ENTRO
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

Eastern Nile Subsidiary Action Program

Eastern Nile Multi- Sector Investment Opportunity Analysis

Summary Report 2017

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Acronyms and Abbreviations

AHD	Aswan High Dam
BCM	Billion Cubic Meter
BSG	Beni Shangul Gumuz Region
CC	Country Consultation
CRA	Cooperative Regional Assessment
EAC	East African Community
EEPCO	Ethiopian Electric Power Corporation
ENID	Eastern Nile Irrigation and Drainage
ENCOM	Eastern Nile Committee Of Ministers
ENIMIS	Establishment of Eastern Nile Irrigation Management Information System
ENPT	Eastern Nile Power Trade
ENSAP	Eastern Nile Subsidiary Action Plan
ENSAPT	Eastern Nile Subsidiary Action Plan Team
ENTRO	Eastern Nile Technical Regional Office (NBI)
EWUAP	Efficient Water Use for Agricultural Production
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GERD	Grand Ethiopian Renaissance Dam
GIS	Geographic Information System
GWh/y	Giga Watt hour/year
HDI	Human Development Indices
IDEN	Integrated Development of Eastern Nile
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
JMP	Joint Multipurpose Project
MCA	Multi Criteria Analysis
MEDIWR	Ministry of Electricity, Dams, Irrigation and Water Resources
MSIOA	Multi Sector Investment Opportunity Analysis
MW	Mega Watt
NBI	Nile Basin Initiative
NCORE	Nile Cooperation for result project
NELCOM	Nile Equatorial Lakes Council of Ministers
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NELSAP-CU	NELSAP Coordination Unit
NGO	Non-Governmental Organization
NIB	National Irrigation Board
Nile-COM	Nile Council of Ministers
OMM	Operation, Maintenance and Management
RATP	Regional Agricultural Trade and Productivity Project
RSS	Republic of South Sudan
SAP	Subsidiary Action Program
SVP	Shared Vision Program
UNDP	United Nations Development Program
WB	World Bank

Foreword

Fekahmed Negash Nuru
Executive Director, ENTRO

The Eastern Nile Sub-basin has been central in human history, giving rise to some of the most advanced civilizations of antiquity.

Yet todays Nile is more stressed – hosts millions and millions more people; much, much more demand is placed on it, and to make matters complex, is likely to bear more extreme stresses arising from Climate Change impacts. All the same, the Eastern Nile now – as it was millennia ago – has to provide food, energy , transport, drinking water, sanitation, environmental and critical ecosystem services, etc. for its inhabitants spread across Egypt, Ethiopia, South Sudan and Sudan, and to a lesser degree Eritrea,

This is our first ever but modest attempt to bring together the various sectoral water resources development plans of these countries, constrain them by the imperatives of judicious utilization and sustaining the river system for future generations and thus finding a safe development space for cooperative win-win development outcomes. We hope, despite its limitations, this document will stimulate and provoke decision makers and water resources professionals as well as investors to work toward realizing a regionally optimized water resources investment that addresses the development needs of countries. We also hope that this contribution will at the same time prompt us all to appreciate the finiteness, fragility and vulnerability of the Eastern Nile and thus the imperative of institutionalizing a planning culture that emphasizes interdependencies, synergies and regional cooperation and basin/sub-basin orientation and perspectives. We thank the World Bank (Nile Cooperation for Results/NCORE and CIWA/Cooperation in International Waters in Africa programs) for the invaluable technical and financial support.

August 20, 2017

Executive Summary

Eastern Nile Basin: Introduction and Background

The Eastern Nile Basin (ENB), consisting of Egypt, Ethiopia, South Sudan and Sudan, and with a population of over a quarter of a billion inhabitants (expected to double in less than two decades) is perhaps the most important part of the Nile Basin. Its significance is not only because of its geo-hydro-political relevance or the fact that it is home to over half the population of the entire Nile Basin (important as these are), but also because of the hydrological significance of the river Nile that courses through it.

The ENB has been the site of some of the most advanced civilizations of the ancient world. The annual Nile flood that carried fertile sediment from the Ethiopian Highlands transformed the deserts of Sudan and Egypt into rich agricultural lands along its course. Apart from the Nile River itself, the ENB encompasses an extraordinary range of ecosystems from high mountain moorlands, montane forests, savanna woodlands, extensive wetlands and arid deserts. Within the ENB, most of the people in Ethiopia, Sudan and the newly-independent South Sudan are rural, depending largely on the natural resource base for their livelihoods, while in Egypt nearly half the population is urbanized, although the Nile provides the basis for irrigated agriculture, water supply for human, livestock , industrial, power generation and water transport. The richness of the natural and human resource base notwithstanding, the basin's peoples face huge challenges:

Hydrology and Water security

The Eastern Nile Basin is a water scarce region. About 86% of the waters of the Nile are generated in very limited watersheds of the highlands of Ethiopia (16% of the total area of ENB) and for most of its course of nearly 7000 kilometers the Nile flows through desert, incurring huge evaporation and conveyance losses. Recent studies of the Nile Basin Initiative (NBI) show that, due to the rapidly rising water demands (population of the ENB has grown from 58.3 in 1960 to 243.5 million in 2015 and will grow more than 330 million in 2030; average urban population distribution as a percentage of total will reach up to 37%), the basin countries are expected to face huge water shortage in the next 2 – 3 decades.

One of the most distinctive features of the Nile Basin in general, and the ENB in particular is extreme spatial and temporal variability of water resources. Temporally, 70% of the waters of Eastern Nile are generated in only 3-4 months, between the months of July to September, but there is also huge variation in the volume of river flow across years: in dry years the flow can go as low as 40% of its annual average and in wet years it can go as high as 140% of the average - and the dry years are getting more frequent, more prolonged and consecutive. With climate change such year-to year and within-year variability is likely to worsen significantly. All this makes water availability in the Eastern Nile Basin increasingly uncertain. Even now, the ENB is sustaining significant deficits in meeting basic human needs such as for potable water, sanitation, food production and municipal supply.

Agriculture and Food Security

For nearly half a century now agricultural productivity and food production (both rain-fed and irrigated agriculture) in the ENB countries shows a low figure, as agricultural production has been unable to cope with population growth. This means the basin's population, mostly subsistent farmers and low-income earners in cities – will be more and more food insecure in increasing numbers in the coming decades. That the basin is becoming increasingly food insecure is demonstrated by the recurrent droughts, crop failures and subsequent famines devastating Ethiopia, South Sudan, Eritrea and Sudan with increasing frequency.

Irrigation and water availability
Currently some 5.3 million hectares of land is under irrigation in the Eastern Nile (3.45, 0.91, 0.5, 1.76 respectively for Egypt, Ethiopia, South Sudan and Sudan). However, water use efficiency and productivity of irrigated agriculture in the sub-basin still has a lot of room for improvement. Upstream countries, pressed by the increasing frequency of drought devastation of their rain-fed agriculture, have planned to expand irrigated agriculture – as do Egypt and Sudan. But the availability of water is increasingly becoming uncertain. For example, a 2010 ENTRO Irrigation Cooperative Regional Assessment (CRA) revealed that if Egypt, Ethiopia and Sudan implement all their planned irrigation development, there would be a deficit (or additional demand for) 48.6 BMC of water – a quantity of water almost equivalent to the entire annual flow of the Abbay/ Blue Nile! To complicate this complex situation further, there is, despite the potential, as of now minimal, or near absence, of intra- ENB agricultural trade, which would have contributed to the improvement of production and location efficiencies, access and availability and water saving thus in combination would have ameliorated the food insecurity. While all the ENB countries appreciate that irrigated agriculture is key to productivity increases, their ambitious future plans for irrigated agriculture face resource constraints, in particular, the availability of adequate water in the river Nile.

Fisheries and Livestock
Although there are widespread fishery activities in the ENB, with huge potential, their development is highly constrained – as is the case with the other widespread and critical livelihood activity in the Eastern Nile Basin, livestock rearing.

Energy security
With the exception of Egypt which secure more than 90% of its power generation from thermal sources, energy supply in the NBI countries remains inadequate, unreliable and expensive. The ENB relies on biomass-sourced energy which, besides continuous depletion of its source, is resulting in land degradation, soil erosion and habitat loss. All the same, demand for energy in the basin is expected to increase from 37 GW in 2015 to 96 GW by 2030, an increase of 260 %. And yet all this unmet demand is sustained in the midst of huge hydropower potential exceeding 45 GW. Current use of the ENB's hydro-power potential is no more than 8%. Underdevelopment of the hydropower potential across the basin and the resulting energy deficit is constraining the economic growth of Ethiopia and Sudan that rely mostly on hydro-power. Even worse, the ENB countries are only beginning to put in place a functional regional power grid and thus increase significantly volume of power traded among the countries.

Ecosystem and biodiversity
The Eastern Nile Basin is home to globally valued, unique terrestrial and aquatic habitats, ecosystems and biodiversity. According to the Nile Basin Water Atlas (2016) the Eastern Nile Basin hosts some important eco-regions with their specific association of flora and fauna, including the Ethiopian highland montane grasslands and woodlands, the Sudanese Savannah and Sahelian Acacia. These eco regions are home to the last remaining large mammals including elephant, buffalo, giraffe, lion, cheetah, white eared kobo, gazelles, including their majestic annual migrations, etc. As regards wetlands the ENB is home to important, equatorial wetlands such as the Machar Marshes and the Dinder Mayas. ENB wetlands play crucial roles in maintaining environmental quality (e.g. ground water recharge, flow regulation); sustaining livelihoods (e.g. fisheries, fuel wood, timber, medicinal herbs) and maintaining biodiversity (home for fish, birds, reptiles, mammals). The ENB hosts internationally significant Ramsar sites in addition to designated biospheres and protected parks such as the Dinder National Park-Biosphere in Sudan, the Boma National Park in South Sudan and the Semien and Gambella National Parks in Ethiopia.

Terrestrial and aquatic ecosystems are facing multiple threats, including the expansion of irrigated and rain-fed agriculture and increasing land conversion to residential and industrial purpose, the growing rate of the expansion of cities and the rising rate of harvesting of biomass for energy - which are degrading the life support capability of the ecosystems and are threatening the biodiversity of the ENB. If current rate of degradation continues unmitigated, the Eastern Nile could potentially lose all or most of its natural assets in the next decade or two. This means that there is a very narrow window of opportunity to protect and conserve the biodiversity and critical ecosystems of the ENB – which would be a tragedy not only for the Nile Basin, but for the entire world.

Climate Change

Climate change manifests itself largely through the hydrologic cycle. Water thus is the primary medium through which the impacts are mediated. Though there is general agreement that surface temperatures in the Eastern Nile Basin will rise by 1-2 degrees centigrade in the foreseeable future, and therefore the implication of this temperature rise on crop water requirements, there is significant uncertainty about the location and direction of specific impacts of climate change on the hydrological cycle - i.e., whether there would be more or less rainfall, more or less droughts and floods, how prolonged the droughts and floods would be, how frequently they would recur – and where. Given the uncertainty of water supply and threats thereof, the Nile Basin needs to urgently prepare for more variable conditions and design structures, investments and water resource management.

However, several factors make sub-basin wide planning and management difficult. First, there is dearth of long-term hydro-meteorological data (sub-basin-wide hydro-meteorological measurement, monitoring and early warning systems are only in their nascent stages of development). Coupled with the region's strong degree of natural variability in precipitation, this makes reliable forecasting of river flows more difficult. This in turn substantially hampers operational water resources planning and management to combat the impacts of climate change, especially extreme events. Second, the characteristic low discharge and high evaporation rates make the Nile highly sensitive to small climate change effects – which make reliable climate predictions even more complicated and challenging. Third, there is low Nile-Basin level water-storage capacity for absorbing shocks of short to medium term climate extremes (droughts and floods).

Summary of challenges

The multiple insecurities of the ENB – including water insecurity, food insecurity and energy insecurity – are likely to be amplified and intensified with the impact of climate change, the rise in populations and growing urbanization. Most climate change models agree that surface temperatures will rise in the ENB, which will translate into more water demand to produce the same quantity of agricultural yield. Water will be the main conduit thru which climate change will be mediated. Water, hence, will be a key constraint in the coming decades to realize both food and energy security, not to speak of securing water for industrial and municipal use along with that for maintaining ecosystems. Critical ecosystems, habitats and biodiversity assets of world significance will be at risk, if not extinction if countries do not intervene in the small window of opportunity still open.

Each of the ENB countries is striving to increasingly tap into the Nile water resources in a bid to meet the ever–growing demand for food, energy and water for their growing populations. Almost the entire irrigated agriculture in the Eastern Nile, if not the entire Nile Basin, is located in Egypt and Sudan – and both countries have long been relying on the Nile resources for their agriculture. In addition to the new planned irrigation schemes in Ethiopia (and eventually in South Sudan), Egypt and Sudan are also planning to expand their irrigated agriculture. Currently, therefore, national irrigation projects are planned without taking much account of water availability across the ENB as a whole, likely climate change impacts and possible improvements in irrigation water use efficiency and productivity, including the potential for crop zoning to enhance crop water use efficiency.

