely to increase and most of the riparian countries have now gross water requirement exceeding 15 km3/y

Figure 27: Africa: Forecasted annual gross water requirement (2040).

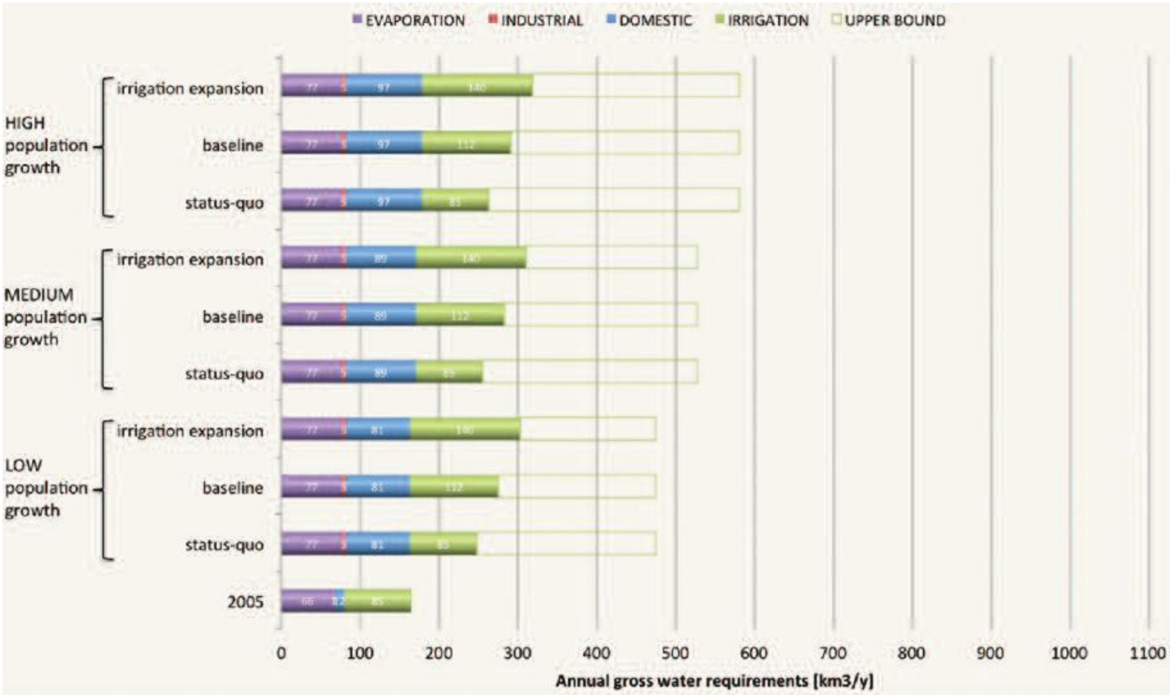


4.2.3 Analysis of net water requirements

A distinction must be made between gross water requirements and net water requirements. While the former is the volume of water withdrawn from the river, reservoir or aquifer, the latter refers to the requirement needed for actual consumption uses. The difference is the combined losses that occur between point of abstraction and point of use. Hence, compared to gross water requirements, net water requirements are lower by a factor proportional to the efficiencies in the different water-using activities.

Figure 28 shows the annual net water requirements for the reference year 2005, as compared to the net requirements by 2040 for the various scenarios. On the basis of the assumptions on efficiencies introduced in the methodology, Figure 28 shows that the net consumption for the year 2005 is around 165 km3/y while the gross requirements were around 265 km3/y. By 2040, the net annual water requirement forecast could range from 248 to 318 km3/y depending on the development scenario considered, with an upper limit of around 580 km3 per year.

Figure 28: Africa: Current (2005) annual net water requirements and forecasted (2040) net requirements depending on the various scenarios.



4.3 Current and forecast water resources withdrawals and requirements in the selected basins

4.3.1 Analysis of gross water requirements

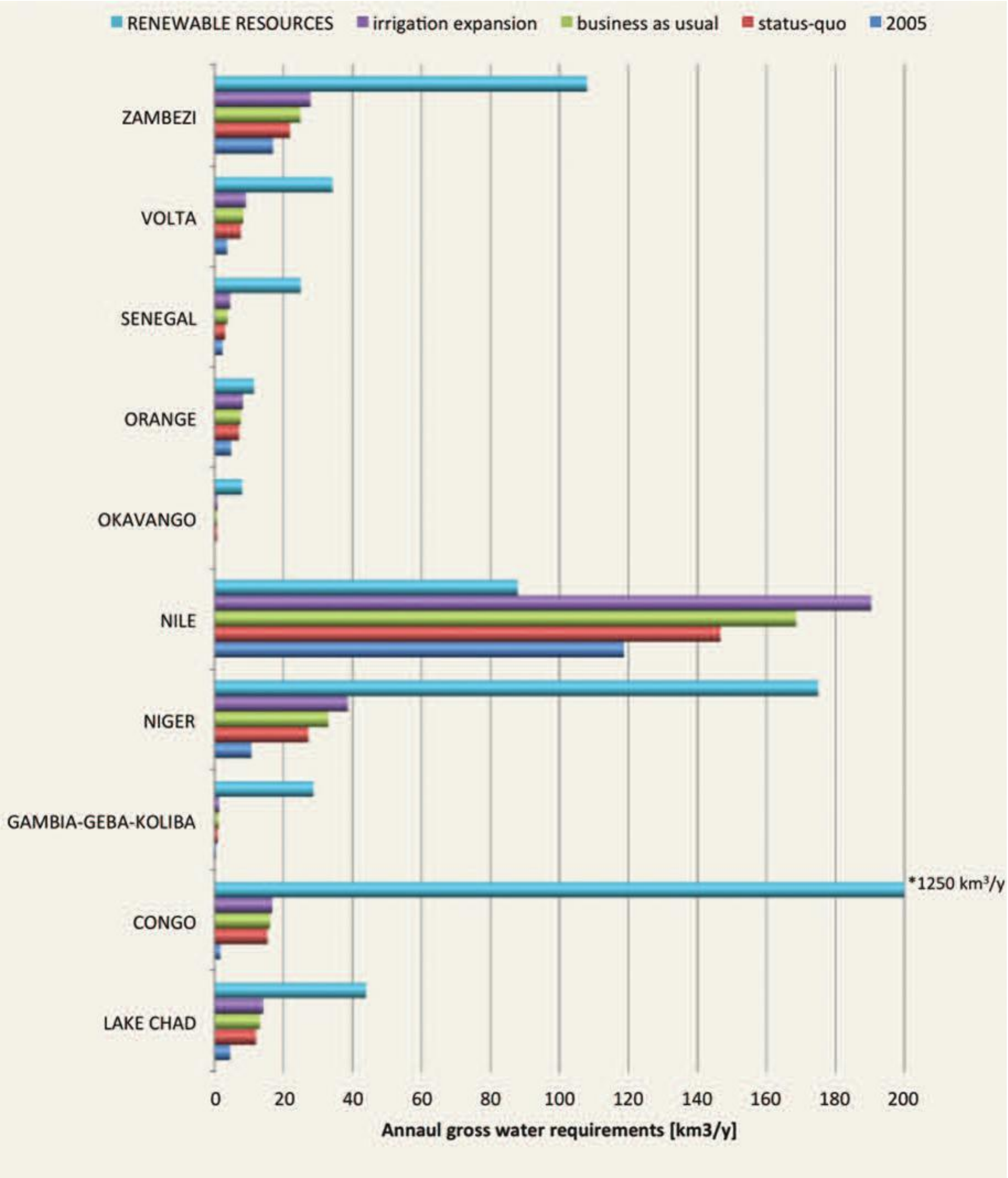
Table 6 and Figure 29 list the gross water requirements aggregated by basin. One can observe that:

- In 2005, the total gross water requirement of the selected basins corresponded to 62% of that of the African continent (162 km3 per year for the PIDA basins against 265 km3 per year for the African continent)
- In 2005, the Nile was the basin with the largest gross water requirement, followed by the Zambezi and Niger basins. The share of these three basins in the total water requirement of the continent was as high as 56% (or 89% of the selected basins)
- The aggregated gross water requirement for the selected basins is likely to increase by 69% by 2040 considering a medium population growth scenario and that the irrigated area growth rate of the past 30 years remains constant until 2040, all other parameters remaining unchanged ("business as usual" irrigation development scenario)

Table 6: Annual gross water requirements in the selected basins [km3/year]

		GROSS water requirements [km3/y]									
		LAKE CHAD	CONGO	GAMBIA-GEBA-KOLIBA	NIGER	NILE	OKAVANGO	ORANGE	SENEGAL	VOLTA	ZAMBEZI
RENEWABLE RESOURCES		44.00	1250.00	28.70	174.99	87.90	8.00	11.44	25.00	34.25	108.00
	2005 withdrawals	4.49	1.66	0.45	10.69	118.75	0.19	4.82	2.31	3.65	16.99
"Low" population growth	status-quo	11.49	14.27	0.97	25.91	144.11	0.63	6.91	2.94	7.32	21.39
	business as usual	12.51	14.97	1.11	31.63	165.99	0.70	7.49	3.71	8.05	24.34
	irrigation expansion	13.53	15.68	1.26	37.34	187.88	0.76	8.07	4.48	8.78	27.30
"Medium" population growth	status-quo	12.09	15.37	1.02	27.24	146.67	0.66	7.09	3.02	7.65	21.88
	business as usual	13.11	16.08	1.16	32.95	168.56	0.73	7.66	3.78	8.38	24.83
	irrigation expansion	14.13	16.78	1.30	38.67	190.44	0.79	8.24	4.55	9.11	27.79
"High" population growth	status-quo	12.71	16.51	1.07	28.60	149.31	0.70	7.27	3.09	7.99	22.38
	business as usual	13.73	17.21	1.21	34.31	171.19	0.76	7.85	3.86	8.72	25.34
	irrigation expansion	14.74	17.91	1.35	40.03	193.08	0.82	8.42	4.62	9.45	28.30

Figure 29: Annual gross water requirements in the selected basins for a medium population growth scenario.



* Natural renewable resources of the Congo basin are around 1250 km3/y (removed from the graph to avoid scaling issues)

Figure 30 shows the relative contribution of the various uses for 2005 and the two most likely scenarios ("business as usual" and "accelerated" irrigation expansion scenario, both of them assuming a medium population growth). One can see that:

- In 2005, 71.2% of the gross water requirements (withdrawals) were made to be used in irrigated agriculture. This highlights the central role of agriculture in the analysis
- In 2040, that proportion will decrease and reach between 54% and 59% for the medium population growth scenario depending on the irrigation development policy.
- The largest differences between scenarios are observed for the domestic sector, given the expected population growth and higher living standards; the industrial sector remains fairly constant.

Figure 30: Different sector's contribution to gross water requirements in the selected basins.