Countries could as well be planning with water that may not be there at all in the system, and could thus lead to conflicts, especially when the system is stressed with rising water demands, such as during prolonged droughts. Uncoordinated development of the common Nile resources will ultimately not only lead to competitive utilization among countries, but could threaten the very sustainability of the river Nile itself.

Nile Basin Initiative

This precarious state of water resources, the vulnerability of such a sizeable population to increasing variability in rainfall and water flows in the river Nile and the looming future threats of burgeoning populations, urbanization, industrial pollution and climate change prompted the formulation of the Nile Basin Initiative (NBI) - a partnership between the ten riparian states of the Nile River - Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda – that seeks to develop the river in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security. The NBI has a strategic action program comprising two sub-programs: a basin-wide Shared Vision Program (SVP) and a Subsidiary Action Program (SAP) to promote cooperation at the sub-basin level. The SAP comprises the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) and the Eastern Nile Subsidiary Action Program (ENSAP).

ENSAP's first set of water resources related investments consisted of the Integrated Development of the Eastern Nile (IDEN) was the first ENSAP project, agreed in 2002, with an initial set of seven sub-projects aimed at tangible win-win gains in the areas of watershed management, flood preparedness, early warning and response, irrigation and drainage, power supply interconnection and regional power trade and later the Joint Multipurpose Program [JMP]. The Nile Cooperation for Results (NCORE) Project is the first phase of the Nile Basin Climate Resilient Growth Program and is part of the 5-year NBI Strategic Plan and aims to "facilitate cooperative water resource management and development in the Nile Basin."

ENSAP has been promoting sub-basin water resources development planning and management i.e. taking the entire ENB from the headwaters in the Ethiopian highlands to the Mediterranean delta in Egypt as one hydrologic planning unit so that the entire complex impact systems could be holistically captures, and trade-offs and optimization potentials explored. In the long run, there is no alternative to this basin approach.

Multi-Sectoral Investment Opportunities Analysis

The Eastern Nile Multi-Sectoral Investment Opportunities (EN-MSIOA) study is one of several specific studies being undertaken by ENSAP to achieve the general objective of the NCORE from the Eastern Nile perspective.

Rationale

The Irrigation and Drainage and the Power Trade Studies, two of the seven IDEN Projects ENTRO completed, have made the earliest contribution in terms of alerting decision makers for the need for integrating water resources planning across sectors and across the EN basin if we are to learn to do more with less and less per capita available water. Their findings have never been integrated across sectors to provide direction for wider basin level water resource optimization and efficiency. Their main conclusions, however, are significant: (a) Country-focused planning misses the basin perspective i.e. upstream-downstream (and vice versa) consequences (b) aggregated planned demand already exceeds availability of water in the Nile (c) regionally optimized investment planning is required to address the mismatch. The EN MSIOA, therefore, is borne out of these three needs – that is, to make a Multisector Investment Assessment of existing Opportunities in order to formulate a coordinated water resources investment strategy for the Eastern Nile Basin that promotes shared economic growth and development while sustaining the environment.

Objectives

Drawing from and/or updating earlier ENSAP studies as needed, the EN MSIOA aims to undertake water resources analysis that would promote (a) sustainable management of common Eastern Nile water resources; (b) cooperative investment planning that takes into account the water scarcity of the basin and the social and environmental and economic implications of such investments.

Limitations

The study has been constrained by the following: (a) incompleteness or complete lack of data and information particularly on South Sudan (b) outdated and incomplete baseline social and environmental data (c) inability to hold the requisite consultations in Egypt (due to the freeze) (d) limitations in factoring in climate change impacts (downscaling of GCM, for example) (e) inability to input studies from the ongoing Baro-Akobo/Pibor-Sobat (BAS) Study (f) inadequate attention to watershed management issues

Methodology and Process

The EN MSIOA started by identifying key EN basin-wide water resources development and management challenges (as outlined above). This Situational Analyses assessed the current state of the water resource in the basin including the hydrological (e.g. water balance per basin; spatial and temporal variability), key environmental issues (e.g. biodiversity hotspots; key watersheds; land degradation; sediment and water quality) and social issues (e.g. poverty, demographic changes, etc).

The core analysis involved the definition and analysis of different combinations of water resources management and development across sectors (termed Development States), and the analysis of the economic, social and environmental implications of each of the twelve Development States defined, using a three-step process:

A. Water demand requirement was worked out using the Eastern Nile Basin Simulation Model, which modeled (a) the functioning of the EN region hydrological systems, including natural and man-made reservoirs, wetlands, irrigation and hydropower schemes in the EN river systems and its main tributaries and (b) the satisfaction of water demand (for irrigation, hydropower, water storage operations and environmental flows), under different water resources management and development states.

B. Annual mass balance analysis of water use was calculated using an EXCEL-based Tool for the water demand requirements of each development state from the EN Basin Simulation model. This provided the implications on water availability at each node in the system.

C. Economic assessment of major infrastructure investments was done using a 30-year time horizon, in US dollars and assuming a (social) discount rate of 8%, yielding Net Present Values (NPVs), Economic Internal Rates of Return (EIRRs) and Benefit-Cost (B-C) ratios. Detailed economic analysis was carried out for irrigation investments in Sudan, South Sudan and Egypt, while the most recent analysis done for large-scale hydropower schemes was accessed and used.

D. Multi-Criteria Analysis was then used to compare the impacts of each Development State, especially in terms of how they meet the water resource and sustainable development expectations of the ENB countries. This involved a two-stage process:

    1. Selection of evaluation criteria (by key national stakeholders) which comprised economic criteria (net economic returns generated by hydropower and irrigation schemes) and water productivity in the irrigation sector); social criteria (employment created in the irrigation, fisheries and livestock sectors (a proxy for poverty reduction); resettlement of people displaced by a project (a proxy of the social damage generated by the project); and the equity of distribution of benefits to users); and environmental criteria (the annual flow at the Nile delta and total evaporation losses from reservoirs in the Basin).

    2. Weighting the criteria (by stakeholders) to ensure that key criteria were given the highest importance): This was done using a pair-wise matrix ranking, which is a structured method for ranking a list of indicators in a priority order. These rankings were collated across stakeholders and applied to the criteria to yield a set of weights, which were then applied to weight the performance of each Development State on the selected criteria.

Even though each development state that was the basis of the comparison comprised of ongoing and planned water resources investment projects of all Eastern Nile countries, the MCA exercise, was not however meant to result in the prioritization of specific regionally optimized water resources investments. This is so because of its's suspension of participation in the NBI (over disagreement on the conclusion of the CFA in 2010) Egypt was not represented in all phases of the study, including the MCA exercise. All the same, the methodology has yielded interesting results that helped **outline the prerequisite enabling strategic action areas** for regionally optimized and prioritized package of water resources investment projects subsequently.

Conclusions and Key Messages

The MSIOA yielded fundamental insights into the challenges, complexities and possibilities of water resources investment planning while adopting a regional or ENB-wide and hydrology-based perspective. The following conclusions and key messages stand out:

Overall Conclusions

- **Business as usual, i.e., water resources planning and investment strategies that do not consider the basin as a whole will not lead to sustainable outcomes.** For one, regionally uncoordinated planning and investment lacks consideration of inevitable upstream and downstream impacts which affect other countries within the same Basin. For another, such planning could either result in significant and adverse social and environmental impacts elsewhere or foreclose better options elsewhere in the basin, from a regional-perspective. Finally, such planning would violate the hydrologic unity of the river.
- **A regional, whole-basin perspective, orientation and modus operandi in investment planning is a must,** if adverse impacts are to be avoided, minimized or managed successfully. In the long run, the only option is a regionally optimized investment portfolio for the basin as a whole.
- **There is scope for new irrigation, but in the longer-term, there is not enough water to fulfill the development plans of all countries.** Unchecked or unilateral expansion of planned irrigation will lead to major water shortages and/or the abandonment of some irrigation schemes. Even a step back from the full development of irrigation potential will lead to a shortage of water in the system.
- **Regionally planned hydropower development has minimal impact on regional water resources**, once the dams are filled. Although the study did not analyze the filling of dams and this needs further investigation, the study established that, being non-consumptive water use, new hydropower can be managed in a trans-boundary context while working to reduce evaporative losses from reservoirs, and coordinating filling and operation.
- **Where reservoirs are used for hydro-power and irrigation, water availability may be impacted.** But if well-planned, there are win-win-win development opportunities.
- **Choice of crops, agricultural water use efficiency improvements and a regional approach to food security and agricultural markets** should be explored further and developed.
- **Other areas to further explored to reach favorable win-win development outcomes for all** include watershed management, groundwater management, salinity control, flood forecasting, wetland preservation – and climate change across all sectors and the basin
- **Multi-sector coordination and analysis are critical** to identify sustainable development and feasible investments.
- **There are huge information gaps in the basin,** which need to be plugged urgently in order to improve the basis for decision-making on critical resource management issues.

Implications for Development Strategy

The MSIOA study points to the following directions for development strategy in the ENB:

- **Prioritize most deserving (hydropower and irrigation) infrastructure projects:** The Investment strategy should ensure that the infrastructure hydropower and irrigation projects on which there is consensus are prioritized on the basis of economically feasibility environmental sustainability & social equity, and prepared for implementation to meet identified needs at least in critical areas.
- **Coordinate operational rules for reservoirs for better performance:** Apart from creating new water resource infrastructure, a key activity will be to modernize and synchronize their operating systems – which will also improve dam safety along different cascades.
- **Select the most economically-viable irrigation schemes:** Since the potential for uncoordinated irrigation expansion is limited, the irrigation schemes selected for implementation should be the most economically viable.
- **Ensure that crops most suitable to the agro-climatic zone are grown:** Since the sum total of currently planned Irrigation schemes – and possibly even those that pass the primary screening suggested above – may not be feasible given the availability of water, all possible options to improve their water efficiency should be considered, a primary one being their suitability for a particular agro-climatic zone.
- **Take a regional approach to markets and food security:** Promoting regional trade of agriculture-based products - that are grown in the most suitable agro-climatic zone but made available to other areas where there is demand but which may be unsuitable for its production – will also optimize irrigation water use within the basin.
- **Continue improving and updating tools and data to support future decision-making:** There is now a useful suite of planning tools in place to support the making of the best choices in the future. The detail and applicability of these tools will be enhanced by water sources models that will be set up at the sub-basin level as part of planned studies.
- **Take forward 'no or low regrets' opportunities urgently:** There are many "no or low regret" initiatives that should be taken forward as a matter of urgency. Ten such initiatives have been identified and endorsed by country stakeholders at a workshop in Addis Ababa on 31 October 2016, and are detailed further below.

'No-regret' Sectoral Initiatives

- **Energy sharing**

The ENB enjoys comparative advantage in hydropower generation and could be more economically viable as it is a non-consumptive use of water. However, more will be achieved if hydropower generation and consumption is managed within a regional context. In order to realize full potential there is a need to expand transmission interconnection linking the grids of all ENB countries and put in place a power trade regime which will involve the utilities of all ENB countries. Hydropower development needs to be sequenced in such a manner that filling and operation are based on accurate factoring in of flow rates, reservoir volumes, hydrologic conditions, up and downstream demands, etc.

- **Irrigated agriculture**

ENB countries have planned either new irrigation schemes or expansion ones. It is imperative that such plans are accompanied or preceded by measure that improve management and efficiency of existing schemes; of water saving; study on tradeoffs (such as between new irrigation vs. rehabilitation vs. improving productivity and efficiency vs. investments in hydropower, etc.). Investment in irrigation could benefit most from optimizing production in terms of locating crop production where maximum yield per unit of water is possible (crop, agro-climatic zoning). Such planning can be rendered possible only when such planning is done cooperatively i.e. in a regional, basin-wide context.

- **Coordinated dam operations**

If the potential of ENB hydropower dams is to be fully realized, their operation needs to be coordinated. This in turn requires putting in place the requisite technical, institutional, and legal enabling conditions for such coordination, on a priority. Ensuring the safe operation of the dams likewise requires a priority focus. Coordination of the operation of dams is a must if conflicts among uses (such as between irrigation and hydropower generation, or environmental flows, or flood protection) are to be avoided. Also, countries need to build national and regional capabilities to manage flood and drought events effectively (e.g. flood/drought forecasting, early warning, real-time data and information exchange, etc.), and coordination of dam operations is a critical part of such planning. Investing in efficient coordination mechanism of cascade operation thus has many-fold returns, not only in optimizing water use and increasing efficiency, but also in terms of avoiding potential conflict among countries and building regional peace and confidence.