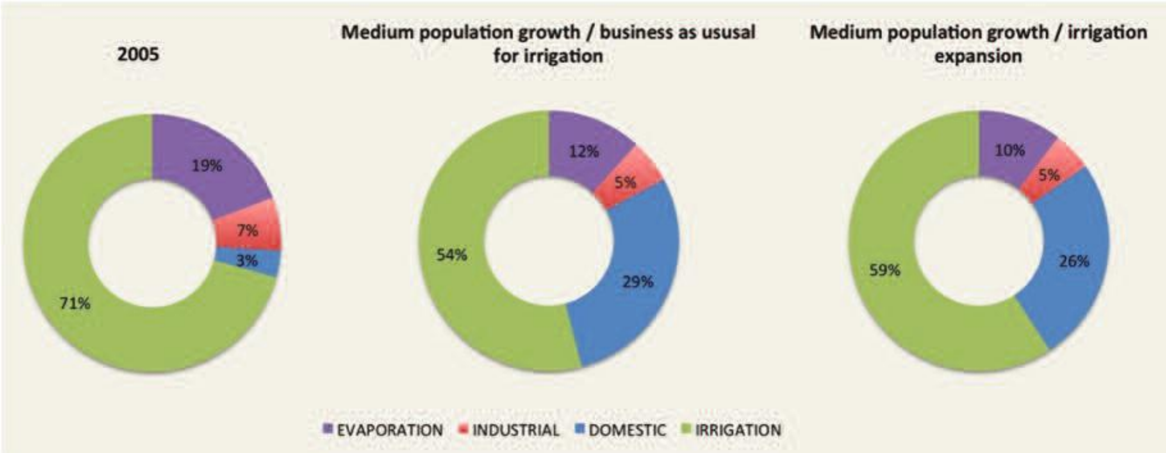
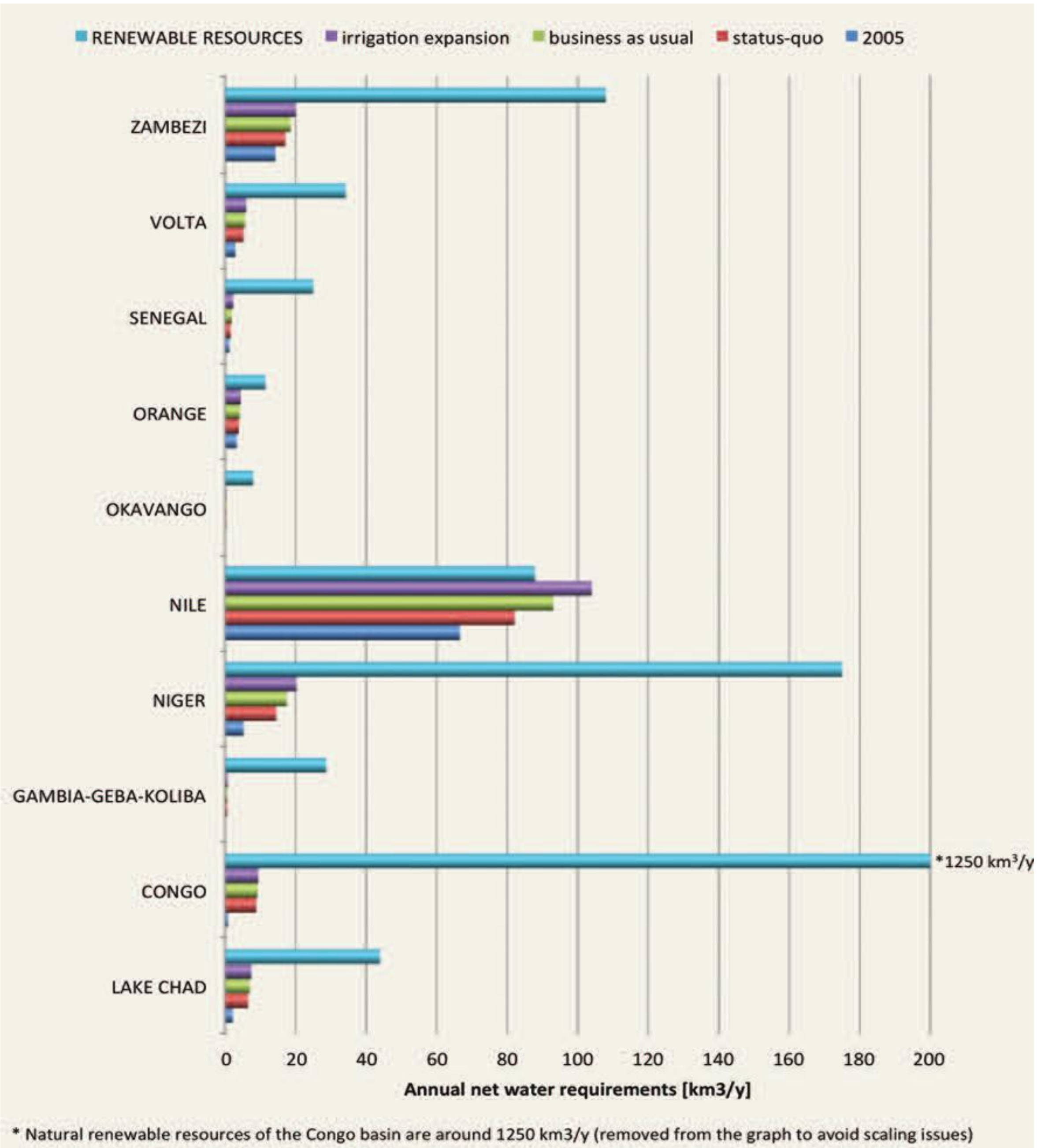


Figure 31 shows the annual net water requirements for the year 2005 and the net water requirements considering a medium population growth scenario and the various irrigation development scenarios.

Figure 31: Annual net water requirements in the selected basins.



4.3.2 Gap between supply and net requirements/Level of commitment of the selected basins

Level of commitment

The level of commitment in a river basin is defined as the ratio between water consumption and the natural renewable resource available in the river basin. In other words, the total current available yield (available renewable resources before infrastructure) is compared with water consumption at the basin level, taking into account the possible use of return flows. The objective is to make a distinction between basins that are likely to be fully committed and those where there is still some degree of flexibility for water allocation to domestic, industrial and agricultural activities.

Figure 32 presents the level of commitment modelled for the medium population growth rate scenario while considering three irrigation development scenarios. The situation in 2005 is also presented for comparative purposes. A spatial illustration of the same information is presented in Figure 33. It shows that:

- Currently, the Nile basin is almost fully committed while the level of commitment of the Orange-Senqu basin is around 30%
- In 2040, the level of commitment in the selected basins may remain as low as 0.8% in the Congo, while it will rapidly approach 100% in the Nile
- The river basins where the level of commitment will be close to or exceed 15% are: Zambezi, Volta, Orange-Senqu, Lake Chad and Nile.

Figure 32: Percentage of commitment in the selected basins.

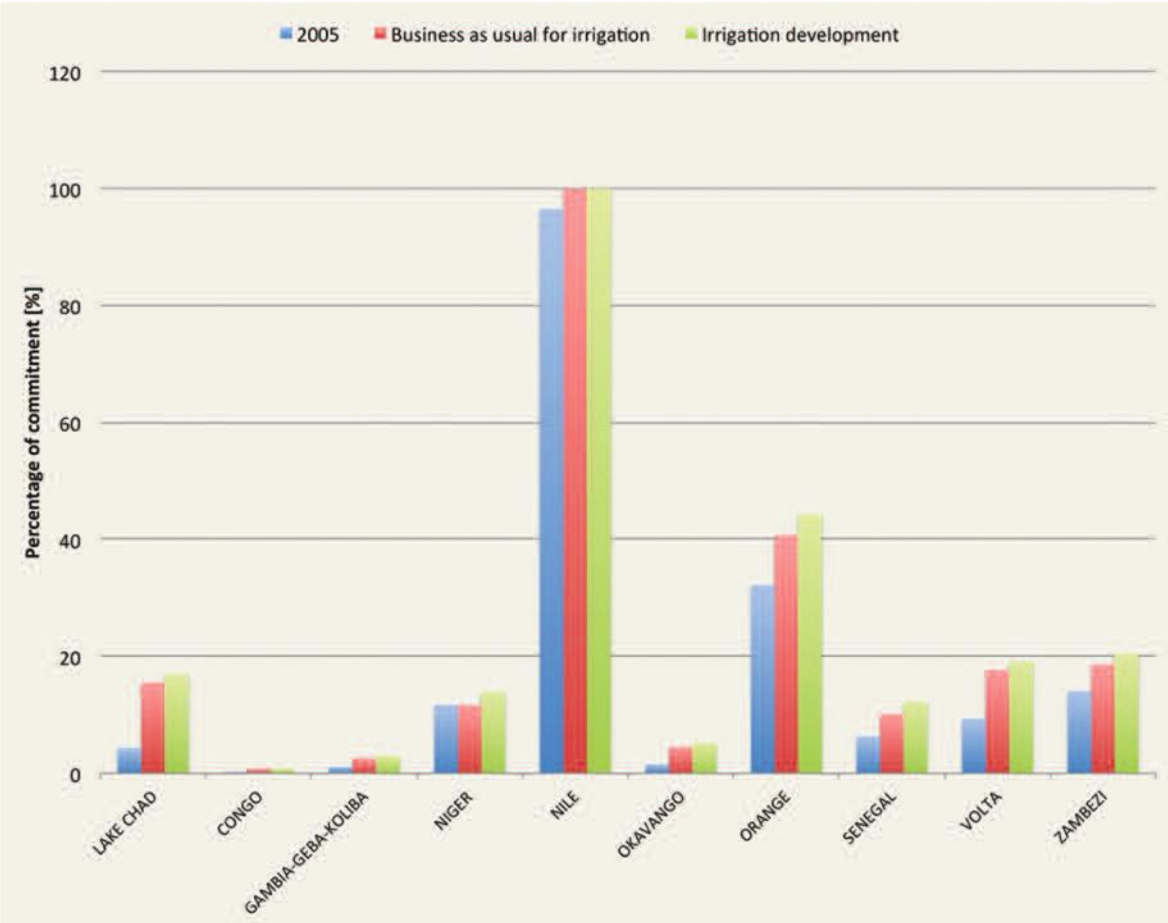
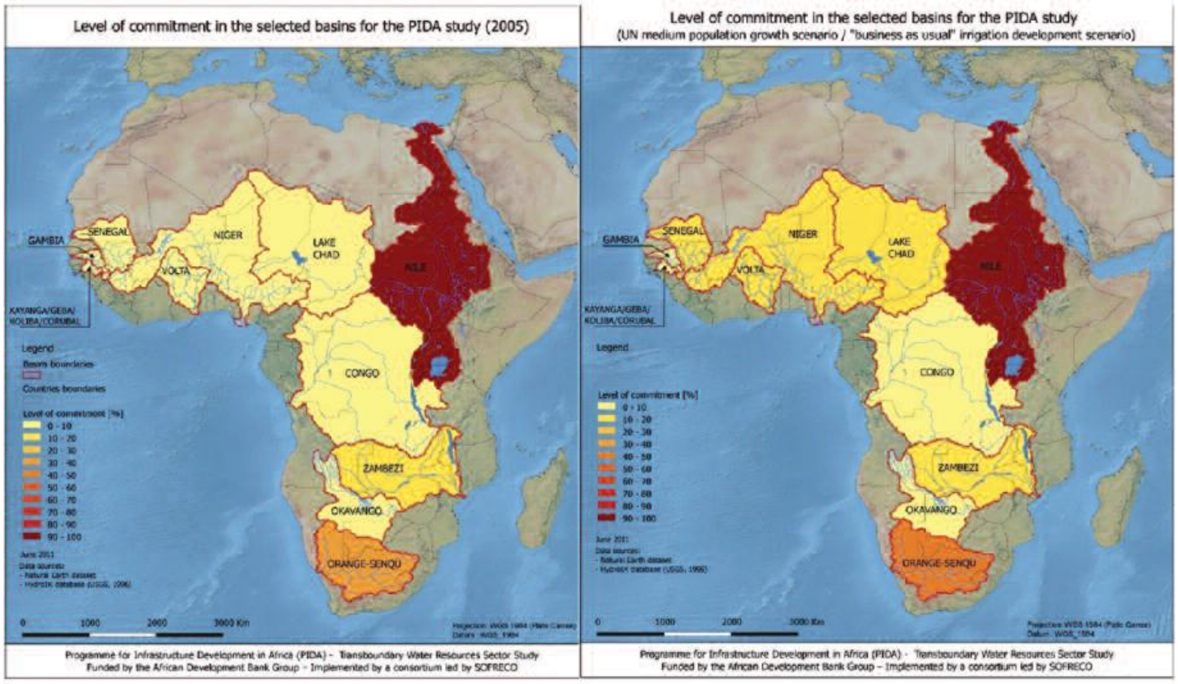


Figure 33: **Map of the level of commitment of the selected basins: comparison of the situation in 2005 and in 2040 for a medium population growth rate scenario and considering a "business as usual" irrigation development scenario.**