- **Environment and social measures**

The Nile supports not only vibrant socio-economies but also critical ecosystems and biodiversity of global significance. ENB water resources investment promotion can and needs to be done in a responsible manner, so as not to threaten these critical ecosystems and habitats as well as wetlands, national parks, biosphere reserves and protected areas. This requires that environmental flow requirements are better understood and maintained, that wetlands are better mapped, their functions and dynamics better understood, and better managed overall. Delta management and salinity control should constitute part of the consideration of environmental flow and ecosystems conservation.

- **Ground water**

Considering the likely water scarcity the ENB is likely to face, the conjunctive use of groundwater with surface water for irrigation, drinking water and livestock, is critical. What is limiting the pursuit of this potential, however, has been paucity of data on ground water, and hence the first step to setting up an effective planning and management framework for groundwater use is a monitoring network and studies to assess the quantum and quality of groundwater in different parts of the ENB.

- **Watershed Management**

Many large water infrastructures (dams and irrigation schemes) have been performing poorly, delivering economic, social and environmental returns below their design, because their construction and operation has not been accompanied by watershed management including arresting land degradation and erosion, afforestation, improved land management) around these huge and expensive infrastructures. Land degradation and the huge sedimentation rates that result render existing schemes inefficient and will similarly affect new ones. Focused watershed management thus needs to be accorded priority, not only to rehabilitate degraded watersheds, but to restore also threatened livelihoods as well. ENSAP has already pioneered and piloted successful watershed interventions and these need to be re-evaluated and scaled up.

- **Optimization of Water Resources use for Enhancing win-win Opportunities**

Determine optimal planning and management of the EN that will yield highest net benefit to each country under historical as well changing climate; determine alternative storage allocation schemes for operation under severe drought condition to enhance water availability for all uses in the system; define drought conditions (indices) that will trigger different operation paradigms.

- **Water resources data and information**

Two major short-term limitations of investment planning are the availability of reliable, long-term hydrological, environmental and socio-economic data; and the technical capacity to generate the necessary analytic and modeling tools to be agreed and adopted by all countries. Hydro-meteorological, sediment, ground water, flood, etc. data and information generated on the basis of actual measurements on-site and validated will be needed to ensure that investment planning is well-informed. Countries will hence need to put in place flow gauging and hydro-metrological stations in important reaches of the ENB; real-time information and data sharing protocols, mechanisms, and agreements; as well as data processing and analytical models and toolkits.

Chapter 1

The Eastern Nile Basin: Background and Context

1. The Eastern Nile Basin: Background and Context

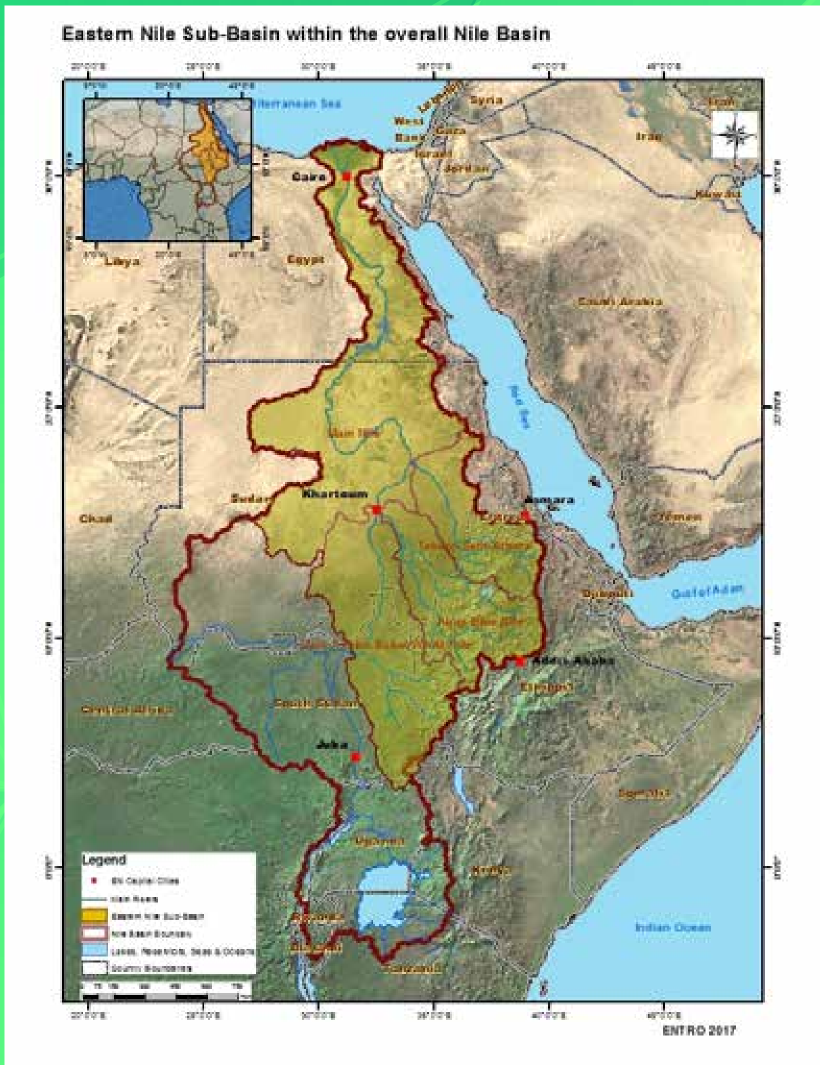
The Eastern Nile Basin (ENB) is home to more than 150 million people and includes parts of Egypt, Ethiopia, Sudan and South Sudan.[1] It covers some 1.7 million square kilometers and comprises four sub-basins: the Baro-Akobo-Sobat-White Nile, the Abbay-Blue Nile, the Tekeze-Atbara and the Main Nile from Khartoum to the Nile delta (see Figure 1.1).[2]

The ENB has been the site of the some of the most advanced civilizations of the ancient world. The annual Nile flood that carried fertile sediment from the Ethiopian Highlands transformed the deserts of Sudan and Egypt into rich agricultural lands along its course. Apart from the main Nile river itself, the ENB encompasses an extraordinary range of ecosystems from high mountain moorlands, montane forests, savanna woodlands, extensive floodplains, wetlands semi-arid plains and arid deserts.

Within the ENB, although the Nile river provides the basis for sedentary agriculture, power generation, and transport, most of the people in Ethiopia, Sudan and South Sudan are rural, depending largely on the natural resource base for their livelihoods, while in Egypt nearly half the population is urbanized.

The richness of the natural and human resource base, notwithstanding, the basin's peoples face huge challenges:

Figure 1.1: The Eastern Nile Basin and sub-basins



[1] In 2010, according to the United Nations Population Division, around 83 million of the 85 million population of Egypt lived in the ENB, while Ethiopia's share was 34 million (out of a total of 85 million), Sudan's was 32 million (out of 34 million) and South Sudan, 3.5 million (out of 11 million).

[2] See Annex 1 for a detailed description of river systems, catchment characteristics, areas and populations of each of these sub-basins

The incidence of poverty is high, and with high population growth rates the pressure on the natural resource base and ecological systems is enormous and increasing. Poverty reduction efforts are constrained by land degradation, underdevelopment of water resources, high sediment loads and consequent sedimentation of dams and irrigation canals, the loss of products and services provided by forests and wetlands, and the overgrazing of rangelands and declining biodiversity. The vulnerability of people's livelihoods in the ENB is further threatened by the looming threat of climatic change and the potential negative impacts on increasing variability of rainfall.

Photo istock/NBI

1.1 The Eastern Nile Basin Context

With the Eastern Nile Basin comprising almost half of the 3.4 million square kilometer catchment area of the Nile River Basin and contributing much more than half of the runoff to the Main Nile,[3] water is both a central challenge and opportunity. Rapid population growth, severe land degradation, and lack of adequate storage infrastructure are among the key challenges that has hindered development in the ENB. These are briefly outlined below, under five headings: (a) Water management issues; (b) social and environmental issues; (c) agriculture and irrigation; (d) fisheries, and livestock; (e) electricity and public service infrastructure.[4]

1.1.1 Water Management Issues[5]

Growing demand on the Nile and rising vulnerability to climate change

The Nile is water-scarce compared to major international rivers and faces growing demand, due to population growth, rapid urbanization and growing irrigated agriculture demand. Apart from geographical variability, there is a high degree of seasonality in annual and inter-annual variation in rainfall and temperatures across the Eastern Nile basin, as the river Nile flows from the Ethiopian highlands through the Sahara desert to Egypt. The high spatial and temporal variability in rainfall across the Eastern Nile basin equally highly variable river flows and runoff resulting in frequent extreme events such as droughts and floods, which in turn affect agriculture and livelihoods in both rural and urban areas. This vulnerability is poised to be worsened by future climate change. However, the understanding of the hydrology in many parts of the sub-basin is limited and there is urgent need to improve knowledge in these areas through further studies and improved data collection (especially in groundwater).

Inadequate water storage and high evaporation

Coping with extreme events and ensuring steady water supply, given high temporal and spatial rainfall variability requires adequate storage, so that surplus water from abundant rainfall years (or from places with abundant rainfall) can be stored and used after the season and during rainfall scarce years (or in rainfall scarce places). This notwithstanding per capita sstorage in the basin is low by world standards.

Further, there are high levels of evaporation from both man-made reservoirs (estimated to be almost 20 BCM annually)as well as natural lakes, wetlands and river channels (estimated at 20-23 BCM annually). The high evaporation losses from dams can be mitigated by locating storage in parts of the basin with least evaporation loss (e.g. in cooler highland regions of the basin). This however requires strong

[3] The White Nile which flows from Lake Victoria makes a much smaller contribu3tion not only because most of the 100 billion cubic meters (BCM) of rainfall that falls annually on Lake Victoria evaporates but also because only about 15 BCM of the substantial flows from White Nile tributaries (such as the Bahr-el-Ghazal) emerges from the Sudd, Africa's second largest wetland (MSIOA, 2014a),

[4] Detailed analysis is available in Annex 1, drawing on MSIOA (2014a),

[5] Details are in Annex 2 and Annex 3.

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basin-wide cooperation. Also, the hydrology of wetlands is not understood well enough to prescribe methods to utilize or reduce evaporation from these areas as wetlands provide critical ecosystem and environmental services for wild life and livestock and any intervention in their functioning requires careful planning.

Frequent extreme events: droughts

Although the period from 1950 to 1988 saw 18 droughts some leading to serious famines in Ethiopia, the worst was during 1984-5 when hundreds of thousands starved to death and images of dying children burned itself into the collective memory of the world.[6] Ethiopia also faced a devastating drought in late 2015, occasioned by an El Nino weather phenomenon that disrupted rainfall patterns: By December 2016, around 10 million people were estimated to be in need of US$ 1.4 billion in food aid, with 400,000 children severely malnourished, overwhelming the Government's Safety Net program that was supporting around 8 million people.[7] Egypt has also been drought-prone since time immemorial, due to very low levels of the Nile. Historically deaths and famine have followed the lack of water for irrigation that badly affected agriculture. In 1913-14, for instance, Egypt suffered one of its worst droughts in recorded history (since 1695), while dry years in 1979-84 coincided with the drought in the Sahel that extended to Ethiopia and the Sudan.

Frequent extreme events: floods

Average annual flood damage due to floods in the Eastern Nile Basin is estimated to be US$ 25.77 million in rural settlements riparian to the Blue Nile and the Main Nile in the Sudan, and US$ 5.54 million in the Fogera and Dembiya floodplains adjoining Lake Tana in Ethiopia. Flood impacts include deaths, the displacement of large numbers of people, damage to infrastructure, loss of crops and agricultural land, damage to agricultural inputs and equipment (e.g., seeds and pumps), water logging and associated deterioration of health conditions due to the increased incidence of malaria and other water-borne diseases, and the disruption of social services and public goods (e.g., education, health, safe water supply and sanitation). Nearly 1 million people live in flood-prone areas around Lake Tana, while around 100,000 are in high-risk flood prone areas near the Blue Nile and Atbara rivers. The 1988 flood in Sudan is still vivid in the memories of many people so much so that flood levels frequently are compared to the levels in that year. The serious floods in 1988 were the first of a series of high floods to affect the country. These floods were caused by both riverine floods and flash

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[6] History of droughts and famines in Ethiopia (2015), Available at http://www.progressivegardening.com/soil-moisture/history-of-droughts-or-famines-in-ethiopia.html

[7] The Washington Post, 'History repeats itself in Ethiopia', 22 February 2016. Available at http://www.washingtonpost.com/sf/world/2016/02/22/history-repeats-itself-in-ethiopia/

floods. There is also great variability across the basin: While the High Aswan Dam (HAD) has completely protected Egypt from flood damage, areas like the Baro-Akobo-Sobat sub-basin still continue to suffer periodic flooding events, which are not well documented or publicized.