Residual volume of water at river mouth

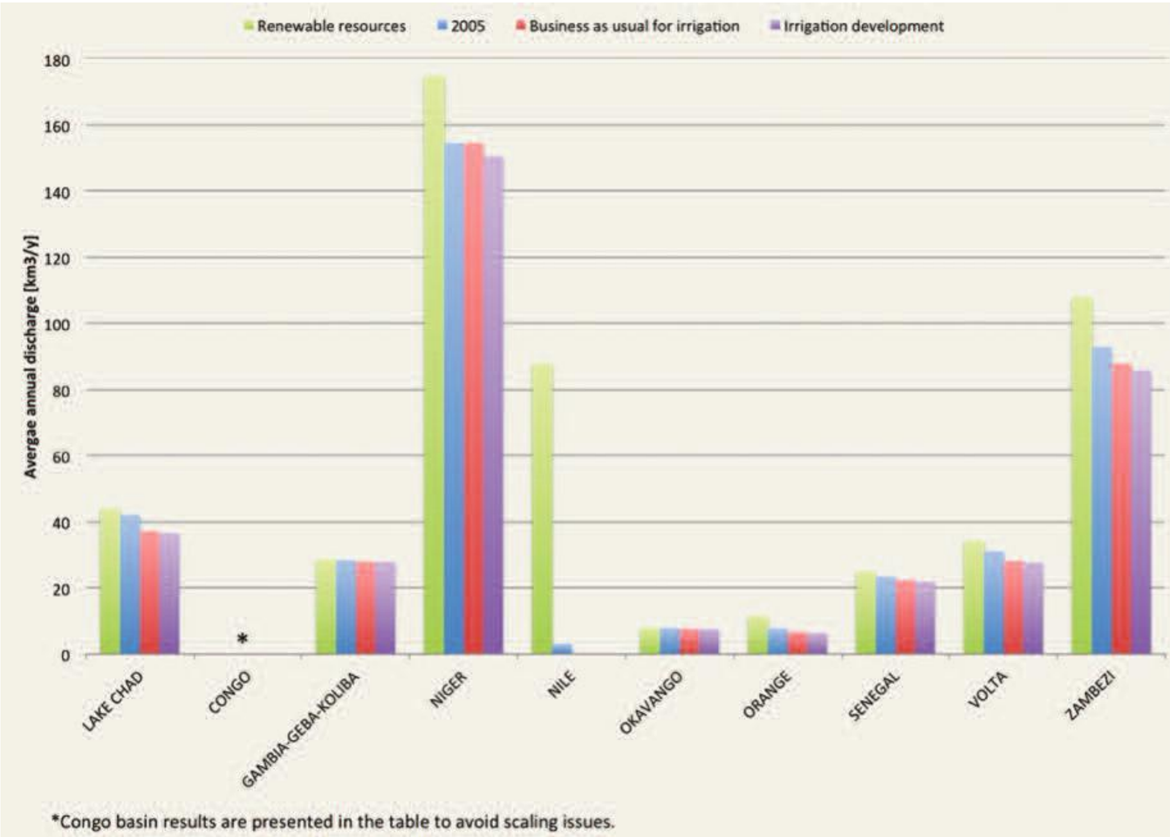
Table 7 lists, for all selected basins, the volume of water available (km3/year), the net water requirements in 2040 and the remaining of the natural discharge (flow at river mouth). The situation in 2005 is also presented for comparative purposes. As described above, for basins with higher topological complexity (Nile, Zambezi and Niger basins), detailed arc-node models have been implemented while for other basins, countries were aggregated into one single node for each basin. The results are presented in Figure 34 and demonstrate that:

- Currently, the annual residual volume of water in the Nile basin is around 3 km3/y. If the development scenarios are considered, the residual volume reaches zero. The Nile River basin will therefore, as mentioned-above, be rapidly fully committed
- In the Niger basin, the annual volume of water that reach the Gulf of Guinea would be reduced from 167.90 km3/y currently to around 154.6 or 150.6 km3/y in 2040 if future water requirements for industrial, domestic and irrigation uses are fully met
- Taking the topology into account, it is estimated that in 2005, the discharge of the Zambezi into the Mozambique Channel will be around 92.9 km3/y. The analysis reveals that, regardless of the scenario considered, no deficit would occur in the Zambezi basin in an average year. But the river flows would be heavily reduced with possible significant environmental impacts
- The level of commitment is less significant in the other basins.

Table 7: **Water requirements and supply in the selected basins [km3/year]**

		Gross req.	Net req.	Flow at mouth	Gross req.	Net req.	Flow at mouth	Gross req.	Net req.	Flow at mouth
LAKE CHAD	44	4.49	2.22	42.09	13.11	6.99	37.17	14.13	7.50	36.54
CONGO	1250	1.66	0.83	1248.94	16.08	9.16	1240.47	16.78	9.51	1239.98
GAMBIA-GEBA-KOLIBA	28.7	0.45	0.23	28.39	1.16	0.62	27.96	1.30	0.69	27.86
NIGER	174.99	10.69	5.30	167.90	32.95	17.43	154.58	38.67	20.29	150.58
NILE	87.9	118.75	66.60	3.05	168.56	93.05	0	190.44	103.99	0
OKAVANGO	8	0.19	0.09	7.88	0.73	0.32	7.64	0.79	0.35	7.59
ORANGE	11.44	4.82	3.30	7.76	7.66	4.15	6.78	8.24	4.44	6.37
SENEGAL	25	2.31	1.16	23.43	3.78	1.96	22.47	4.55	2.34	21.94
VOLTA	34.25	3.65	2.98	31.06	8.38	5.69	28.20	9.11	6.05	27.69
ZAMBEZI	108	16.99	14.24	92.87	24.83	18.60	87.94	27.79	20.08	85.87

Figure 34: **Average annual residual volume of water at river mouth.**



The results of the analysis show that the Nile basin is the only basin where the future requirements are likely to rapidly exceed the available resources. In several other basins, the requirements may be met, but often to the detriment of the environment, which will need well-informed political decisions.

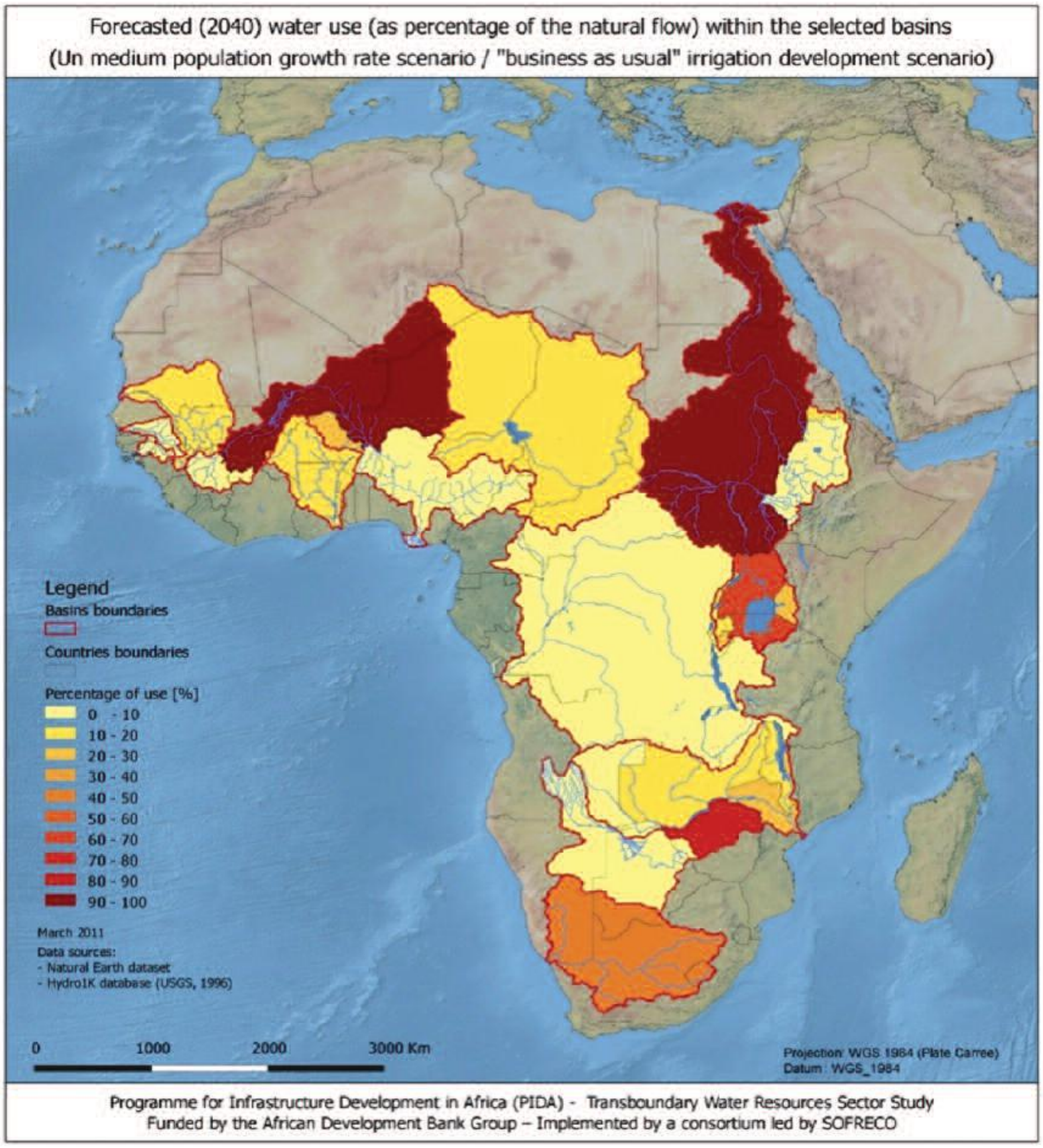
This report stresses that the results need to be interpreted with some caution given the limited depth of analysis that can be provided by an analysis of this scale in this context. Whereas the results are of very useful indicative value for highlighting the challenges in the TWR sector in the next three decades, a number of additional aspects need to be considered for strategic planning purposes at the basin level, namely:

- No seasonal variations in supply and demand have been considered in the analysis. However, timing of demand and supply usually does not match and therefore requires the construction and operation of reservoirs (dams) to provide seasonal river discharge regulation for irrigation, domestic and industrials uses

- The analysis is based on average values for demand and supply. However, supply and to a lesser extent demand, exhibit high seasonal and inter-annual variability. For example, in the Nile basin, the annual volume of water at Aswan can be below 50 km3/y during dry years but it can be higher than 120 km3/y during wet years
- Environmental uses are not included in the projections: minimum flow requirements, high and low flows patterns (artificial floods) etc. This means that areas with no projected water deficit may nevertheless face important environmental consequences. The above-mentioned projected deficits would also increase should minimum flow discharges to the sea be imposed (e.g. to prevent sea water intrusion in the coastal aquifer, fish production, etc.). It would be useful for further analysis to make simulations with several values of the ratio between projected river flow at the mouth and natural flow.

Figure 35 shows the percentage of natural flow that would be used (in an average year) if each country decides to consume as much as required (net water requirements)—assuming a medium population growth and considering a "business as usual" irrigation development scenario (irrigated area growth rate of the past 30 years remains constant until 2040—all other parameters remain unchanged). The higher this ratio, the more competition between sectors (including the environment) is likely to occur.

Figure 35: Percentage of natural flow which would be used (in an average year) if each country decides to consume as much as required to maintain the current SSR and assuming a medium population growth.



5. INFRASTRUCTURE GAP IN THE TRANSBOUNDARY WATER RESOURCES SECTOR

This section presents a quantitative estimate of infrastructure gaps in the trans-boundary water resources sector focusing on hydropower and irrigation.

5.1 Hydropower infrastructure gap

A cross-sectoral analysis has been carried out with the PIDA energy team in order to provide coherence of analysis between the PIDA sectors.

5.1.1 Current picture of the energy sector in Africa

Africa has 15% of the world's population but accounts for only 3% of the world's primary energy consumption (renewable energy and waste excluded) and 5-6% of the world's final energy consumption (renewable energy and waste included). Electricity consumption per capita is 1/6 of world overall average. Access rates, particularly in Sub-Saharan Africa, are amongst the lowest in the world with only 1/5 of the population having access to electricity. The continent therefore needs to make renewed efforts to increase the exploitation of its significant energy generation potential.

The incentive to pool energy resources in Africa is strong and led to the formation of regional power pools in the 1990s. However, cross-border power trade has yet to take off outside of the Southern Africa Power Pool (SAPP) as noted. In West Africa, power trade is only 5% of total consumption. In the meantime, many Sub-Saharan African countries continue to experience an acute shortage in energy supply which will take time to overcome. This obstacle makes the goal of universal access to electricity by 2040 very challenging for a majority of African countries. Expanding regional energy integration is therefore an essential step to improve affordability by households if these universal access goals are to be achieved.