Reducing yields and lifetimes of water infrastructure due to sedimentation

Most of the sediment in the ENB originates from the Ethiopian Highlands, with highest sediment concentrations during the rising flood waters from late July to early August. The average specific sediment yield rate of the Eastern Nile basin is 90000 tons/ year (Shenkut, 2006), resulting in high rates of sedimentation of river channels, reservoirs and irrigation canals, reducing their storage or carrying capacities and shortening their service lives. High sediment loads in streams also pollute drinking water and raise maintenance costs of various water management infrastructure/structures. Sediment has reduced the lifetimes of major reservoirs: The Sennar is estimated to have lost 66% of its capacity, the Girba 60% and Roseires 30% (Ahmed, 2006).

Deteriorating surface water quality

Watershed erosion and heavy sediment load during the flood season cause high turbidity and suspended solids in the Nile River, making the water unsuitable for domestic use and drinking purposes – which is a major problem since several areas and cities in the Eastern Nile depend on the Nile system for their drinking water). The discharge of untreated or partially treated industrial and domestic wastewater, leaching of pesticides and residue of impurities associated with navigation, petroleum exploitation and mineral mining affect the quality of water in the Nile river systems., especially in Egypt downstream of Aswan. Egypt faces a rapidly increasing deterioration of its surface (and ground) water due to increasing discharge of heavily-polluted domestic and industrial effluents into its waterways, and also due to high use of pesticides and fertilizers in agriculture.

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The threat of increased water-logging and salinity

The widespread use of flood irrigation, the discharge of salt-laden drainage water into the Nile River and poor drainage has led to water logging and consequent increase in soil salinity. Studies show that salinity in drainage water increases closer to the Mediterranean sea (to about 10,000 mg per liter), partly caused by leaching of salts from the soil but mostly by the upward seepage of brackish groundwater. In addition, studies have predicted that sea level increases in the Mediterranean sea could lead to increased flooding and saltwater intrusion along the 950 km long Mediterranean coastline in Egypt. The three main causes for sea water Intrusion could be reduced freshwater flow in dry seasons, increasing water withdrawal for irrigation and sea level rise due to climate change.

1.1.2 Agriculture and Irrigation[8]

Major economic driver but agriculture does not provide food and nutrition security

Agriculture is the backbone of most of the countries of the ENB, contributing the most to GDP, employment and exports. All these countries consider irrigated agriculture as the major driving force for enhancing food and nutrition security and alleviating poverty and are intent on increasing the contribution of the agricultural sector in their economies.[9] None of these countries, however, are able to grow adequate food to meet the demands of their growing populations and have to rely on food aid

[8] Details are in Annex 4.

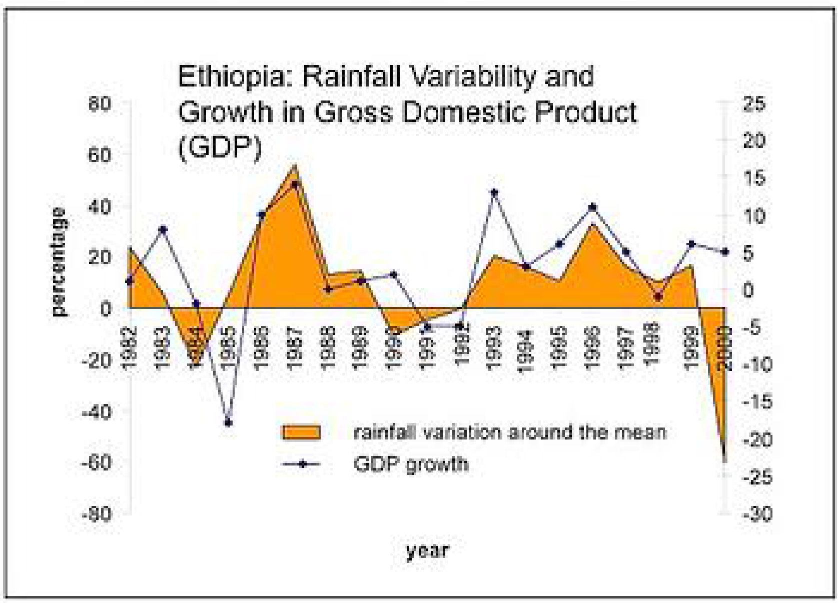
[9] While Agriculture in Egypt is the most important productive sector in the economy, providing 20% of GDP, 34% of total exports, 32% of the labor force and much of the Egyptian food supply.

or imports to meet a significant portion of their domestic food requirements: The Ethiopian economy has been too weak to purchase food on the international market and many Ethiopians are too poor to buy food even when it is available; South Sudan imports as much as 50% of its requirements from neighboring countries, particularly Uganda and Kenya; Sudan has to import a substantial amount of food annually to fill the gap between demand and supply; and food imports in Egypt reached USD 10 billion in 2012 (Nour, 2013).

Vulnerable rain-fed smallholder farms

Rain-fed agriculture is dominant in upstream and midstream countries of Ethiopia, South Sudan and Sudan. In Ethiopia, nearly 12 million smallholder households contribute nearly 95 per cent of the agricultural GDP of the country (Ministry of Agriculture, 2014). In Sudan, over 90% of the cultivated area is rain-fed and traditional flood recession agriculture has been practiced for centuries using the annual flood waters of the Nile. Despite the huge potential for rain-fed agriculture in these countries (over 95% of the total area of South Sudan, for instance, is considered suitable for agriculture), however, production levels are low largely due to the fact that this is largely subsistence smallholder cultivation with low levels of inputs and extreme vulnerability to climatic variability. Ethiopian GDP

Figure 1.2: Ethiopia: Rainfall variability and growth in Gross Domestic Product (GDP)



growth, for example, is strikingly vulnerable to rainfall variability (see Figure 1.2 below).

Irrigation is key to agricultural production and productivity increases but faces limits

Irrigation is seen as a major vehicle for boosting agricultural production and productivity; and enhancing food and nutrition security in the ENB countries. Ethiopia has huge water and land potential for irrigation development, although only 3% of cultivated land is estimated to be under irrigation, but despite better yields (2-3 times) than on rain-fed farms, yields on irrigated farms are still low. South Sudan also has extensive land and water resources, as revealed in the 2015 Republic of South Sudan Irrigation Development Master Plan (IDMP), a study that has determined the country's water resources and irrigation potential. Yet, only two irrigation schemes exist in the country, covering just 42,500 hectares, but require heavy rehabilitation. In Sudan, irrigated agriculture covers only about 10% of the total cultivated area; and it contributes more than half the total volume of agricultural production. But its importance has significantly increased due to drought and rainfall variability, causing uncertainty in rain-fed farming, particularly in the last few decades – but there has been no major expansion after the 1970s. Egypt's 3.4 million hectares of cultivated area is irrigated (except for some rain-fed areas in the Mediterranean coast and in north Sinai); cropping intensity is 180% on average; and there are limits to expanding irrigated agriculture further.

Ambitious future plans for irrigated agriculture but not enough water

Irrigation development is a priority in all the EN countries and is considered an effective vehicle to mitigate the impacts of climatic variability, enable rural development, and enhance food and nutrition security. The total area of planned expansions in the three sub-basins of the ENB in Ethiopia totals 1.59 million hectares (out of a total cultivated areas of 15.5 million hectares now under rain-fed agriculture). Planned irrigation schemes in the Sudan total around 2.2 million hectares in the three EN sub-basins, which is more than double the existing area under irrigation (1.9 million hectares). Egypt plans on a 'horizontal expansion' of irrigation schemes, to the extent of 1.12 million hectares. But the Egyptian National Water Resources Plan 2017 estimates that rising demand from industry and municipalities is expected to decrease water availability for irrigation from 11,400 cubic meters/hectare (cum/ha) in 1997 to 8,100 cum/ha in 2017. South Sudan views irrigation as the key to increasing future agricultural production and improving food and nutrition security; and plans to put 415,128 ha under irrigation development/production by 2040. But the future expansion of irrigated areas all across the basin faces two critical and limiting constraints: funding to meet the high investment cost of new irrigation schemes; and water scarcity – i.e. whether there will be enough water in the River Nile to satisfy the future national-level plans of all the ENB countries.

1.1.3 Social and Environmental Challenges[10]

High population growth rates, especially of the rural poor

A large proportion of the populations of the four Eastern Nile basin countries fall within the basin, except for Ethiopia (Figure 1.3 and Table 1.1). Medium term projections show that the populations of the four ENB countries will increase from around 215 million to about 305 million by 2030 (see Table 1.1). A majority of the population in these countries were rural in 2010: South Sudan 83%, Ethiopia 82%, Egypt 57%, and Sudan 55%). Although these proportions are estimated to decrease over time, given the limited level of infrastructure de-

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[10] Details are in Annex 3.

Figure 1.3: Population living in the Eastern Nile Basin, 2015

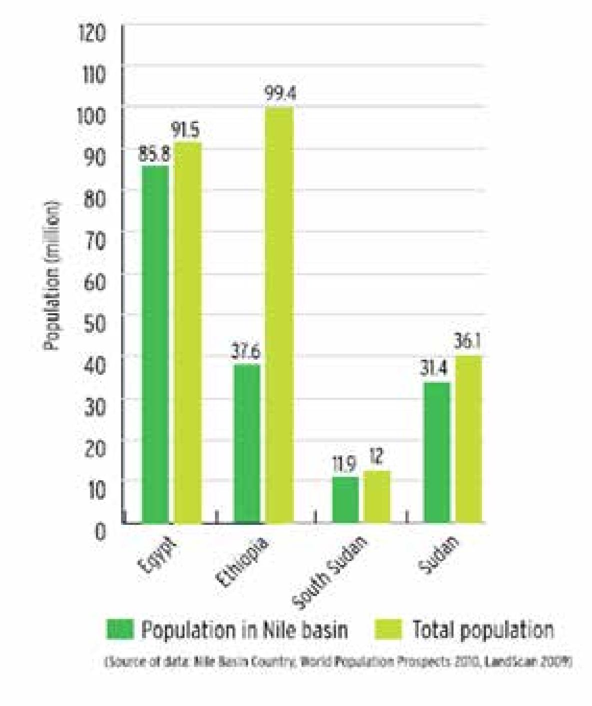

Table 1.1: Population data for the Eastern Nile Basin countries (millions)

Population Estimates	Egypt	Ethiopia	South Sudan	Sudan	Total
Crent Total (2015)	91.5	99.4	12	36.1	239
Crent Total in Eastern Nile Basin	85.8	37.6	11.9	31.4	166.7
Proportion of population in the Eastern Nile Basin(%)	94%	38%	99%	87%	70%
Midium-term Projected Total(2030)	111	132	17	46	306
Current Rural Proportion (2010)	57%	82%	83%	55%	-
Medium-term Projected Rural Proportion (2030)	50%	73%	NA	39%	-

velopment, the majority of the populations in these countries is likely to remain rural. Also, a large proportion of this population lives below the poverty line, and being agrarian, are intimately dependent on the natural resource base for their livelihood and for food and nutrition security. A growing population will not only increase the demand for water resources, but will also affect food and nutrition security levels, given that the majority of the large rural populations cannot afford food imports.

Poverty, natural resource base degradation and social conflicts thereof

The NBI State of the River Nile Basin Report (2012) notes that increasing population pressure and demand for land are projected to result in encroachment into nature reserves which, in turn, will impact the functioning of natural ecosystems. Population growth will also result in the fragmentation of agricultural holdings, settlement on marginal lands and rising landlessness. As a result, tension over access to and use of natural resources such as water, arable land and grazing is likely to intensify and create the potential for local conflicts. Such conflicts are already widespread in the ENB and local authorities will come under growing pressure to provide improved services such as clean water, sanitation, health and education to scattered rural settlements. Failure to improve rural livelihoods will perpetuate poor living conditions and accelerate rural to urban migration with marginalized and landless people moving to larger towns and cities in search of work, better services and better education opportunities. This will place growing pressure on towns and cities in the ENB. There is also a growing incidence of inter-ethnic, inter-community and sub-group conflicts, triggered and aggravated by a multiplicity of contributory factors, but mainly over shared natural resources

Land degradation and declining agricultural productivity

Soil fertility in the ENB is declining due to land degradation. Basins, catchments, watersheds are the interface between land and water management. Poorly managed catchments ultimately lead to land degradation and the ensuing soil erosion (sheet, gully and river bank) which in turn leads to loss of agricultural productivity, declining livelihoods and increasing poverty in rural areas whose economy is natural resource based. Further, the use of traditional and inefficient irrigation techniques and the inadequacy of drainage systems have increased salinity and water logging in some parts of the ENB. In the

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Ethiopian Highlands, the burning of dung, removal of grain harvest byproducts and soil erosion are key reasons for land degradation. Removal of land cover, high rainfall and steep slopes in the upper part of the basin are believed to cause severe soil erosion hazard, affecting nearly 40% of the basin.