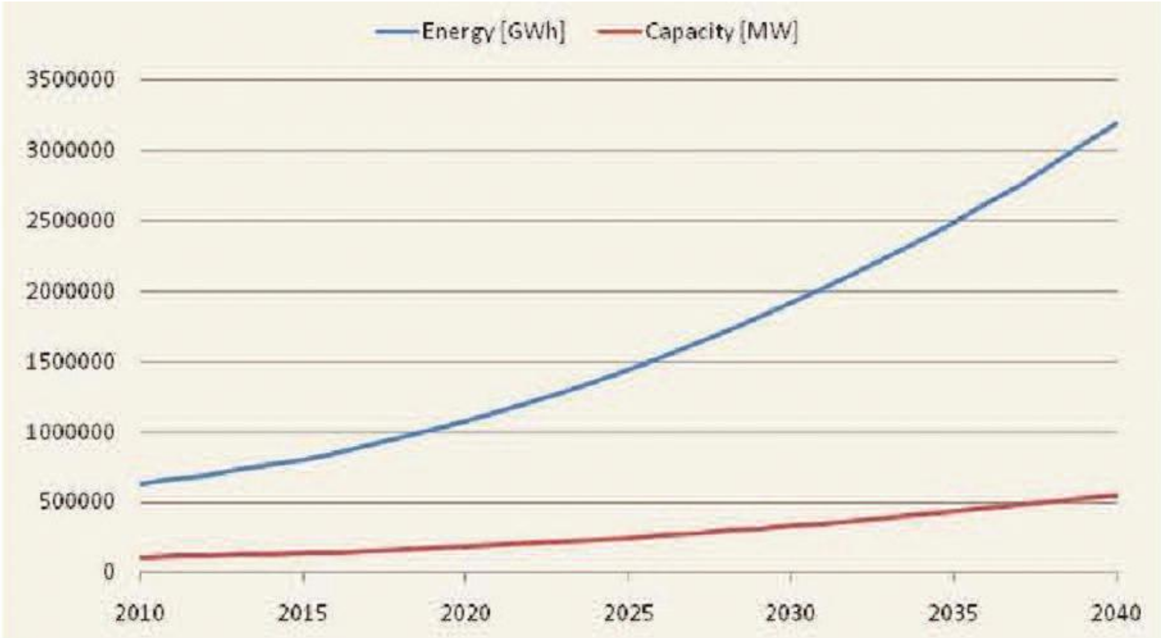
5.1.2 Forecast energy demand

The PIDA energy sector team defined the projections in terms of energy produced and consumed (kWh) and peak demand to be met (kW) through available generation capacity using optimum and least cost technology mix, and high voltage transmission flows through existing, reinforced and new lines. This (TWR) analysis reflects the following findings of the PIDA energy team which are used as a basis:

Overall, the power demand is forecasted to increase considerably by a factor of four (410%) over the period until 2040 for the African continent. The average growth rate of energy demand is 5.5% p.a over the entire period (from 2009 to 2040). The evolution of the power and energy demand during the forecast period (from 2009 to 2040) is depicted in Figure 36 where it shows that, overall, the continent will need 447.4 GW of additional capacity to reach a capacity of 556.5 GW in total (PIDA energy sector).

Furthermore, under the assumption of the PIDA energy sector team, it appears that the costs of interconnections are very small compared to the total generation costs (about 1% of the total generation costs) while the costs of building new transmission lines would be small compared to the cost of building the new additional power plants. As a consequence, an underlying assumption for the analysis is that a full pan-Africa interconnected power grid will be operational in 2040.

Figure 36: Forecast peak power and energy demand in Africa



(Data source: PIDA energy sector).

5.1.3 Hydropower infrastructure gap

Currently, the “operational” and “under construction” installed capacity of hydropower plants in the ten selected basins for the PIDA study is estimated to be 15 756 MW. In 2040, the planning model of the PIDA energy sector team estimates that an additional 72 563 MW will be commissioned (in the selected basins) comprising of 64.71% in the Congo basin, 18.47% in the Nile basin and 13.41% in the Zambezi basin (Table 8). This represents an increase of 360.5% in the installed hydropower capacity (+ 56 807 MW). It is to be noted that this increase will occur on a step by step basis during the next 30 years according to the planning results and commissioning calendar.

Even on the assumption of this significant increase in hydropower plants commissioning, the contribution of the hydropower sector will represent only around 16% of the forecast peak power demand by 2040 (around 556.5 GW or 556 463 MW). Even by assuming that the full hydropower potential of the selected basins is exploited, it would only cover 35.1% of the forecast demand. However, it is noted that a full exploitation of the hydropower potential is unlikely due to a variety of reasons ranging from social and environmental concerns, to political instability and associated lack of security of investments.

In the light of the role played by the hydropower sector in the selected basins to supply the total power demand by 2040, two hydropower infrastructure gaps can be defined:

- The theoretical gap can be defined as the difference between the current developed (and under construction) hydropower generation capacity and the estimated (theoretical) potential. The theoretical gap is estimated at 179 744 MW.
- The planning gap can be defined as the difference between the current developed (and under construction) hydropower generation capacity and the planned installed capacity in 2040, given the commissioning calendar established by the planning model of the PIDA energy sector. The planning gap is estimated at 72 563 MW (39.5 % of the theoretical gap).

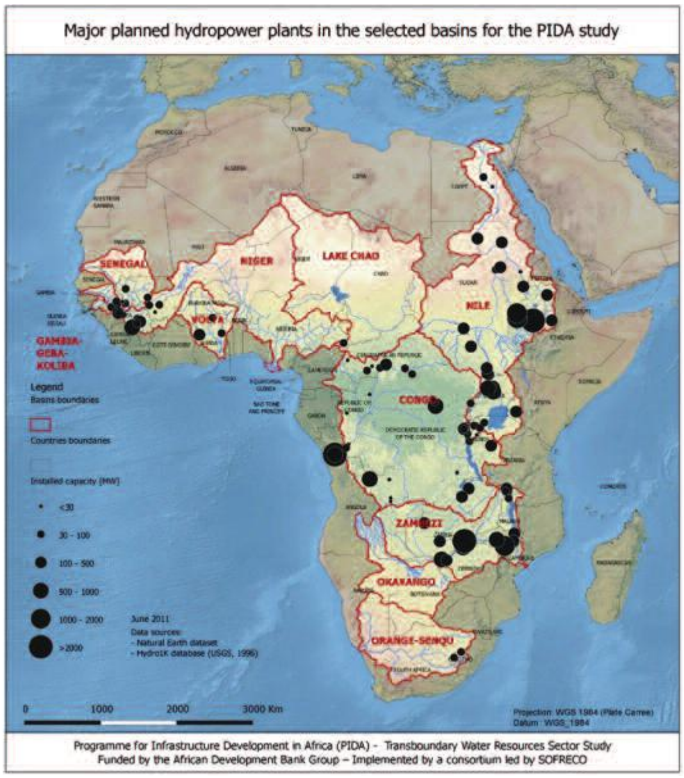
Table 8: **Operational, under construction and planned hydropower plants in the selected basins**[24]

BASIN	Installed capacity [MW]			
	Operational	Under Construction	Planned	Potential
LAKE CHAD	0	0	75	
CONGO	840	0	46957	123 600
GAMBIA-GEBA-KOLIBA	0	0	120	4 000
NIGER	2 068	0	1 054	6 000
NILE	5 407	185	13 404	45 000
OKAVANGO	0	0	0	400
ORANGE-SENQU	625	0	77	
SENEGAL	216	0	609	2 000
VOLTA	1511	0	538	2 500
ZAMBEZI	4 904	0	9729	16 000
TOTAL PIDA BASINS	***15 571***	***185***	***7 2563***	***199 500***

Table 9: **Hydropower infrastructure gaps in the selected basins**

BASIN	Installed capacity [MW]	
	Theoretical Gap	Planning Gap
LAKE CHAD	0	75
CONGO	12 2760	4 6957
GAMBIA-GEBA-KOLIBA	4 000	120
NIGER	3932	1054
NILE	39 408	13 404
OKAVANGO	400	0
ORANGE-SENQU	-625	77
SENEGAL	1 784	609
VOLTA	989	538
ZAMBEZI	11 096	9 729
TOTAL PIDA BASINS	***183 744***	***72 563***

Figure 37: **Map of the major planned hydropower plants in the selected basins. Points are proportional to the installed capacity of the hydropower plant.**



[24] Although efforts have been made to ensure consistency of data use across PIDA sectors, some figures presented in the table may differ from the ones used in the Energy Outlook due to different spatial scales of analysis (RECs/Power Pools for the energy, transboundary river basins for TWR).

5.2 Irrigation

5.2.1 Current picture of the irrigation sector in Africa

At present, irrigation is relatively marginal particularly in Central Africa where the percentage of area equipped for irrigation (regarding the cultivated area) is below 5% in most countries and even below 1% in some countries. This is largely due to the humid climate that provides good conditions for rain-fed agriculture. On the other hand, irrigation plays a crucial role in Northern and Southern regions where the climatic conditions are drier (arid and semi-arid). Currently, merely 20% of the potential irrigation area in Africa is exploited. During the past decade (from 1998 to 2008), the annual growth rate of area equipped for irrigation in Africa was only half of that observed in the world (0.62% regarding 1.10% respectively). In terms of irrigated area, this represents an annual increase of 81 030 ha per year in Africa while it was 3 178 300 ha per year in the world. A comprehensive description of the current situation of the irrigation sector in Africa and in the ten selected basins can be found in section 3.2.2 of this report.

5.2.2 Irrigation infrastructure gap

Based on the findings presented in Chapter 4 (Forecast Water Requirements – Outlook 2040), it can be extrapolated that:

- In 2005, the cereal consumption (production + imports – exports) in Africa was 191.89 million tons of which 34.18 million tons were produced by irrigated area (estimation). As a consequence, the difference (157.71 million tons) must be provided by rain-fed agriculture (107.48 million tons) and a net import balance of 50.23 million tons)
- In 2040, assuming that through the "business as usual" irrigation development scenario, the crop yield of irrigated cereals would increase by 10% and that the current self-sufficiency ratio for cereals would remain constant, the irrigated cereal production would be around 66.96 million tons while the requirements would be around 319.34 million tons (assuming a medium population growth scenario). As a consequence, it would be necessary to cultivate 252.38 million tons of cereal through rain-fed agriculture or imported
- In 2040, assuming the "accelerated irrigation expansion" scenario and the similar assumptions as in the previous scenario, the irrigated production would be around 79.58 million tons of cereals. As a consequence, the gap to be filled by rain-fed and net imports of cereals would be around 240 million tons.

Based on this forecast of cereal requirements, the required land surface that will need to be irrigated by 2040 can be roughly estimated[25]. Assuming that in 2040 rain-fed agriculture will be able to produce 50% more than at the present time, rain fed cereal production would then be around 161.22 million tons/year. The remaining food requirements (158.12 million tons) would then have to be produced through irrigated agriculture.

Assuming a crop yield increase reaching 4 tons/ha and a cropping intensity[26] of 1.5, the total irrigated area should then be 26.3 million ha for a medium population growth scenario. This would be an increase of 12.85 million hectares compared to 2008.
The situation is summarized in table below (Table 10).
In light of the above observations, it is evident that the forecast demand for food for 2040 can only be met with an intensification of both irrigated and rain-fed agriculture. The various options to bridge the estimated gap and intensify the food production are as follow:

- Find the right balance between rain-fed and irrigation agriculture
- Increase agriculture productivity
- Expand irrigated area and increase irrigation efficiency
- Increase the yield of stressed river basins (for instance by reducing evaporated areas)
- Consider inter-basins water transfers.

These options will be addressed in the next section.
However, it should be noted that irrigation expansion is expensive and is not the only way to provide food security in Africa. As water resources per capita will become increasingly scarce, priority should be given to the production of high-value crops. While irrigation expansion will still be needed in arid and semi-arid regions, there is a huge potential for improved rain-fed agriculture practices especially for small-holders which could have profound impacts on crop yield and hence improved food security. Achieving food security is a complicated issue that includes inputs availability, market infrastructure, trade, research, extension and other factors and will be further discussed in the following chapter on options.

[25] The percentage of the total cereal production that comes from irrigated agriculture is available for only a few countries. Where it is not available, this percentage is assumed to be equal to the ratio between irrigated and rainfed agriculture.
[26] Cropping intensity is the ratio between irrigated crop areas (where double or triple cropping areas are counted twice or three times respectively), and the physical areas equipped for irrigation.

Table 10: Irrigation infrastructure gap

Irrigation development policy	Year	Irrigated cereal production* [million tons]	Cereal demand [million tons]	Gap to be filled by rain fed and net imports [million tons]
Assessment	2005	34.18	191.89	157.71
Business as usual[27] + 10% of crop yield increase	2040	66.96	319.34	252.38
Accelerated irrigation expansion[28]+ 10% of crop yield increase	2040	79.58	319.34	239.76

[27] Business as usual scenario assumes that the irrigated area growth rate of the last 30 years (from 1978 to 2008), would remain constant until 2040.
[28] Accelerated irrigation expansion scenario assumes that the irrigated area growth rate of the last 30 years (from 1978 to 2008) is multiplied by a factor two until 2040.

6. CHALLENGES AND RESPONSES

Given the above, it is obvious that Africa has highly untapped (trans-boundary) water resources potential and it is well recognized that their development can play a key role in economic development and poverty reduction in the continent. While the varied climatic and ecological areas in Africa provide great potential for food and energy production, the continent suffers from underutilization of its water resources potential. The key challenges and a number of possible response options (within and outside the scope of PIDA) are described below.

6.1 Key challenges

The African Water Vision 2025, the continent's overarching policy instrument for water, identifies a number of key issues facing the African water sector, thereby differentiating between resource-side issues, demand-side issues and compounding issues. These issues, presented in Box 1.1 below, remain relevant today and paint a realistic picture of the context in which water management in Africa takes place.