Deforestation and degradation of woody biomass

Deforestation (a sudden and complete clearing of biomass): Large areas of forest have been altered in the ENB, for human settlement and agriculture. Around 32,300 hectares of high forest and 67,700 hectares of woodland is estimated to be cleared annually for agriculture and settlement, while another 29,100 hectares of high forest (between 1,100 and 1,900 meters above sea level) is estimated to be cleared annually for coffee cultivation (CRA Watersheds, 2007, p. 16). Some disturbed forests remain in few areas as National Priority Forests; and very few primary forests remain (either on the steepest slopes where agriculture is not feasible or within national parks and game reserves). Thus the situation has become critical with level of exploitation and uncontrolled burning, exceeding the rate of forest growth. War conditions have led to the destruction of plantations through unauthorized felling of trees: official figures on government plantations in the lower altitudes reveal that 85% of the teak plantation has been damaged.

Degradation (the gradual and partial removal of woody biomass, e.g., for fuel wood and charcoal): Population growth with concomitant increases in demand for agricultural land and pasture, long droughts and flooding and high winds have increased fuel wood harvesting beyond their regenerative capacity. 20 million tons of wood is estimated to be unsustainably harvested as fuel wood and charcoal in the ENB, causing other un-quantified losses in terms of non-timber forest products (fruits, medicinal products, gums and resins, etc.) and biodiversity (ibid). Overgrazing and gathering of shrubs for domestic animals, and the hazard of fires has caused severe reductions in wildlife habitats, particularly in the more densely populated higher and cooler altitudes where few large animal habitats remain intact.

Loss of biodiversity

The Dinder, Alatish and the Boma-Gambella National Parks are home to the only remaining endangered species besides having a high diversity of flora and fauna. These areas are under threat from rising numbers of pastoralists, agro-pastoralists and internally-displaced people (especially in the Dinder and Boma), with concomitant increases in poaching, fishing, fuel wood collection, honey collection and illegal hunting. Constraints to effective management of these areas include a lack of management plans, inadequate infrastructure and research capacity, and insufficient staff, awareness and finance. Populations of a wide variety of wildlife in the Abbay/Blue Nile sub-basin, including the Walia ibex, the Ethiopian wolf, the Gelada Baboon and the Mountain Nyala, are on the decrease due to anthropogenic pressures. The Alatish National Park contains 180 bird species and 48 mammal species (including such endangered species such as loxodonta Africana, panther pardus and panther leo). The 890,000

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hectares of the Dinder National Park not only preserves a migration corridor for but is home to over 160 species of birds, 27 species of large mammals (including some animals of international conservation importance such as lions, the African Elephant and the African buffalo) and an unknown number of small mammals. Annual records show a continuous decline in the population size of nearly all species. Egypt has an estimated 18,000 species of flora and fauna but its biodiversity is under threat from intensive chemical-based agriculture, pollutants from rapid industrialization, excessive hunting of animals and destruction of plant life. In order to design effective intervention to reverse biodiversity loss, there is the need to quantify the rate and extent of ongoing biodiversity loss.

Degradation of wetlands

The abrupt change in gradient of highly seasonal rivers like the Dinder, Rahad and their tributaries in the Ethiopian Highlands have caused a large number of 'cut off meanders' called maya'as. These are generally flat and cover an area of 0.16 – 4.5 square kilometers which are filled during the rainy season. The maya'as provide valuable source of water and forage for domestic livestock and wildlife as well as unique habitats rich in biodiversity. With the accelerated erosion in the Ethiopian Highlands, the gradual and long-term evolutionary processes of maya'a formation and development (young maya'as are deeper with clear water, which become gradually silted up till they become non-productive dry maya'as and new ones are formed) has been disturbed and the annual flooding in the area is causing many of the maya'as to become silted up quicker, with consequent loss of habitat biodiversity and forage productivity. Increasing rates of sedimentation of the maya'as also reduces their flood buffering capacity leading to higher flood peaks which cause extensive crop damage.

The wetlands of the Pibor sub-basin support very distinctive flora and fauna uniquely adapted to conditions in the swamps – but there is inadequate information on the ecology and biodiversity status of this sub-basin. This is also the case in relation to the major Baro-Akobo-Sobat wetlands of Machar marshes, which are presently exposed to oil exploitation disturbances and pollution. The Dinder National Park is a designated Biosphere Reserve and has been designated as an international wetland under the Ramsar Convention. Nevertheless, with exponentially increasing population pressure, exacerbated by in-migration, large wetland areas are being converted to small and large-scale agriculture. Proposed plans for hydro-power and irrigation, and around 30 years of civil war, will have (had) significant impacts on flow-regimes and sediment loads to these wetlands. The Lakes in the Main Nile sub-basin (Manzala, Burullus, Edku and Qarun) support productive fisheries. Salinity in the Qarun lake is on the rise and by 2020 it could become another Dead Sea.

Increasing incidence of water-related diseases

A major concern in the southern parts of the ENB is the increasing incidence of malaria, which is difficult to control and has the potential to infect a very large population in epidemic outbreaks. Other epidemics and disease outbreaks due to water-borne or water-related pathogens have plagued most areas of the ENB throughout history, including schistosomiasis; typhoid; diarrhea; helminthiasis; leshimaniasis; onch ocerchiasis; salmonella; shigella; cholera; hepatitis; gastroenteritis; and poliomyelitis in the last 50 years.

1.1.4 Fisheries and Livestock[11]

Widespread fishery activities with huge potential but development is constrained

The fisheries sub-sector is an important source of cheap proteins for poor communities and a major economic activity for those living around major lakes, wetlands, and reservoirs in the ENB, along the River Nile and in coastal areas. But the present rate of fishing in many of the natural water bodies in the ENB is excessive and fish stocks are decreasing because of over-fishing. The huge potential for aquaculture in the inland freshwater bodies of Ethiopia, South Sudan and Sudan face numerous constraints: lack of a commercialized approach, inadequacy of trained personnel and experience in modernized fishing; lack of fishing equipment and vessels; high post-harvest losses (from improper handling at source and during distribution), lack of adequate research, technology and extension services; and a lack of support infrastructure such

[11] Details are in Annex 5.

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as access roads, landing and onshore processing facilities such as cold storages. Aquaculture in the Egyptian portion of the basin, however, is well developed (with a targeted harvest of 1 million tons by 2017), and lessons from this experience could be scaled up to the other EN countries.

Growing constraints on livestock rearing

Livestock is a critical subsistence and economic activity in all the EN countries, the region being home to the largest livestock population in Africa. It is a major means of livelihood, especially for pastoralists and agro-pastoralists (living in the semi-arid areas of Ethiopia, Sudan and South Sudan). Livestock potential in the region has not yet been fully exploited due to a number of constraints including: technical factors, such as genetic limitations for production, inadequate and ever shrinking and poor quality of feed (due to grazing land conversion into agriculture), shortage of drinking water supply for cattle; institutional factors such as poor linkages between research, extension and technology users, inadequate extension and training services, unreliable markets and lack of access to credit, limited and irregular access to appropriate health services (which themselves have poor facilities); socio-economic factors including poor availability of adequate grazing land (due to shrinking of rangelands, recurrent drought and inter-sectoral conflict), insufficient forage during the dry season and reluctance of pastoralists to commercialize cattle because of their social importance and lack of alternative assets; and governance-related factors, including the absence of clear strategic policies and legislation aimed at supporting and promoting the sub-sector and the limited involvement of the commercial sector.

1.1.5 Electricity and Public Service Infrastructure[12]

Growing demand, limited supply in the midst of significant HP potential

Regional and national electricity demand is growing rapidly. Currently in Ethiopia only 17% of population has access to electricity and even so, peak demand was forecasted to surpass installed capacity by 2015; in South Sudan currently, only 1% of the population has access to electricity and electrification is limited to major cities provided by diesel generating units using expensive fuel – and imports electricity, in a limited way, from Sudan; and Sudan itself needs to import power if it has to meet current demand. Only Egypt has installed generating capacity greater than peak demand, but only by a small margin. Currently, regional electricity demand can only be met by increasing capacity and by sharing or trading power through an expanded interconnected network. The latter will require strong regional cooperation between the eastern Nile basin countries.

Ethiopia is well endowed with huge hydropower resources as well as a significant geothermal potential for the generation of electricity. The economically exploitable potential is estimated at 45,000 MW – which is several times the 2012 generation capacity of around 2000 MW. The new Expansion Plan anticipates to add by 2023 a further 12,414.9 MW to the already existing and under construction total of 10,237 MW, which will bring the total to 22,651.9 MW, necessary to face the rapidly increasing demand (EEPC, 2013). South Sudan also has large hydropower potential on Bahr el-Jebel (towards the border with Uganda) within the Nile Equatorial Lakes basin, while there is also potential for small hydropower development all over the country. Sudan will have commissioned the 350 MW Upper Atbara scheme in December 2016, while several other dams are being planned. Ethiopia has procured the finances necessary to begin exploiting the hydro-

[12] Details are in Annex 6.

power potential in the Basin, especially with the Great Ethiopian Renaissance Dam (GERD). Currently there are six large hydropower dams along the Blue-Nile Main Nile in the Eastern Nile Basin under construction and more are planned to be built. This will require ensuring their safety (over 150 million people downstream these dams) and coordination of their operation, if hydropower generation is to be optimized and enhanced.

Public services and infrastructure are poor

Social infrastructure and public goods and services are not well-developed in the basin, in terms of road networks, water supply and sanitation facilities, health and education services, provision of credit and extension services, etc., all of which affects the quality of life of citizens and thus the capacity of the current and future workforce in these countries. Another factor to consider is the deleterious effect of the protracted civil wars that consumed northern Ethiopia (in the 1970s and 1980s) and South Sudan (in the 1980s, 1990s and currently) on social infrastructure and services, which are only now being reversed. Services in the Main Nile sub-basin, however , are the best in the Basin.

With the exception of Egypt and some major cities in the other countries, the provision of and access to safe and adequate water supplies and sanitation (liquid and solid waste management facilities) is low or absent in most parts of the Basin. The Nile is the main source of drinking water for majority of the populations that live along the banks of the Main Nile in Egypt and Sudan. In Sudan, 87% and 62% of the households in the Northern State and Nile Regions have access to safe water that are concentrated along the Main Nile. In Egypt 98% of the population have access to safe water. Sanitation, similarly, is best in northern Sudan and Egypt, which means meeting the demand for drinking water supply, sanitation and waste generation will put more pressure on the Nile water resources, both in terms of quantity and quality.

1.2 Nile Basin Initiative

The precarious state of water resources, the vulnerability of such a sizeable population to the variability in rainfall and run-offs/flows; and the looming future threats of a burgeoning population, urbanization, industrial pollution and climate change prompted the formation of the Nile Basin Initiative (NBI). The NBI is a partnership among the ten riparian states of the Nile River - Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda – that seeks to develop the river in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security. The NBI started with a participatory process of dialogue among the riparian countries that resulted in an agreement on a shared vision, namely, to "***achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources***", followed by a Strategic Action Program to translate this vision into concrete activities and projects. It is led by the Nile Council of Ministers (Nile-COM) assisted by a Technical Advisory Committee (TAC) and a Secretariat (Nile-Sec) based in Entebbe, Uganda. The subsidiarity principle, among others, has been adopted to enable countries to leverage unique sub-basins potential and address equally their unique management challenges.

The NBI has a strategic action program comprising two sub-programs: a basin-wide Shared Vision Program (SVP) and a Subsidiary Action Program (SAP) to promote cooperation at the sub-basin level. The SAP comprises the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) and the Eastern Nile Subsidiary Action Program (ENSAP).

The Eastern Nile Subsidiary Action Program (ENSAP) of the NBI was launched by Egypt, Ethiopia and the Sudan (with South Sudan joining in 2012) to initiate concrete joint investments and action on the ground in the Eastern Nile sub-basin in the areas of power generation and interconnection, irrigation and drainage, flood preparedness and early warning, watershed management, development of planning models and joint multipurpose programs. ENSAP is governed by the Eastern Nile Council of Ministers (ENCOM) assisted by a ENSAP Team (ENSAPT); and implemented by the Eastern Nile Technical Regional Office (ENTRO), based in Addis Ababa, Ethiopia. ENSAP receives its funding from the Eastern Nile countries and also from a range of bilateral and multilateral development partners.

The Integrated Development of the Eastern Nile (IDEN) was the first ENSAP project, agreed in 2002, with an initial set of seven sub-projects aimed at tangible win-win gains in the areas of watershed management, flood preparedness, early warning and response, irrigation and drainage, power supply interconnection and regional power trade and later the Joint Multipurpose Program [JMP]. These projects have been successfully completed An ongoing effort based on the results of IDEN (particularly the Watershed Management, the Irrigation and Drainage Studies and Power Trade Studies Cooperative Regional Assessments) and additional new studies to identify a second round of ENSAP Investment Projects has been supported by the World Bank under the Nile Cooperation for Results Project (NCORE Project).