Box 1.1: Key water resources issues in Africa as identified by the African Water Vision 2025.

Resource related issues

1. Multiplicity of trans-boundary water basins
2. High spatial and temporal variability of rainfall
3. Growing water scarcity
4. Inadequate institutional and financing arrangements
5. Inadequate data and human capacity
6. Inadequate development of water resources
7. Depletion of water resources through human actions

Demand related issues

1. Lack of access to safe and adequate water supply and sanitation services
2. Lack of water for food and energy security
3. Inefficiency and wastage in water use
4. Threats to environmental sustainability

Compounding Issues

1. Political instability and conflict within and between countries
2. Weak institutional arrangements and legal frameworks for the ownership,
3. Inadequate public awareness and stakeholder involvement
4. Inadequate research for water-resources development
5. Weak socio-economic development and technology base
6. Low public capacity to finance required investments in the development and management of water resources, including protection and restoration
7. Inadequate private sector participation in financing

As part of the identified key issues, the African Water Vision 2025 identifies a number of key challenges for the African water sector that need to be addressed (Box 1.2).

Box 1.2: Key challenges for the African water sector as identified by the African Water Vision 2025.

1. Ensuring that all have sustainable access to safe and adequate water supply and sanitation services to meet basic needs.
2. Ensuring that water does not become the limiting factor in food and energy security.
3. Ensuring that water for sustaining the environment and life-supporting ecosystems is adequate, both in quantity and quality.
4. Reforming water-resources institutions to establish good governance and an enabling environment for sustainable management of national and trans-boundary water basins and for securing regional cooperation on water-quantity and water quality issues.
5. Securing and retaining skilled and motivated water professionals.
6. Developing effective systems and capacity for research and development in water and for the collection, assessment, and dissemination of data and information on water resources.
7. Developing effective and reliable strategies for coping with climate variability and change, growing water scarcity, and the disappearance of water bodies.
8. Reversing the growth of man-made water-quantity and quality problems, such as over-exploitation of renewable and non-renewable water resources, pollution and degradation of watersheds and ecosystems.
9. Achieving sustainable financing for investments in water supply, sanitation, irrigation, hydropower and other uses, and for the development, protection and restoration of national and trans-boundary water resources.
10. Mobilizing political will, creating awareness and securing commitment among all with regard to water issues, including appropriate gender and youth involvement.

As illustrated above, the key issues and challenges facing the African water sector are manifold. While they provide an adequate picture of the overall context in which the PIDA operates, not all of them can be directly addressed by the programme with its clear focus on investments and infrastructure development. In the context of PIDA, four main categories of challenges which the programme can respond to, directly or indirectly have been identified.

Inadequate amount of available water resources in some basins in light of forecast demand

Chapter 4 of this report has presented the forecast water demand at the continental and basin levels. The results for the latter show clearly that the level of commitment in some of the selected PIDA basins is already high and increasing significantly, leading eventually to a situation where total demands will outstrip supply.

Inadequate governance frameworks

Chapter 3.3 describe the governance frameworks for trans-boundary water resources in Africa and identify the weaknesses in current TWRM governance frameworks. On the one hand, the inadequacies relate to the legal and institutional (less so the policy) architecture for TWRM itself. On the other hand, a significant shortcoming is the inadequate integration and coherence of different sector policies (transport, energy, trade) and strategies within an overarching regional economic strategy.

Inefficient existing infrastructure

Existing water infrastructure in Africa is often operating below full capacity and/or with a high degree of inefficiency. Several hydropower dams on the continent, for various reasons, no longer use the full generation capacity once installed. Likewise, many irrigation schemes use outdated technology with high water losses.

Inadequate levels of infrastructure development

As illustrated in Chapter 3, the current levels of storage capacity, installed hydropower generation capacity and areas under irrigation in Africa are very low compared to international standards. Likewise, the growth rate in infrastructure development, particularly with respect to irrigation, falls significantly short of that experienced in other developing regions, particularly Asia, and is inadequate in light of the forecast future water, food and energy demands.

6.2 Response options

In order to address these four key challenges, a number of response options have been identified, categorised into the two broad options of "governance responses" and "investment responses". A tabular overview of challenges and corresponding responses is provided below before the response options are discussed in further detail.

Table 11: Overview of challenges in the TWR sector and corresponding responses

Challenge	Governance responses	Investment responses
Inadequate amount of available water resources in some basins in light of forecast demand	▪ Demand management ▪ Finding the right balance between rain fed and irrigated agriculture ▪ Regional integration, sector integration and trade strategies ▪ Benefit sharing ▪ Strengthening TWRM governance frameworks	▪ Reducing water losses and increasing the efficiency and productivity of existing irrigation and rain fed systems ▪ Coordinated planning and operation of infrastructure ▪ Conjunctive use of surface and groundwater ▪ Increase multi-purpose water storage ▪ Irrigation expansion ▪ Inter-basin water transfers
Inadequate governance frameworks	Strengthening TWRM governance frameworks	
Inefficient existing infrastructure	▪ Strengthening TWRM governance frameworks ▪ Benefit sharing	▪ Reducing water losses and increasing the efficiency and productivity of existing irrigation and rain fed systems ▪ Coordinated planning and operation of infrastructure ▪ Conjunctive use of surface and groundwater
Inadequate levels of infrastructure development	▪ Strengthening TWRM governance frameworks ▪ Benefit sharing	▪ Increase multi-purpose water storage ▪ Irrigation expansion ▪ Inter-basin water transfers

It should be noted that effectively addressing the identified challenges usually requires more than one response and often a combination of governance and investment responses.

This is of great relevance in the context of the strategic framework and PAP developed during Phase II of PIDA for two reasons:

- Whereas the focus of PIDA is on promoting and facilitating direct investment projects (hard projects), some so-called “soft” interventions, i.e. governance interventions, can be directly supported by PIDA where they contribute to creating the necessary enabling environment for effective and efficient investments.
- Some governance responses cannot be directly facilitated or supported through PIDA but are nevertheless essential in order to address the identified key challenges. In these cases, policy-makers and strategic planners need to be aware that PIDA interventions need to be complemented with governance responses outside the immediate scope of PIDA.

The described response options inform the formulation of the PIDA strategic framework and PAP and help defining strategic objectives and realistic targets that African decision makers could set for their long-term regional and continental infrastructure, both hard and soft.

6.3 Governance responses

In light of the forecast results presented in Chapter 4, it is clear that many countries on the continent are unlikely to be able to meet their future food and energy demands through domestic production, even if the water resources potential is fully exploited. At the same time, it will be difficult in practice to meet all identified investment needs. It is therefore critical that investments in water infrastructure are accompanied by innovative policy choices and the strengthening of regional integration and trade regimes. A number of possible macro-level policy options, ranging from regional to basin levels, are presented below.

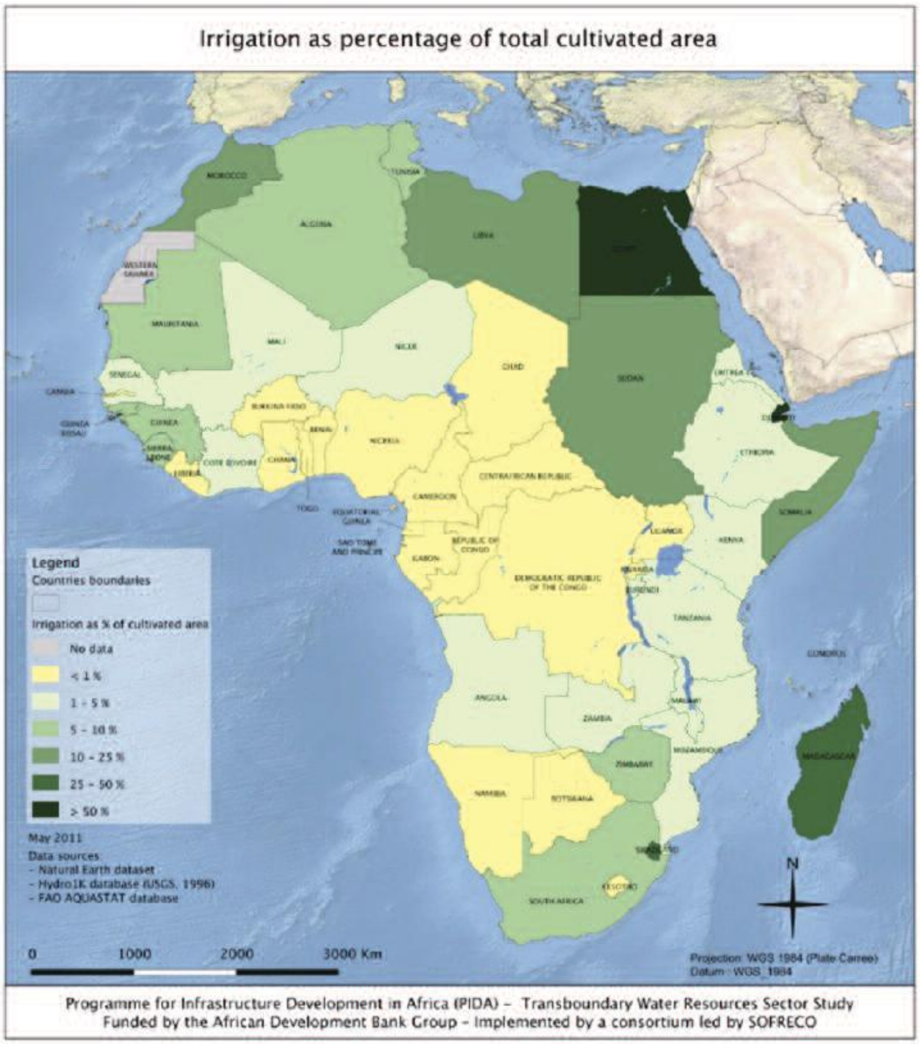
6.3.1 Demand management

Growing water scarcity, high spatial and temporal variability of rainfall and the impact of climate change, lack of water security and great vulnerability to floods and droughts require a two-pronged approach of supply and demand management. Supply management means the development of new sources of water, while demand management is concerned with the efficient use of water and water conservation. The right mix of supply and demand management must be tailored to the specificities of each river basin. In so-called "closed" river basins, where water is already fully allocated and competition for water increases, the adoption of demand management measures becomes crucial. As water scarcity increases, so does the value of water. Efficient allocation becomes more and more important as this is the only strategy to increase benefits from the use of water. The (early) adoption and implementation of demand management policies and strategies in trans-boundary basin planning can contribute to curbing the rate of increase in the level of commitment a basin experiences and thus allow more of the competing demands to be met. It is clear from the analysis in Chapter 4 that in some basins not all demands (in 2040) can be met even if the full storage potential of the basins is exploited, making the implementation of demand management strategies at the basin level even more relevant.

6.3.2 Finding a right balance between rain-fed and irrigated agriculture

Most of the global food output is produced by rain-fed agriculture. It represents 60% of the world cereals production and covers around 80% of the world's cultivated area. As highlighted in chapter 5, in Sub-Saharan Africa, irrigation is relatively marginal particularly in Central Africa where the percentage of area equipped for irrigation (regarding the cultivated area) is below 5% in most countries and even below 1% in some countries (Figure 38).

Figure 38: Map of irrigation as percentage of cultivated area in Africa

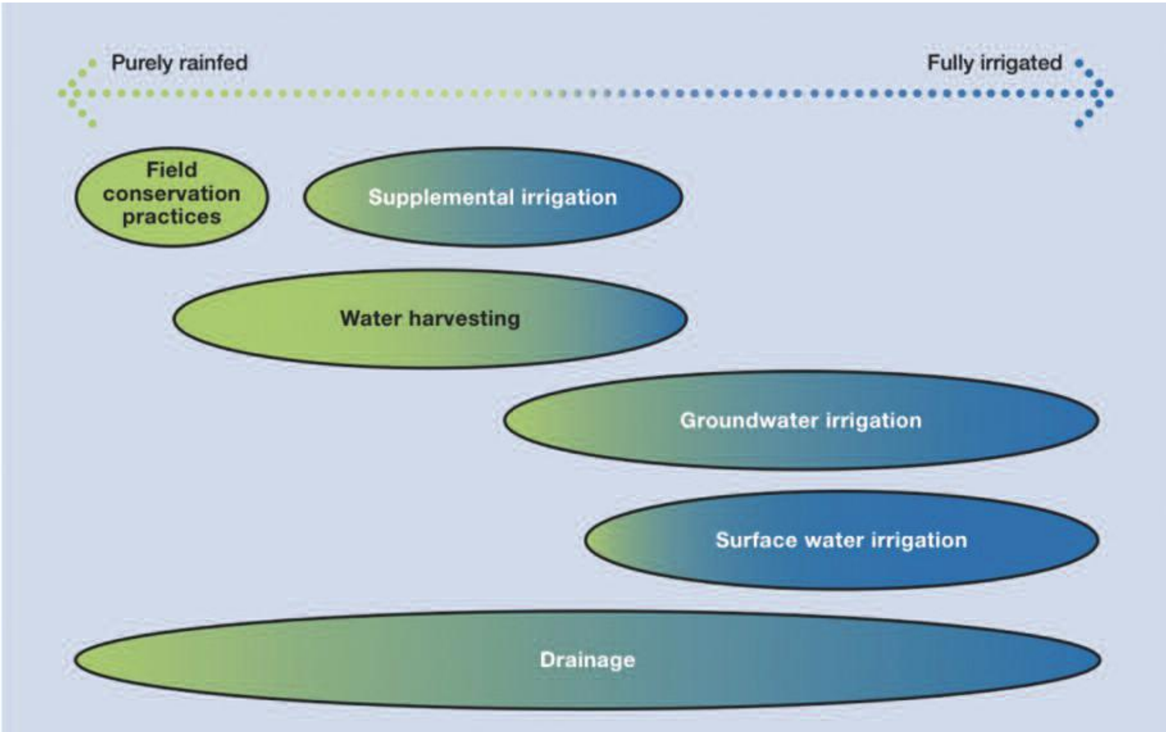


(Data source: FAO AQUASTAT database).

Currently, people relying on rain-fed agriculture are highly vulnerable to short- and medium-term drought and are therefore not inclined to invest in (costly) agricultural inputs that could significantly increase yields (IWMI, 2007). Important agricultural practices such as improving the soil moisture conservation could play a role in upgrading rain-fed agriculture that could then provide supplemental irrigation. From that perspective, it is clear that investment in rain-fed agriculture can contribute to poverty alleviation and sustainable environmental improvement.

As pointed out by IWMI (2007) in their Comprehensive Assessment of Water for Agriculture, the agricultural water resources management options are manifold and range from purely rain fed to fully irrigated with many intermediate options (Figure 39). As one moves from purely rain fed systems (where green water is the only source of water for agriculture) to irrigation, more blue water (surface and groundwater) is used to increase crop production. This often provides a good opportunity for multiple uses such as fisheries and livestock rearing alongside crop production.

Figure 39: The spectrum from rain fed to irrigated



(Source: IWMI, 2007)

Achieving food security will require a good balance between rain-fed and irrigated agriculture (and in the case of many countries supplementation through food imports). Determining an appropriate balance between rain-fed and irrigated agriculture depends on the country or region specifics as well as many factors such as the climatic zone, economy, access to technologies, and others. The potential contribution of rain-fed agriculture to future world food production and its role in achieving food security is still a controversial issue amongst sector professionals. Forecast estimates of the role of rain-fed and irrigation vary greatly (IWMI, 2007). Moreover, focusing on rain-fed agriculture only carries considerable risks (IWMI, 2007) if increase in crop yields and measures for better water management do not materialize at the rate it is supposed to occur. However, improving food security cannot be achieved through irrigated agriculture alone and investments in improving crop yields and the efficiency of rain-fed agriculture overall need to be a political priority and complement any future investments in irrigation expansion.

At the same time, the climate-proofing of investments in both rain-fed and irrigated agriculture needs to be ensured. It is now well recognized by the international community that climate change will affect temperatures and precipitation patterns with potentially significant impacts (at least in some regions) on water availability and crop water requirements. According to IPPC experts, a large part of Sub-Saharan Africa will be adversely impacted. It is therefore important to consider the possible climate change impacts in future infrastructure planning and management of projects.

6.3.3 Regional integration, sector integration and trade strategies

This report has highlighted the uneven distribution of water resources across the continent and pointed out the fact that some countries will continue to have to rely on food imports while others have huge potential to become food exporters (even when using mostly rain fed agriculture).

In this context, the possibility of so-called "virtual water trade strategies" should be explored. Virtual water refers to the quantity of water used in when a product results from the process. As the final product (e.g. wheat) does not contain that water anymore it is called "virtual" water. Virtual water trade essentially means that water scarce countries can potentially mitigate the local scarcity of water by importing large amounts of virtual water instead of building new water supply infrastructure. In other words, water scarce countries could for example primarily import grain (which requires significant amounts of water during production) for local use instead of producing it locally. Through the export of food stuffs on the other hand, water rich countries could make use of their water abundance by becoming large-scale exporters of water intensive goods, primarily agricultural goods. For some water-rich developing countries, export oriented agriculture could be a driver of economic growth and substantially contribute to poverty reduction. While such virtual water trade is de facto already practised by some countries, including African countries, its implementation at the regional level within Africa is only starting to be considered. In this context, it is noted that the Nile Basin Initiative (NBI) has recently commissioned a study exploring the possibility of a virtual water trade strategy for Nile basin States.

Any trade-based solutions, whether virtual water trade or other strategies, require significant improvements in trade regimes and supporting infrastructure, mainly transport. The conditions for cross-border trade in Africa are currently far from optimal. Even if the countries with high export potential were able to produce enough food stuffs for export (following investments in rain-fed and irrigated agriculture) inter-regional grain trade would be impeded by the numerous trade barriers that are still in place. Effectively using the full potential of regional markets in Africa could prove to be a major growth factor if certain trade impeding factors were to be removed. Despite the establishment of Free-Trade Areas (for example the launch of a regional trade blocs comprised of the members of SADC, EAC and COMESA in June 2011), the elimination of tariff and non-tariff barriers has in practice been neglected. Likewise, for grain trade, which requires large volumes of cereal to be moved, transport costs are an important factor that influences the competitiveness of a production region. In order to develop a competitive agricultural sector, many African countries already have to overcome disadvantages (compared to suppliers from outside the region which do not face such constraints), resulting from the distorted nature of international agricultural trade. The underdeveloped transport links on the continent are a further impediment for the development of a competitive sector. Consequently, the existing regional initiatives to build a functioning and cost-effective regional transport network need to be continued and intensified in order to make trade-based solutions a viable policy option for African regions.

Thus, sector integration as promoted by PIDA is an important step in the right direction and needs to be actively supported by political and policy decision-makers and strategic planners. Whereas the importance of transport networks has been illustrated above, the same is true for the link between investments in water infrastructure and energy. On the one hand, through the generation of hydro-power, water, can be a substantial component of the overall energy generation capacity. On the other hand, investments in irrigated agriculture are highly dependent on the availability of (cheap) energy. The availability of energy (for the pumping of water) is essential for future expansion of irrigation and energy costs are a significant cost factor in irrigated agriculture. While energy costs for irrigation are highly site-specific and a continental forecast of additional energy needs associated with the described irrigation scenarios is not possible, it is clear that there is a strong inter-dependence between energy availability and the possibility of irrigation expansion. It is thus clear that investments in water infrastructure need to be well integrated into coordinated, cross-sectoral investment and infrastructure plans (primarily transport and energy) in order to achieve the desired outcomes.

6.3.4 Benefit sharing

The concept of benefit sharing is increasingly recognised as a promising option for improving the basket of options to address water resources scarcity. Its implementation in practice is gaining momentum. Benefit sharing has been proposed as an alternative to the volumetric allocation of water, potentially offering greater scope for underpinning equitable agreements between riparians (Sadoff & Grey, 2002[29]). In the context of trans-boundary watercourses, the concept can be defined "as the process where riparians cooperate in optimising and equitably dividing the goods, products and services connected directly or indirectly to the watercourse, or arising from the use of its waters" (Phillips & Woodhouse, 2010[30]), thus extending the benefits from the river beyond the river.

The rationale for the benefit sharing approach is that in international river basins (and more specifically in basins

[29] Sadoff, C.W. and D. Grey (2002) Beyond the river: the benefits of cooperation on international rivers. Water Policy, 4, 389-403.
[30] Phillips, D.J.H. and Woodhouse, M. (2010) A Guideline on Benefit Sharing in Trans-boundary Watercourses in the Southern African Development Community (SADC). Gaborone, GIZ.

approaching closure), re-allocation of water resource, due to development of the water resources system, can be problematic. Benefit sharing, at least in its most advanced form, is based on the concept of sharing the benefits from the water instead of the physical water itself through a basin-wide cooperation process (Phillips & Woodhouse, 2010).

Broadly four types of benefits have been identified (Table 12) of which some have already been elaborated in the preceding sections.

A possible option for benefit sharing that has been proposed (Phillips, 2010) would for example be where a downstream riparian would support dam construction and hydropower development by its upstream neighbour, but would negotiate seasonal flows that protect its agricultural sector and tourism revenues. Hydropower could be traded to the downstream riparian at favourable terms, reflecting the cooperation between the parties and the fact that the new dam represents an additional consumptive use of water upstream. The downstream riparian could improve its agricultural and tourism sectors (in part through the energy provided by the dam) and could trade staple crops back to the upstream party at favourable costs. While the development of benefit sharing options for specific basins requires a lot of detailed analysis and strategic planning, it is clear that innovative concepts such as these need to be increasingly used and accompany infrastructure investments if the above-mentioned challenges are to be addressed effectively.

Table 12: Benefit types and opportunities (adapted from Sadoff & Grey, 2002)

Benefit type	Opportunities
Increasing benefits to the river	Improved water quality, river flow characteristics, soil conservation, biodiversity and overall sustainability.
Increasing benefits from the river	Improved water management for agriculture/hydropower, flood-drought management, navigation, environmental conservation, water quality and recreation.
Reducing costs because of the river	Policy shifts from dispute/conflict to cooperation/development; from food/energy self sufficiency to food/energy security; reduced conflict risk and military expenditure.
Increasing benefits beyond the river	Integration of regional infrastructure markets and trade.

6.3.5 Strengthening TWRM governance frameworks

In addition to the macro-level policy options presented in the preceding section, improvements to the governance frameworks for TWRM in a narrower sense also need to be made in order to ensure the optimal, sustainable utilisation of the continent's water resources and the effectiveness and efficiency of water infrastructure investments.

The governance analysis conducted during Phase I of PIDA (see Chapter 3.3-) has highlighted the shortcomings in the current governance frameworks. While the macro-level alignment and integration of policies need to be strengthened (see 6.3.3 above), the water policy framework (in the narrower sense) on the continent is relatively solid and the main shortcomings lie in the legal and institutional architecture.

The overview and analysis presented in the preceding chapters have highlighted the benefits of strong regional frameworks within which trans-boundary water resources management and development take place. RECs, RBOs (of various types and mandates) as well as Member States all are important cogs that together move the engine of trans-boundary water resources management or development. To stay in the picture, the absence or malfunctioning of any of the cogs can bring the engine to a standstill or at least impact negatively on its performance. That said, where RECs are not (yet) in a position to exercise their role (for one or more of the reasons cited above), RBOs are nevertheless important platforms for driving trans-boundary water resources management and development, although the desired regional coordination of development efforts across basin boundaries will be more difficult to achieve.

As noted, some of the main governance related reasons for slow identification and implementation of trans-boundary water resources development options include underdeveloped legal frameworks, inadequate planning and limited coordination mechanisms. Therefore, the creation of strong planning mechanisms at the REC and RBO levels, supported by relevant implementation capacity at the national level is

recommended to improve project identification and implementation. Cooperative approaches at the basin and/or regional levels increase the basket of options and thus increase the probability of making the "right" decision that achieves a good balance between the urgent need for social and economic development and sustainable long-term natural resources use.
Given that conditions in each basin and region are unique, this report cannot make tailor-made recommendations for each but the following generic recommendations are applicable to all regions of the continent, but may vary in degree.

- Clearly define the role and mandate of each REC with respect to trans-boundary water management and development
- Strengthen the capacity of RECs to facilitate the development of regional policy, and legal frameworks with particular emphasis on sector integration and coherent cross-sectoral planning
- Establish regional legal frameworks for trans-boundary water management
- Support the harmonisation of policy and legislation at the national level with regional policy objectives and legal frameworks
- Over time, facilitate the development of basin-specific agreement in line with the adopted regional legal frameworks
- Support the establishment of RBOs for all major basins where they do not yet exist
- In line with the above, assist countries in identifying the RBO types best suited for the specific management and development needs of the basin
- Strengthen the capacity of RBOs to play an effective role in coordination with regional actors (REC) and joint planning between Member States
- Assist RECs and RBOs with creating the necessary planning and management tools to identify the best development options and making the "right" investment choices

6.4 Investment responses

6.4.1 Increasing the efficiency of existing infrastructure

Reducing water losses and increasing the efficiency and productivity of existing irrigation and rain fed systems

In the future, the nature of the investment at the national level in the irrigation sector will be a key factor in the sustainable development of the international river basins. Investments need to be targeted at increasing efficiency and productivity, requiring a combination of technical and policy measures.
High water savings, substantial increases in irrigated areas and a high rate of return on investment can only be achieved if the irrigation efficiency and the water productivity are significantly increased through ambitious capacity building investments that are able to reach millions of farmers. Therefore, besides the increase of irrigated areas, the increase of irrigation efficiency (ratio between water consumed by the plants and water withdrawn from the river or reservoir) as well as the water productivity (food production per cubic meter of water) are of utmost importance.