The Nile Cooperation for Results (NCORE) Project is the first phase of the Nile Basin Climate Resilient Growth Program and is part of the 5-year NBI Strategic Plan. As part of implementation of the projects identified in the Strategic Plan, NBI applied for funding from the World Bank –administered Nile Basin Trust Fund (NBTF) and the World Bank-funded Cooperation in International Waters in Africa (CIWA) to support the three NBI centers – the Nile-SEC, the NELSAP Coordination Unit (NELSAP-CU) and ENTRO.

The Eastern Nile Multi-Sectoral Investment Opportunities (EN-MSIOA) study is one of NCORE-funded ENSAP studies to support identification of new round of Eastern Nile Projects using resources studies from the IDEN projects (e.g. from the Cooperative Regional Assessments of the Watershed Management; Irrigation and Drainage and Power Trade Studies) and additional new material.

1.3 The Multi-Sectoral Investment Opportunity Analysis Study

1.3.1 Study Rationale

Since 2002 ENTRO conducted several studies for various ENSAP Projects including the Cooperative Regional Assessment (CRA)[13] of Watershed Management, Power Generation and Interconnection, Irrigation and Drainage, and the Joint Multi-purpose Project, that reached key conclusions:

- **Water resources:** Uncoordinated planning of expansions without basin wide, "no-borders" analysis (i.e., a basin-wide perspective) for irrigation development in the EN can have serious impacts, including sub-optimal development and resource use inefficiency, especially given the water scarcity that the basin is likely to experience in the future, due to increasing climatic variability.

- **Hydropower:** There is huge untapped hydropower potential in the ENB which could be unlocked with a coordinated investment strategy in power generation and trade.

- **Watershed management:** The degradation of the ENB natural resource base can have serious downstream costs, including high sediment loads from the uplands increasing the costs of reservoir and channel dredging, loss of hydropower generation during peak flood seasons when gates have to be opened to release flood waters carrying high sediment loads. The estimated cost of such degradation was around US$ 670 million per year (in 2007) projected to reach US$ 4.5 billion by 2030 – but sustainable and integrated watershed management interventions (costing US$ 4.6 billion) can yield net benefits of more than US$ 13 billion.

Although all these studies provided valuable information, neither their analyses nor their findings have been integrated across sectors to yield direction for wider basin-level water resource optimization and efficiency. Currently, therefore, there is absence of a region-wide assessment of where the challenges lie, and what can realistically be achieved, given the available resources, and especially water resources, in the Eastern Nile region. Three clear conclusions that arise from this situation are the following:

- Un-coordinated water resource investment planning does not consider trans-boundary dimensions (e.g., plans of other countries, upstream-downstream impacts, etc.)

[13] The CRAs used a regional, consultative and deliberative process to validate and agree upon study findings and courses of action.

- Aggregate basin-wide water resource requirements of current and planned investments exceed the available water in the Nile
- Regionally optimized investment planning is required to address the mismatch between water demand (by planned investments) and water supply (from the Nile)

A multi sector investment assessment of existing opportunities is thus needed to identify a coordinated water resources investment strategy for the Eastern Nile Basin that promotes shared, economic growth and development while sustaining the Eastern Nile environment.

1.3.2 Study Objective

The MSIOA aims to draw on (and update as needed) ENTRO's past work across different sectors in order to undertake a basin-level analysis of water resources that would promote (1) sustainable management of the common Eastern Nile water resources and (2) cooperative investment planning, that take into account the water scarcity of the basin and the social, environmental and economic implications of such investments.

1.3.3 Study Limitations

In addition to limitations of budget and time constraints, the major limitations of the study are the following:

- **Outdated data and information from IDEN Projects**: The first round of studies undertaken by ENTRO as part of the IDEN projects provided the data and information for the current study. These were completed between 2007-2010, and are in urgent need of updating.
- **Incompleteness/lack of relevant data and information in South Sudan.** Many of the water and development related institutions in South Sudan are either relatively new or not yet in place, as is also the case for the related planning tools including policies, development strategies and plans, etc. As a result, some assumptions have been made and updating of some parts of the MSIOA will probably be required when more detailed information on development plans for South Sudan becomes available.
- **Dated baseline data on environmental and socio-economic issues.** There was little opportunity to update existing ENTRO resources such as the One System Inventory (ENTRO, 2007) and data used in the CRAs, that would have been most useful in assessing the social, environmental and economic tradeoffs among alternative pathways of basin-wide optimized water resources investment options. .
- **It was not possible to carry out the planned consultations in Egypt**. As a result, while potential impacts on flows and activities downstream have been taken into account in the various analyses, it was not possible to consult potential stakeholders in Egypt.
- **Factoring in potential climate change impacts.** The data from available global and regional climate change models are only being analyzed at ENTRO after the MSIOA study was commissioned and it was therefore not possible to include these in the MSIOA study.
- **Inability to include new information from ongoing ENSAP studies:** The ENTRO study of the Baro-Akobo-Sobat sub-basin was not completed and thus its findings unavailable for this study.
- **Insufficient attention paid to watershed management opportunities.** Rain-fed cultivation, forestry, livestock, fisheries, and ecosystem services, all of which are major livelihoods in the Eastern Nile Basin, warrant much more in-depth analysis than was possible in the time available.

Chapter 2

Multi-Sectoral Analysis of Opportunities

2. Multi-Sectoral Analysis of Opportunities

2.1 Conceptual Framework

The multi-sectoral investment opportunities analysis (MSIOA) study defined different combinations of water resources management and development across sectors (termed Development States),[14] analyzed the implications of each Development State on water resources (availability), on poverty reduction (economic returns, employment creation) and on the social and biophysical environments, before asking key country-level stakeholders to rank these Development States using multi-criteria analysis.

The conceptual framework at the core of the study builds a regional perspective on the various studies that have been conducted by ENTRO since 2002, including the Cooperative Regional Assessments (CRA) for (a) EN Power Trade and Power Interconnection, (b) EN Irrigation and drainage study, and (c) EN Watershed Management, all of which are sectoral analyses. The data and information generated from these studies were collated as part of the central Eastern Nile Knowledge Base at ENTRO, developed under the Eastern Nile Planning Model (ENPM) project under ENSAP. A number of analytical tools – including a suite of simulation, optimization and multi-criteria analysis tools - were also developed under the ENPM to facilitate the process of informed decision making in the region. In addition, a situational analysis was carried out under the MSIOA study to identify sectoral and multipurpose projects under implementation and being planned across the eastern Nile basin countries. While all this development has the potential to contribute to overall economic development and poverty reduction, which are key concerns in each of the Eastern Nile Basin countries, it is clearly unrealistic to develop all of them simultaneously without considering the resource constraints of the basin. Although a few sectors such as energy have taken into account trans-boundary considerations to prioritize projects and thus respond to both regional and national needs, **in most sectors – and especially the water sector - there is an absence, of any regional-level prioritization and region-wide assessment of what can realistically be developed using the available resources**. It is clearly likely that there may not be sufficient water resources to satisfy all users and uses in the basin and there is, therefore, a need to understand where the issues are – across sectors - and where in the basin water-related challenges can worsen in the future.

There are, thus, three key elements of the analytical framework developed to analyze potential Development States of the ENB:

1. Definition of Development States
2. Understanding potential impacts of each Development State
3. Multi-criteria analysis of potential impacts

Each of these is further explained below.

2.1.1 Definition of Development States

The aim of the study was not to evaluate individual projects and indeed what sets it apart from conventional single-project feasibility analysis is that it is designed to look at the overall impacts of different combinations of water resources development and management options (across different water-using sectors), called Development States.[15] A total of 12 Detailed Development States (which are fine-tuned and are more specific) were investigated, building on the four Major/Main basic Development States (which are broader and orientating) that were initially defined, with differing levels of investment in (and development of) hydropower, irrigation, livestock, fisheries and domestic water use:

1. **Current Situation (CS):** This represents the baseline state (2014 development level) of each sector in the ENB and includes all current irrigation and hydropower projects, demand for water for domestic uses and livestock needs, and fisheries activities.[16]

[14] The details of the methodology used are given in Annex 7

[15] A particular Development State of the basin – or state of development of the basin – is taken here to mean a pre-defined combination of investments in hydropower and irrigation, with concomitant impacts on other sectors such as livestock, fisheries and domestic water supply. The achievement of this Development State will require active efforts by national governments to realize the investments described.

[16] Note that (1) the water requirement for livestock is only assessed in terms of opportunities related to growth of livestock associated with irrigated agriculture; (2) only fisheries in the main reservoirs have been considered; (3) only water demand for domestic uses have been

2. **Improved Situation (IS):** This is basically a 'near future' or short-term state of the ENB, adding to the Current Situation, investment in irrigation modernization and rehabilitation of ***existing*** schemes (deemed to be economically viable), hydropower projects ***already*** under implementation and potable water supply, livestock and capture fisheries. The IS therefore adds the following to the Current Situation:

   a. Irrigation schemes in the EN countries that are (i) low-performing but can be rehabilitated or modernized (1) without acquiring supplementary storage infrastructure; and (2) within 30% of the costs of the current assets; and (ii) Currently under construction and expected to be in operation within 5-10 years.[17]
   b. Hydropower schemes under construction, to be commissioned in the next 5-10 years
   c. Water demand needs based on expected population growth
   d. Livestock and feed water requirements, based on expected increases in demand
   e. Supplementary fisheries related to the implementation of the most interesting and advanced hydropower/reservoir projects

The IS state effectively corresponds to plans being implemented or about to be implemented – and thus, external factors have very low impacts on the probability of its achievement.

3. **Large Development (LD):** This state corresponds roughly to a 'medium-term' state of the ENB, and adds the following to the IS situation:

   a. Potential irrigation schemes advanced to pre-feasibility or feasibility study level
   b. Projects identified under country Master Plans or the Diagnostic Study of the Eastern Nile Irrigation and Drainage Study (ENIDS) and ranked as feasible with an Economic Internal Rate of Return (EIRR) of 10% or above
   c. Potential hydropower projects that have been advanced to pre-feasibility or feasibility study level.

4. **Full Development (FD):** This state is broadly similar to a 'long-term' state of the ENB, and adds the following to the IS situation:

   a. All irrigation potential (in terms of identified projects) is converted into irrigated agriculture
   b. Additional livestock due to opportunities from additional irrigated agriculture
   c. All identified hydropower/reservoir projects in the ENB are implemented
   d. Supplementary fisheries related to the implementation of all planned reservoir projects

These development states were meant to be incremental, moving from CS to IS to LD to FD, but stakeholder discussions led to more potential development states being investigated, increasing their numbers from four to 12. These are discussed further below, presenting the findings of the analysis of the impacts of these states on water resources, hydropower, irrigation, etc.

2.1.2 Understanding Potential Impacts of Development States

The impacts studied cover water flows, and evaporation, economic aspects (returns on project investment, employment creation and water productivity), and social (number of persons to be re-settled and equity of benefit distribution). Potential impacts of each Development State were worked out in a three-step process:

considered (and not, for instance, water for other livelihood uses). Integrated watershed management, tourism and navigation have not been assessed.

[17] This situation thus assumes that all EN countries will rehabilitate irrigation so that current schemes are used according to their command areas – as the area under cultivation using water from existing irrigation schemes is less than the total command areas of the schemes, in most cases (in the Gazeira Scheme in Sudan, for instance, only around 377,000 ha are under cultivation today, out of a scheme potential of 579,000 ha). It also assumes that they will invest in irrigation modernization and efficient water use; and introduce new technologies to increase productivity and reduce costs of production. These assumptions thus include investment in machinery, more efficient use of fertilizers, proper finance to farmers, crop diversification and liberalization (including incentives for high crop returns such as perennial crop), in improved water management and reduced losses on existing schemes, and in agricultural research to improve seed varieties and increase productivity.

A. **Water demand requirement of each development state was worked out** using the Eastern Nile Basin Simulation Model.[18] The objective was to model (a) the functioning of the EN region hydrological systems, including natural and man-made reservoirs, wetlands, irrigation and hydropower schemes in the EN river systems and their main tributaries and (b) the satisfaction of water demand (for irrigation, hydropower, water storage operations and environmental flows), under different water resources management and development states. Thus, a total of 52 demand nodes were incorporated to model both existing and potential future water extractions, two wetlands and spill flows were modeled (the Machar marshes and Tawlor Spills in the Baro-Akobo/Pibor -Sobat river system), and a total of 30 reservoir nodes were incorporated to model both existing and potential water storage infrastructure in the basin.[19] Model validation was carried out by comparing observed monthly flows at selected stations (Jebel Aulia, El Gibra, Border, Khartoum and High Aswan Dam) with MIKE-Hydro models inflows at these stations, and good agreement was found between simulated and observed monthly flows.

B. **Annual mass balance analysis of water use was calculated** using an EXCEL-based Tool for the water demand requirements of each development state from the EN Basin Simulation model. This provided the implications of different development states on water availability at each node in the system. The Tool uses the following information:
   a. Detailed database of existing and potential hydropower and irrigation investment schemes including details of their infrastructure, scheme operation and productivity, historical water abstractions and economic viability (including updated unit rates on profitability for potential irrigable projects in Egypt), detailed costing analysis of initial investment and recurrent costs of all irrigation projects;
   b. Water requirements for irrigation schemes, including crop water requirements (per hectare), equilibrium prices of water, cost of pumping per hectare and livestock (drinking and feed) water requirements.
   c. Production costs and net revenues from existing and potential irrigable projects, to analyze impacts of different irrigation modernization options and economic valuation of the feasibility of rehabilitating low performing irrigation projects
   d. Detailed socio-economic analysis of the impacts of all investment projects using a consistent set of indicators: net revenue, net present value, employment (per irrigation scheme) and the productivity of livestock and fisheries.

C. **Economic assessment of major infrastructure investments was done** using a 30-year time horizon, in US dollars and assuming a (social) discount rate of 8%, yielding Net Present Values (NPVs), Economic Internal Rates of Return (EIRRs) and Benefit-Cost (B-C) ratios (see Annex 8 for details). Detailed economic analysis was carried out for irrigation investments in Sudan, South Sudan and Egypt, using standard templates to evaluate the cost of production of irrigation schemes, net revenue generated per hectare and to perform the cost-benefit analysis. Information on EIRRs, NPVs and B-C ratios for each irrigation project for Ethiopia, was extracted from the ENID study (ENTRO, 2007). EIRRs, NPVs and B-C ratios of large-scale hydropower schemes in Ethiopia and Sudan conducted under the EN Power Trade Study (ENTRO, 2009) and recently updated through a number of feasibility and pre-feasibility studies, were used.

2.1.3 Multi-Criteria Analysis of Potential Impacts

The study opted to use a multi-criteria analysis to compare the impacts of each development state, especially in terms of how they meet the water resource

[18] The EN Basin Simulation Model is a water distribution model, distributing water through the main branches of the EN region water system on a monthly basis over the period 1900 to 2002. As the time of concentration of the water in the river is less than one month in the various branches, no river routing has been used. Propagation delays only occur because of the surface water reservoirs which are used to simulate natural and manmade reservoirs as well as significant wetlands. See Annex 6 for more details

[19] The schematics of the EN Basin Planning Model as it has been elaborated under MIKEHydro are provided in Anne 7 of the report.

Figure 2.1: Pair-wise ranking of criteria

Criteria	Symbol	Description
Economic	NPV-HP	Net present value of revenue generated from hydropower
	NPV-IR	Net present value of revenue from irrigation
	WP	Water productivity in irrigation
Social	Empl	Number of people employed in agriculture, fisheries & livestock
	Restl	Number of persons to be resettled if project implemented
	Equity	Equity of distribution of benefits from water use
Environment	BCM-Eg	Annual flow (in BCM) at the Nile Delta in Egypt
	Evap	Total evaporation losses from basin reservoirs

Instructions: For each pair of criteria, write in the blank cells the criterion you prefer

	NPV-HP	NPV-IR	WP	Empl	Restl	Equity	BCM-Eg	Evap
NPV-HP	X							
NPV-IR		X						
WP			X					
Empl				X				
Rest					X			
Equity						X		
BCM-Eg							X	
Evap								X

Table 2.1: Weights of criteria reflecting stakeholder preferences

Criteria	Number ranking it 'better'than the paired alternative	Weights as percentages
Evap	29	19%
WP	29	19%
NPV	28	18%
BCM-Eg	21	13%
Equity	21	13%
Resetl	17	11%
Empl	11	7%
Total	**156**	**100%**

and sustainable development expectations of the ENB countries. This involved a two-stage process:

1. Selection of criteria to evaluate each development state: The selection of criteria was stakeholder-driven, with stakeholders representing the different thematic areas and Ethiopia, Sudan and South Sudan proposing appropriate criteria and deciding weights to represent their relative importance.[20] Three broad categories of criteria emerged from these discussions:

Economic criteria

- Net Present Value (NPV) (in million US$) of net revenues generated by hydropower schemes (NPV-HP) and irrigation schemes (NPV-IR). The latter is linked to fisheries and the livestock sector and could also be interpreted as a proxy for food security, poverty alleviation and rural development since the agricultural sector is a major driver of economic growth in all four countries.
- Water Productivity (WP) in the irrigation sector (USD/hectare), reflecting the efficiency of water use in the agricultural sector and highlighting the comparative ad-

[20] This exercise was carried out at an ENTRO MSIOA Workshop in Addis Ababa from 8-9 February 2015.

vantages of areas and countries in terms of crop production.

Social criteria

- Employment (EMPL) created in the irrigation, fisheries and livestock sectors by that particular development state, and a proxy for poverty reduction
- Resettlement (RESTL) of people displaced by a project, and a proxy of the social damage generated by the project.
- Gini index showing the equity of distribution of benefits to users

Environmental-criteria[21]

- BCM-Eg which is the annual flow (in BCM) at the Nile Delta in Egypt
- Evap, the total evaporation losses from reservoirs in the basin

2. Weighting the criteria (to ensure that key criteria were given the highest importance): This was also driven by stakeholders, using a pair-wise matrix ranking, which is a structured method for ranking a list of indicators in a priority order. Stakeholders were asked to fill in the table below by comparing the pair of indicators in each blank cell (Figure 2.1).

These rankings were then collated across stakeholders and applied to the criteria to yield a set of weights, which were then expressed as percentages (Table 2.1).

2.2 The Analytical Framework

The analytical framework tries to capture countries interest and planned projects for short and long term by detailing the four main development states (current situation, improved situation, large development and full development) into twelve development states. The analytical framework used this detailed twelve detailed development states with different combinations and their defining characteristics. These detailed development states are developed as follows;

(i) Separating the Major/Main Full Development State into four:

a. State 1 remained the Current Situation (CS).
b. State 2 remained the Improved Situation (IS).
c. State 3 (IS+FDH) adds Full Development Hydropower projects (i.e., all potential hydro-power projects in the ENB) only to the IS.
d. State 4 (IS+FDI) adds Full Development Irrigation (i.e., all potential irrigation projects in the ENB) only to the IS.

(ii) Separating the Major/Main Large Development State into two: The Large Development of hydropower and irrigation (LD) state has been similarly split into two:

a. State 5 (IS+LDH), which is the IS plus only Large Development of Hydropower (i.e., projects taken up to feasibility or pre-feasibility levels).
b. State 6 (IS+LDI), which is IS plus only Large Development of Irrigation (i.e., projects taken up to feasibility or pre-feasibility levels).

(iii) Considering differential development across sub-basins: Two new states, 7A and 7B consider different levels of irrigation and hydropower development across sub-basins.

a. State 7A (IS+LDH+ DI[BAS+TZA]) adds to the IS, all feasible hydropower development and large irrigation development (i.e., all feasible schemes) only in the upper riparian states of the ENB (Ethiopia and South Sudan in the Baro-Akobo-Sobat (BAS) sub-basin) but not in the downstream Sudanese part of the basin.
b. State 7B (IS[BAS+TSA]+LDH + Mixed DI) considers the same level of hydropower development as 7A but large development only in the Sudanese part of the 'basin and not in the upstream parts of the BAS and TSA.

[21] Two criteria defined originally – MEF(SA) and Ter-Ecol – had to be dropped in the final analysis for want of data required to put values to these indicators. MEF(SA) represented the impact on Minimum Environmental Flows in Sensitive Areas, a prpoxy for environmental impacts of both hydropower and irrigation infrastructure projects, while Ter-Ecol represented the total land area lost to reservoirs, a proxy for the biodiversity lost as a result of the implementation of hydro-power projects

(iv) Moderating and modernizing irrigated agriculture: Three new states 8A, 8B and 8C explored the potential of moderate irrigation, with additions of cropping pattern changes and reductions in the operating height of the HAD. 8A**.**

a. State 8A (IS+LDH+MDI) adds to the IS ***only*** (1) Large Hydropower investment (i.e. all projects advanced up to prefeasibility and feasibility levels) and (2) moderate irrigation development (i..e., the top priorities of the countries) in the Abbay/Blue Nile sub-basin and along the Baro-Akobo/Pubor-Sobat and Tekeze river systems.
b. State 8B (IS+LDH+MDI + NileCrops) adds to 8A, less-water using crops and a 7.5% reduction in irrigation water demand in the Main Nile sub-basin.
c. State 8C (IS+LDH+MDI + NileCrops + LowHAD) adds to state 8B, a much reduced operating level of the HAD.

(v) Defining a cooperative win-win State: State 9 is the case of cooperative development that optimizes the benefits of the limited water resources in the ENB – with (a) managed upstream irrigation that still meets downstream water demands; and (b) irrigation and hydropower investments that bring balanced benefits to all ENB countries.

The definition of the detailed 12 Development States is as follows:

1. **Current Situation (CS):** This state is defined by the existing levels of irrigation, hydropower, potable water supply, environmental flows and capture fisheries in 2014, showing that a vast majority of the water uses are in the downstream part of the ENB.

2. **Improved Situation (IS):** This state represents realistic improvement over the current situation, with the most advanced hydropower projects under implementation (i.e., Great Ethiopian Renaissance Dam (GERD) and the Upper Atbara Scheme) and the assumption that a majority of low-performing existing schemes are rehabilitated so that their full command areas are operational and their productivity enhanced.

3. **Improved Situation + Full Development Hydro (IS+FDH):** This state adds to the IS the full development of ***all*** potential hydropower projects identified in the ENB, but no further irrigation is included.

4. **Improved Situation + Full Development Irrigation (IS+FDI):** This state reflects the situation wherein ENB countries pursue uncoordinated irrigation expansion plans and all potential irrigation projects are implemented – but hydropower is only at IS levels (i.e., only GERD and Upper Atbara).

5. **Improved Situation + Large Development Hydro (IS+LDH):** This adds to the IS only those hydropower projects that have been taken to feasibility or pre-feasibility levels – or, to put it another way, removes all low feasibility hydropower schemes from State 3 (IS+FDH). This takes into consideration that opportunities of power trade will minimize the need for costly reservoirs with high evaporation losses along the main Nile river system.

6. **Improved Situation + Large Development Irrigation (IS+LDI):** This adds to the IS only those large-scale irrigation projects that were either advanced to feasibility or pre-feasibility levels.

7A. **Improved Situation + Large Hydro + Irrigation Development in BAS + TZA (IS+LDH+ DI [BAS+TZA]):** This state considers the comparative advantage of differential development: large-scale irrigation development only in the Tekeze-Setit-Atbara (TSA) sub-basin; and in the upper riparian states in the ENB (Ethiopia and South Sudan in the Baro-Akobo/Pibor-Sobat (BAS) sub-basin) – but not in the Sudanese part of the basin.

7B. **Improved Situation in BAS + TSA + Large Hydro + Large Irrigation Development in Sudan (IS[BAS+TSA]+LDH+LDI [Sudan]):** Apart from adding Large Hydro in the ENB, this state adds Large Development of Irrigation in the Sudanese part of the sub-basins (but leaves irrigation in the BAS and TSA sub-basins only at the IS level).

8A. Improved Situation + Large Hydro + Moderate Irrigation: This state adds to the IS only (1) targeted irrigation development in the Abbay/Blue Nile sub-basin (i.e., in Laka Tana, Beles, Arjo Didedessa on the Ethiopian side and the Great Kenana and Rahad II on the Sudanese side); (2) all schemes identified along the Baro river in addition to Gilo-2 (right and left banks); and (3) newly identified potential on Baro at Itang Piibor and Sobat River Systems, as well as both Metema and Humera on the Tekeze River.

8B. Improved Situation + Large Hydro + Moderate Irrigation + Cropping Pattern Changes for the Main Nile sub-basin (IS+LDH+MDI + NileCrops): This state only adds to 8A, cropping pattern changes in agriculture along the Main Nile – specifically, Egypt opting for less water consuming crops and improvements in irrigation water demand (by 7.5%).

8C. Improved Situation + Large Hydro + Moderate Irrigation + Cropping Pattern Changes for the Main Nile sub-basin + Reduced Operating Level of HAD (IS+LDH+MDI + NileCrops + LowHAD)

This state only adds to state 8B, a much reduced operating level of the HAD.

9. Improved Situation + Large Hydro + Managed Irrigation (IS+LDH+ManDI): This state represents a 'win-win' case with (a) managed irrigation growth to meet downstream water demands; (b) balanced irrigation expansion so that each ENB country benefits from the package of investments in hydropower and irrigation. This however requires an enabling environment of cooperation where decision-makers agree to embark on a strong level of coordination to optimize the benefits from the limited water resources.