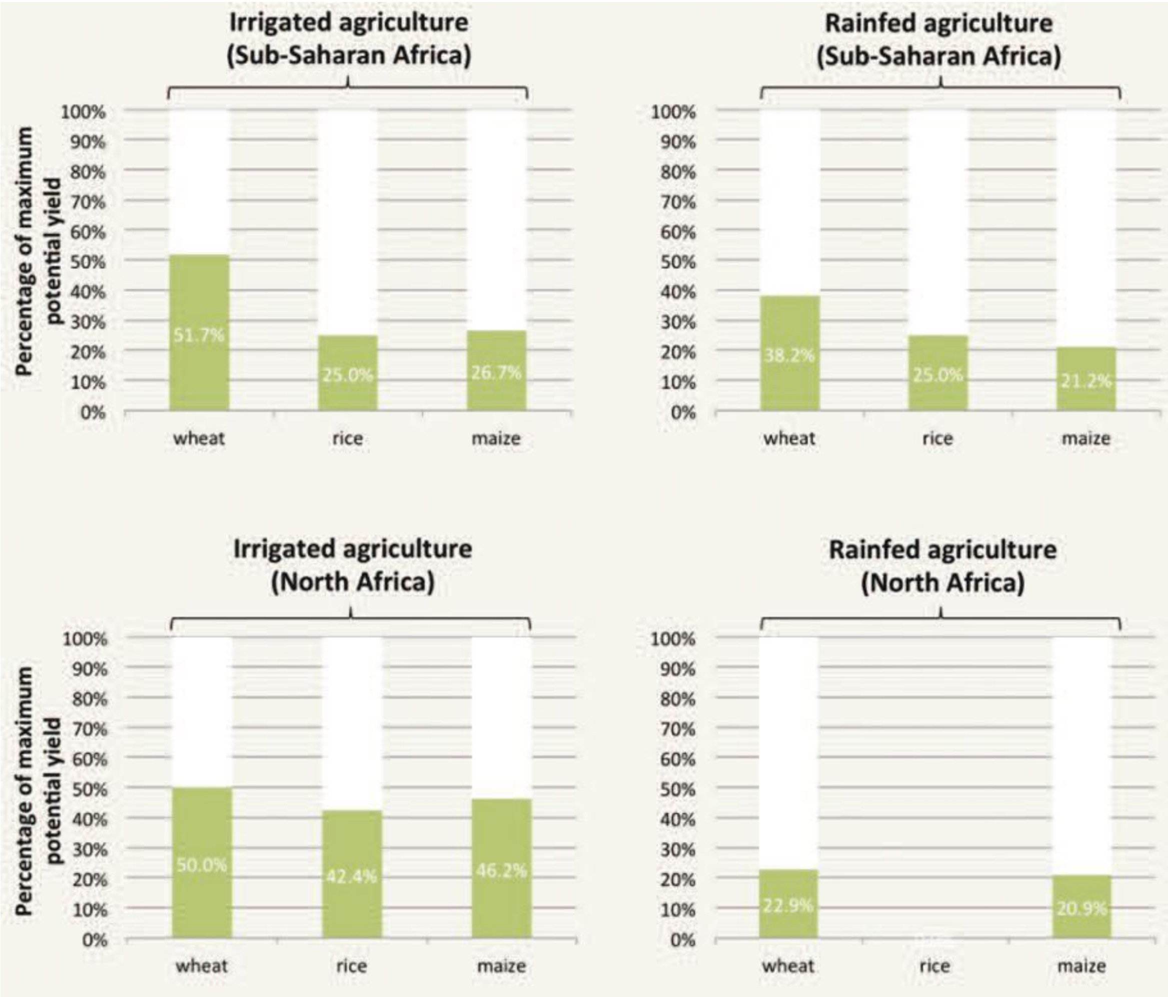
Figure 40 and Table 13 present the estimated current (year 2000) and maximum crop yields in irrigated and rain-fed agricultural systems for Sub-Saharan and North Africa (Data source: IWMI, 2007[31]) showing significant yield gaps (i.e. the gap between potential yield and actual yield).

Table 13: Major actual and potential cereals yields in Africa (Data source: IWMI, 2007).

SUB-SAHARAN AFRICA				
	ACTUAL (2000) [T/ha]		MAX POTENTIAL [T/ha]	
Cereal	Irrigated	rain fed	irrigated	rain fed
Wheat	3	1.3	5.8	3.4
Rice	1.8	1	7.2	4
Maize	2.8	1.4	10.5	6.6
MIDDLE EAST AND NORTH AFRICA				
	ACTUAL (2000) [T/ha]		MAX POTENTIAL [T/ha]	
Cereal	Irrigated	rain fed	irrigated	rain fed
Wheat	3.4	0.8	6.8	3.5
Rice	4.2	n.a.	9.9	n.a.
Maize	6.1	0.9	13.2	4.3

[31] Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture, London: Earthscan & Colombo (Eds.),2007

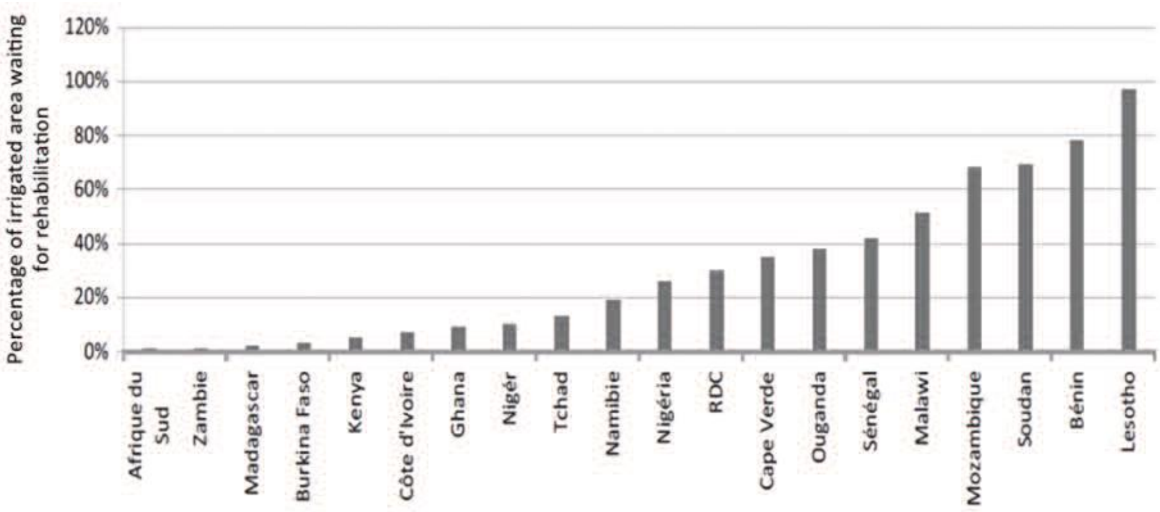
Figure 40: Gaps between current and maximum potential major cereals crop yields in Sub-Saharan and Northern Africa.



Based on the concept of "more crop per drop", initiatives such as the FAO's International Action Programme on Water and Sustainable Agricultural Development place emphasis on increasing water use efficiency through modernization and improvement of existing irrigation schemes and rehabilitation of waterlogged and salinized irrigated lands. The IPTRID Programme (International Programme for Technology and Research in Irrigation and Drainage), a programme initiated by the World Bank and hosted by the FAO, is promoting capacity building and technology transfer for increased water productivity in agriculture in cooperation with a large network of international research centres.

IFPRI Study for the World Bank (within the AICD project) on «Irrigation Investment Needs in Sub-Saharan Africa», estimates that, of the 6 million hectares presently equipped for irrigation (in SSA), approximately 1 million hectares are in need of rehabilitation. The percentage share of irrigation-equipped areas in need of rehabilitation varies dramatically across countries (Figure 41) ranging from almost zero in South Africa and Madagascar to nearly 100 percent in Lesotho. Of the three largest irrigating countries on the continent, Sudan has the highest need, with more than 60 percent of its 1.9 million hectares of irrigation-equipped land in need of rehabilitation.

Figure 41: **Percentage of irrigated-equipped area requiring rehabilitation (Source: adapted from FAO Aquasta database).**



It should be noted that some countries are already characterized by high agricultural productivity and efficiency, limiting their possibilities for further improvements. As proposed by IWMI (2007), a key first step towards improved agriculture productivity and efficiency (both rain-fed and irrigated) would be the development of low-cost technologies that can be rapidly implemented and can quickly produce significant results in countries with low efficiency levels.

Coordinated planning and operation of infrastructure

Dams and reservoirs are central components of large water resources management systems. They provide hydraulic head and storage for hydropower generation but also serve as seasonal (or over-year) storage capacity for multiple purposes (irrigation, industrial and municipal water uses, and flood control). The numerous objectives of reservoirs and dams are often conflicting, especially during extreme hydrological conditions. For example, if both hydropower generation and irrigated agriculture are operating objectives, a trade-off must be found between storing water during the wet season to make it available during the dry season, when the crop water requirements are the highest and releasing water for base-load hydro-electricity generation. Likewise, navigation is sensitive to water levels, which must be more or less constant throughout the year as below and above certain limits the possibility of barge navigation ceases.

The operating rules of reservoirs have evolved over time with environmental and ecological concerns becoming increasingly important. Likewise, reservoirs that were primarily designed for a single objective must now be operated as multipurpose projects in order to serve the needs of various use sectors (including the environment). The optimisation and harmonisation of operating rules for coordinated, basin-wide infrastructure operations in trans-boundary basins provide huge potential for maximising the efficiency of existing infrastructure. The recently completed harmonisation of dam operating rules in the Zambezi basin might provide valuable lessons in this regard.

Conjunctive use of surface and groundwater

This report has highlighted that the conjunctive use of surface and groundwater in Africa is still in its infancy. There is therefore a need for investment in infrastructure that will utilize and improve groundwater management and conjunctive use of water resources. In the development of water resources, priority should be given to new sources of water where synergies with groundwater resources are possible. A key advantage of the conjunctive management of surface water and groundwater is that groundwater can be used to supplement highly variable surface waters and that the pumping of groundwater helps reduce salinity by lowering the water table. In order to fully exploit the potential of conjunctive use, a number of technical aspects need to be further studied before selecting the different options and elaborating a programme of conjunctive use of surface and groundwater. Amongst others, it is necessary to assess the groundwater storage availability, the production capacity of the aquifer(s) in term of potential discharge, the natural recharge, the induced natural recharge, the potential for artificial recharge and the comparative economic and environmental benefits derived from the various possible options. Given the high potential of conjunctive use options, such (soft) studies should be advanced in order to determine the full basket of options and this has been taken into consideration for the development of the PAP in Phase II of PIDA.

6.4.2 Building of new infrastructure

Increase multipurpose water storage

As highlighted throughout this report, Africa has the lowest level of storage capacity globally. A substantial increase of water storage capacity in Africa is needed for increased energy and food production. Increased storage is also a key component in adapting to the natural climatic variability and the impacts of climate change, particularly in mitigating the impacts of natural disasters (floods, extended droughts).

Largely, as a result of the concerns about negative social and environmental impacts, investment in large dams declined substantially throughout the 1990s and in the early part of the 21st century (WCD, 2000). More recently, there has been a re-evaluation of the role of large dams and at the African Ministerial Conference on Hydropower and Sustainable Development, held in Johannesburg in March 2006, African Water Ministers expressed a strong need to accelerate the implementation of dam-building projects throughout Africa.

The estimated infrastructure gap for energy generation and irrigated agriculture has been described in Chapter 5 and estimated investment needs are presented in Chapter 7, pointing a need for a significant increase in storage capacity. Estimating the need for additional water storage at the continental level can only produce crude results as more in-depth analysis, taking into account inter- seasonal and inter-annual climatic variations, and this capacity for in depth analysis further impacted by the uncertainty of climate change, is required. However, to give an order of the magnitude, the following estimate can be made: On the assumption that a per capita storage capacity of 3000 km^3 in 2040 is aimed for (still significantly lower than average storage capacity in other world regions), it would be necessary to increase the total storage from the current 800 km^3 to a range of 4840 - 5750 km^3 depending on the population growth scenario. This is equivalent to the storage capacity of 500 dams the size of the Manantali Dam on the Senegal River or of 30 dams the size of the High Aswan Dam on the Nile.

Irrigation expansion

While the increase in irrigated and rain-fed agriculture productivity and efficiency will have to play a crucial role in achieving food security (as discussed section 6.4.1), the need to expand the current irrigated area, particularly in arid and semi-arid regions remains.

The analysis of the irrigation infrastructure gap has demonstrated that food security could not be achieved without, amongst other factors, productivity gains and the expansion of the cultivated area under irrigation. Globally, the area equipped for irrigation has doubled during the past 50 years. Despite this huge increase, the gap between Africa and the rest of the world remains significant, as illustrated in Figure 42. During the past decade (from 1998 to 2008), the annual increase in area equipped for irrigation was 0.081 million ha per year in Africa and 3.18 million ha per year in the world. This represents an annual growth rate of 0.62% and 1.10% respectively.

Figure 42: Evolution of the area equipped for irrigation.

It should be theoretically possible to irrigate three to four times the size of the areas currently under irrigation with the available water resources at the continental level. However, as highlighted throughout this report, there is a high degree of regional variation in water resources availability and in some regions, particularly in the Northern and the Southern parts of the continent; they are close to reaching the limits to irrigation expansion. In the water scarce regions basin wide, trans-boundary cooperation will be increasingly crucial to optimize the investments in infrastructure and their operation. This is mainly in order to achieve water savings through the improvement of irrigation efficiency and water productivity, to limit the evaporation from large reservoirs, and to improve the transfer and the distribution efficiency of water.

Based on the analysis of the irrigation infrastructure gap in the preceding chapter, it is anticipated that an increase in irrigated area of 12.8 million hectares by 2040, compared to 2008, would help to reduce this gap, bringing the total irrigated area to approximately 26.3 million ha. The ratio between irrigated cereal production and total cereal production would be approximately 50 % under this scenario. However, to achieve this, the irrigation expansion rate would have to be much higher than that experienced in the past 20 years.

Table 14 suggests indicative development targets for the selected basins in the PIDA study. These are broad rough figures and are presented here primarily as a starting point for discussion with the stakeholders. Further detailed analysis for each basin needs to be conducted for these initial estimates to improve.

Table 14: Indicative irrigation development target in the selected basins

Basin	***Irrigated areas in 1000 ha***		
	Current (2005)	***Irrigation potential (FAO)***	***Indicative development targets***
LAKE CHAD	113	1.989	500
CONGO	36	9800	1500
GAMBIA-GEBA-KOLIBA	31	115	100
NIGER	228	2817	1000
NILE	5079	10192	1000
OKAVANGO	0	208	100
ORANGE-SENQU	303	390	20
SENEGAL	118	420	200
VOLTA	27	1.487	500
ZAMBEZI	147	3.160	1.000
Total	**6 081**	**30 578**	**6100**

Inter-basin water transfers

Inter-basin water transfers (IBT) are transfers of water from basins with a (current) surplus of water to water-scarce basins. Whereas few IBTs exist in other African regions, many such schemes have been implemented in Southern Africa, including the Lesotho Highlands Water Project, the world's biggest international IBT. Further IBTs in the SADC region are currently being planned or are in pending implementation.

IBTs are complex technical undertakings that require in-depth technical and environmental studies prior to implementation. Likewise, IBTs require a high degree of technical coordination and cooperative management. Two or more hydrologically separate basins are technically linked through a transfer. Despite these challenges, IBTs have proven to be valuable options where they have been implemented and should be considered as possible options for other African regions.

7. INVESTMENT NEEDS AND FINANCING OUTLOOK

In 2000, the annual investment needs for reaching the African Water Vision goals in the water resources sector were estimated at around 20 billion US$ per year. Out of 20 billion US$, 12 billions US$ were devoted to basic needs (i.e. domestic water supply), sanitation and hygiene. These figures were updated in the Africa Regional Paper for the 5th World Water Forum (2009), which estimated annual investment needs of 50 billion US$ in the water sector.

7.1 Drinking water, sanitation and hygiene

The infrastructure gap for (domestic) water and sanitation supply has not been analyzed in this study as this is essentially a national issue with relatively limited trans-boundary impacts. Nonetheless, a snapshot of the estimated investment needs in this area is presented here in order to provide a more comprehensive picture of total investment needs in the water sector. The cost of domestic water supply has increased rapidly over the past decades. According to Seckler (1993), the per capita investment required to provide water and sanitation services in urban areas is around 500 US$/cap. The Africa Regional Paper for the 5th World Water Forum (2009) refers to an annual investment requirement of $US 12 billion to meet the basic water supply and sanitation services in Africa overall. In addition, it is estimated that additional $US 5 billion will be necessary to upgrade wastewater infrastructure to ensure adequate water quality standards.

As mentioned in Chapter 4, North Africa is already using non-conventional sources of water such as desalination. Given the growing water scarcity, it can be expected that the desalination needs will increase. The Africa Regional Paper for the 5th World Water Forum (2009) refers to an annual investment need of $US 1 billion to support desalination in North Africa.

7.2 Water storage for multiple uses

A substantial increase of water storage capacity is needed for increased water security, for reducing the impacts of climate variability and for preventing disasters exacerbated by climate change. Thus, it is likely that investment in large dams in Africa will increase in the near future. While multi-purpose dams are increasingly being conceptualized, planned and built, hydropower generation is generally the main driver for the construction of large dams. The investment requirements for multi-purpose projects will thus largely depend on the forecast energy demands and the availability and cost of the various types of energy sources. The currently installed hydropower generation capacity in the 10 selected basins is around 15.5 TW while the hydropower potential is around 200 TW. In Chapter 5, the hydropower infrastructure gap has been estimated at around 72 563 MW (with an upper bound of 179 744 MW). The Africa Regional Paper for the 5th World Water Forum (2009) refers to an annual investment need of $US 20 billion for hydropower-driven infrastructure. In addition it refers to an annual investment need of $US 5 billion for storage projects where hydropower generation is not a feasible option within multipurpose planning.

7.3 Irrigation rehabilitation

According to the AICD, 1 million ha of land currently under irrigation in Sub-Saharan Africa need rehabilitation, at a cost of US$1900 per hectare, excluding storage costs. On this basis, the investment needs for rehabilitation of existing schemes in SSA would be $US 1.9 billion. This would include investment in applied research and ambitious agricultural extension programmes aiming at more efficient on-farm irrigation technologies and irrigation management approaches (demand management). While rehabilitation and modernization are also needed in the Northern part of Africa, reliable data has not been found to assess the investment requirement in this region.

7.4 Irrigation expansion

The development of new sources of water will become more costly as the best and cheapest options are already used. In a recent study on the costs and performances of irrigation projects, the International Water Management Institute (IWMI) found that the capital investment costs of irrigated area expansion in Sub-Saharan Africa and North Africa were 5 600 US$/ha and 6000 US$/ha respectively. These values are far more expensive than in Asia or South-America due partly to high transaction costs and the high failure rate of irrigation projects (IWMI, 2007). It is worth mentioning that the poor supporting infrastructure addressed by the other PIDA sectoral studies (i.e. transport, energy) are partly responsible for the high failure rate. However, both the cost and performance of irrigation projects have improved over time, especially in Sub-Saharan Africa. One of the interesting findings of the AICD (2008) study on irrigation investment needs in SSA is that only lower-cost technologies and approaches are viable on any significant scale in Sub-Saharan Africa (AICD, 2008). Finally, the report also stresses the positive impact on the unit cost when the project is implemented within a bigger multipurpose project.

Based on the forecast results presented in Chapter 4, the irrigation infrastructure gap has been estimated in section 5.2 to be around 12.85 million hectares for Africa overall. Assuming a cost[32] of $US 5 800 per ha, the investment need for irrigation expansion at the continental level would be in the range of $US 74.53 billion, over the next 30 years or approximately $US 2.5 billion per year.

It is important to note that this amount does not include operation and maintenance (O&M) costs that increase as the irrigated area expands. The Africa Regional Paper for the 5th World Water Forum (2009) refers to an annual investment need of $US 5 billion for combined irrigation development and O&M costs.

Most of this investment would have to be made at the national level. However, it is worth noting that the gap in the irrigation infrastructure has been estimated assuming that rain-fed agriculture will be able to produce 50% more than today by improving its productivity and expanding its area under cultivation. Also, an improvement of irrigated agriculture productivity has been assumed (in terms of crop yield). Consequently, investment needs for the extension of irrigated agriculture would be significantly higher if specific investments for improving efficiency and productivity of both rain-fed and irrigated agriculture are not made.

7.5 Investment in response to climate change

The water sector will require substantial investments in order to respond to climate change. As predictions by global climate models are converging, it appears increasingly likely that weather patterns will become more variable and will include more extreme events. Rainfall distribution and volumes will change, and investment in increased groundwater and surface storage capacity will be required in order to provide sufficient supply for extended drought periods on the one hand, and flood control on the other hand.

7.6 Summary of investment needs

By combining the estimate in the Africa Regional Paper for the 5th World Water Forum (2009) and cross-referencing them with a range of sources, Table 15 gives an indicative summary overview of investment needs while the distribution across intervention categories is illustrated in Figure 43.

Table 15: Indicative Investment Requirements in the Water Sector

Investment category	$US billion/year
Irrigation rehabilitation	<0.01
Irrigation expansion and O&M costs	5
Drinking water and sanitation	12
Desalination	1
Urban waste water	5
Multipurpose water storage	5
Hydropower-driven infrastructure	20
Total	***48***

[32] The capital costs of irrigation are defined to include all expenses incurred in developing and establishing irrigation schemes beginning with design and planning up to implementation and completion of the project just before the start of regular operation.

Figure 43: **Relative distribution amongst activities of the annual investment needs in the TWR sector. Figures are in billion US$ per year.**

The order of the magnitude of the total investment needs in the water sector in Africa would thus be in the range of $US 48.9 billion per year. Of these categories, desalination is the only factor without relevance in terms of TWRM. Drinking water supply and urban waste water have limited relevance for TWRM in general (because, although investment needs are high, the overall amount of water required is relatively small) but may be of significance in specific basins with a high concentration of urban areas. That said, even where the water use in question is of relevance for the trans-boundary management of the resource, the infrastructure investment itself could still be national (e.g. for a national irrigation scheme in a trans-boundary basin). The portion which would be considered as a regional investment need in the scope of the PIDA programme will therefore be estimated in the second phase of the PIDA Study, after a realistic investment programme has been identified in cooperation with the key stakeholders. Likewise, the proposed financing mechanism will be tailored to the specific programme once the investment needs for PIDA type projects have been determined in more detail in Phase II.

8. CONCLUSIONS

With African population expected to double by 2040, water demand for food and energy production, industrial growth and domestic water supply will grow significantly. While on a continental average Africa seems to have sufficient water resources, the highly uneven distribution of water resources across the continent means that many countries and trans-boundary lake or river basins will face increasing levels of water scarcity or water stress. This is exacerbated by the high degree of natural climatic variability and expected impacts of climate change.

The results of the water demand forecast presented in this report highlight the expected trends in water demand and provide an illustrative picture of the scale of the challenge. At the same time, the report highlights that Africa has significant water resources potential that is currently unused. At present, the African continent on average has the lowest level of water infrastructure development globally with respect to both storage capacity and irrigation development.

With water being of strategic importance for socio-economic development, it is clear that more strategic water infrastructure needs to be built in Africa in order to better harness the continent's water resources potential. At the same time, the report highlights the importance of refurbishing already existing infrastructure, which is often no longer working at full capacity. In this context it is noted that most of the existing large-scale water infrastructure on the continent has been built several decades ago and very few water infrastructure projects have been implemented in the past two decades. PIDA provides an estimate of the existing infrastructure gap and required investment needs for the period until 2040.
The findings of the Outlook 2040 form the basis for the development of the strategic framework and Priority Action Plan for infrastructure development in Africa during Phase II of PIDA. In this context, the report has presented the key challenges that PIDA can meet. It further presents a number of response options that can be addressed either directly through PIDA, or through other PIDA interventions.

A key message emerging from the study in that context is that water infrastructure investments will only be effective in addressing the challenges outlined if accompanied by the strengthening of management frameworks for trans-boundary water management and increased regional and basin-wide cooperation. The report further highlights that investments in infrastructure alone will not be sufficient to meet the challenges but these have to be accompanied by innovative policies and strategies, such as increasing the efficiency of rain-fed agriculture, improved regional trade environments or the development of benefit sharing arrangements. Likewise, the report emphasises that investments in water infrastructure are highly dependent on adequate energy and transport infrastructure and therefore need to be well integrated into coordinated, cross-sectoral investment and infrastructure plans in order to achieve the desired outcomes.