2.3 Analysis and Findings

2.3.1 Analyzing the feasibility of Development States

The feasibility of these Development States was analyzed, based on their potential environmental, economic and social impacts, by comparing the water requirements of each State with basin water resources. Since the water requirement of Development States 4 (IS+FDI) and 6 (IS + LDI) exceed the resources of the ENB by a large margin these are considered non-viable (Table 2.2).[22]

Since the Development States performed differently on different criteria, they were analyzed using Multi-Criteria Analysis, using the indicators highlighted in Table 2.1.

Table 2.2: Feasibility and strategic implications of the Development States

Development State	Key Impacts on water resources	Strategic Implications
2: Improved Situation (IS) All hydro-power and irrigation projects being developed currently	The IS has limited impact on EN water resources, with a small decrease in inflows to the High Aswan Dam (HAD) and some increased abstraction, because irrigation schemes use their full command areas.	The development of hydropower and efficient irrigation can result in significant benefits without having a major impact on water resources further downstream
3: IS + Full Hydropower (IS+FDH) IS + all potential hydro-power projects	Here inflow to the HAD are reduced further (due to evaporation losses in the new reservoirs) but there is no impact on flows into the downstream delta or the Mediterranean Sea – as excess storage in the HAD allows releases as before.	Hydropower can be developed at all potential sites without having a major impact on the availability of water downstream (but without irrigation development)
4: IS + Full Irrigation (IS+FDI) IS + all potential irrigation projects	The development of full irrigation potential will have a major impact on the availability of water downstream: it creates an overall water deficit of 19.3 BCM per year in the ENB	This s not a viable state as uncoordinated irrigation expansion will cause major water shortages and/or the abandonment of some irrigation schemes.

[22] Full details of the economic, social and environmental impacts are in Annex 7.

Development State	Key Impacts on water resources	Strategic Implications
5: IS + Large Hydropower Development (IS + LDH) IS + all feasible hydropower projects	Closely linked to State 3 (IS + FDH), planned hydropower development has minimal impact on ENB water resources compared to other development states	Implement all feasible hydropower projects and investigate the conversion of less viable hydropower schemes into run-of-river schemes
6: IS + Large Irrigation Development (IS+LDI) IS + all feasible irrigation projects	There is still insufficient water in the ENB to meet all the irrigation requirements of locally/ nationally feasible irrigation projects	This Development State is also not viable because it will lead to a shortage of water in the Nile Delta
7A: IS + Large Hydro + Large Irrigation (BAS+TSA) IS + all feasible hydro-power projects + irrigation only in the BAS & TSA sub-basins (not in the Sudanese part of the basin)	This State has feasible irrigation projects developed only in the BAS and TSA sub-basins – but not in the Sudanese part of the basin –but this also results in a deficit of water in the ENB (though it is a much smaller deficit than in State 6 above or State 7B below)	Only the most economically viable schemes are developed in the Sudanese part of the basin and not in the BAS & TSA sub-basins, leaving irrigation in the BAS and TSA sub-basins only at the IS level. Crop choice should become a part of irrigation project planning
7B: IS + Large Hydro + Large Irrigation (Sudan) IS + all feasible hydro-power projects + feasible irrigation projects only in the Sudanese part of the basin (not in BAS & TSA)	This State is the reverse of 7A: Feasible irrigation projects are only developed in the Sudanese part of the basin and not in the BAS & TSA sub-basins – but this also results in a deficit of water in the ENB (less than in States 4 & 6; but higher than in 7A)	
8A: IS + Large Hydro + Moderate Irrigation IS + all feasible hydro-power projects + top irrigation priorities of ENB countries	All three variants result in the same amount of inflow at HAD, but have different implications for the inflow into the Mediterranean Sea. The introduction of cropping pattern changes in the Main Nile sub-basin that are more compatible with the agro-climatic zone, result in some water savings – reducing the deficit in the ENB as a whole. Lowering the operating level of the HAD (and consequent decreases in evaporation) results in further savings	Three imperatives for water management in the ENB are: Appropriate crop choices and replacement of inappropriate choices with those more suitable to the agro-climatic zones A regional approach to food security A regional approach to markets and the entire logistic chain getting agricultural produce to principal regional market centers
8B: IS + Large Hydro + Moderate Irrigation + cropping pattern changes in the Main Nile 8A + cropping pattern changes		
8C: IS + Large Hydro + Moderate Irrigation + cropping pattern changes in the Main Nile + reduced HAD operating levels 8B + reduced HAD operating levels		
9: IS + Large Hydro + Management Irrigation IS + feasible hydro-power projects + managing irrigation within the available water	This State builds on State 8 and aims to reduce the water deficit at the Delta through a small reduction in hydropower generated, and the area under irrigation. But there is still a deficit at the Nile delta	This requires a strong level of coordination among the ENB countries, and an enabling environment of cooperation

2.3.2 Comparing Impacts

The scores of the seven economic, social and environmental indicators of different Development States were weighted with the weights provided by key stakeholders (see Table 2.1 above) and reflect the agreement that uncoordinated expansion of irrigation is unviable in the ENB (see Table 2.3 below).[23] Note that States 4 and 6 have not been presented as their water requirements were unviable.

2.3.3 Assessing Feasibility

These Development States are also represented graphically (Figure 2.2), in terms of the return from the total investments in each State (the larger the circle, the greater the NPV), and the available water resources in the ENB to be used either for hydropower generation (GWh) or irrigation ('000 hectares): Development States outside this oval 'envelope of water availability' are affected by the constraint of water availability. The graphical representation (Figure 2.2) supplements the findings of the analysis (as given in Table 2.2):

Table 2.3: Impact Indicator values and weighted scores for Development States

Indicators		Units	Development States							
			3	5	7A	7B	8A	8B	8C	9
			IS + FDH	IS + LDH	IS + LDH + LD (BA+ TZA)	IS + LDH + LD (Sudan)	IS + LDH + MDI	IS+ LDH + MDI +Nile Crops	8B + Less HAD	IS + LDH + Manl
1	NPV: Hydro-power (NPV-HP)	Billion US$	69.6	46.8	56.6	56.8	54.9	54.9	54.9	46.6
2	NPV: Irrigation, fisheries, livestock (NPV-IR)	Billion US$	5.8	5.8	6.7	7.5	6.8	6.8	6.8	6.8
3	Water Productivity of Irrigation (WP)	US Cents/ Hectare	4.11	4.11	4.15	4.59	4.01	4.01	4.01	4.20
4	Equity of benefit Distribution	Gini Index	0.78	0.71	0.75	0.81	0.76	0.76	0.76	0.71
5	Total Employment Generated (Empl)	Million Jobs	102	102	110	106	111	111	111	109
6	Water Balance at Delta (BCM-Eg)	BCM/ year	8.55	9.54	-0.82	-0.82	-3.35	-0.71	0.31	-0.95
7	Reservoir Evaporation Losses (Evap)	BCM	23.8	22.9	23.5	23.3	23.3	23.3	23.3	23.3
Weighted Scores			**4.2**	**4.4**	**4.6**	**6.6**	**4.3**	**4.5**	**4.6**	**5.0**

[23] How the indicators are calculated is detailed in Annex 7.

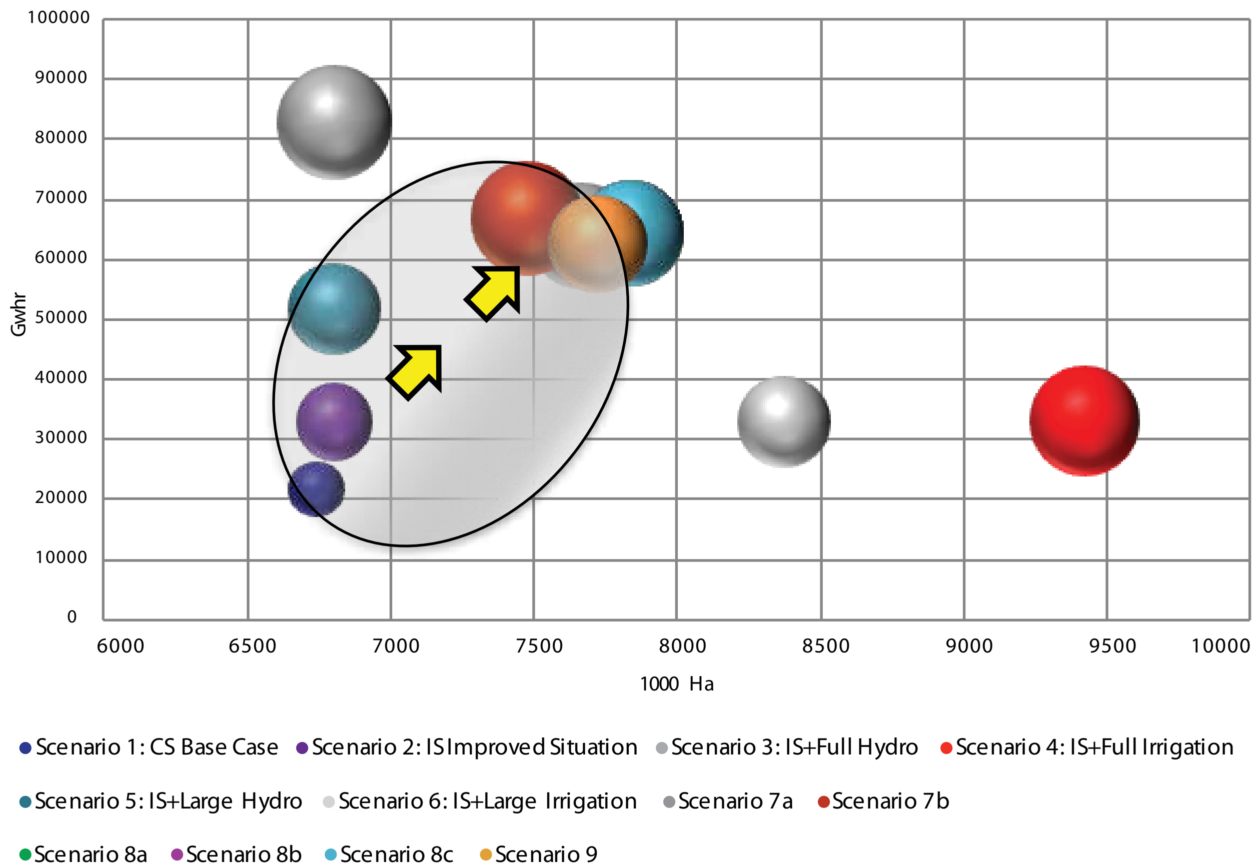
- **The two red circles representing Large Irrigation and Full Irrigation Development are clearly unrealistic** in terms of water constraints.

- **States with increased hydropower yield greater returns than those with increased irrigation,** although investments in both increase the NPV over the Current or even Improved Situation.

- **Very few combinations of planned national-level hydropower and irrigation expansion are feasible at a basin-level** signified by the fact that all except three development states are partly or fully outside the water availability envelope.

The main conclusions from these findings and their implications for the development strategy of the Eastern Nile Basin are discussed in the next section.

Figure 2.2: Hydropower and Irrigation implications of the Development States



Chapter 3

Conclusions and Strategic Implications

3. Conclusions and Strategic Implications

3.1 Conclusions

The main conclusions and action points suggested by the MSIOA study are the following:

- **We now know which possible futures are not sustainable for the basin**. There is much to be learned about what the possible futures have in common and how to steer away from potential trajectories/futures that do not lead to sustainable outcomes. ***Business-as-usual is the least attractive solution***. Instead of uncoordinated national-level investment planning, especially in the water sector, multi-sector coordination and analysis are critical for coming out with sustainable development and feasible investments. This will need strong cooperation between the Eastern Nile Basin countries, especially in sharing data and information, not only concerning resource use and resource availability across sectors (e.g., hydrological flows, flood forecasting, trans-boundary parks, watershed-level impacts, migration patterns and irrigation, livestock and fisheries development) but also about each other's investment planning and implementation for water-impacting sectors.

- **There is scope for new irrigation, *but in the longer-term, there is not enough water to fulfill the development plans of all countries***. Unchecked or unilateral expansion of planned irrigation will lead to major water shortages and/or the abandonment of some irrigation schemes. Even a step back from the full development of irrigation potential will lead to shortage of water in the system. To ensure that more sustainable Development States are targeted in regional and national-level planning and investment, especially in irrigated agriculture, countries should:

  - Improve efficiencies in existing irrigation schemes across the basin by identifying areas where water saving is possible; and by operating the current system differently
  - Closely examine water requirements for irrigation projects under consideration and design new regional water savings programs that include rehabilitation, cropping choice/pattern changes, drainage and modification of operations for greater irrigation efficiencies.
  - Undertake programs to examine livelihoods, environmental flows, salinity, etc., to understand effects of increased irrigation upstream on the downstream water quality.
  - Undertake improvements to national planning processes, to ensure that private sector water use (especially in irrigated agriculture) is included in national plans

- **Regionally planned hydropower development has minimal impact on regional water resources,** once the dams are filled. Although the study did not analyze the filling of dams and this needs further investigation, the study established that, being non-consumptive water use, ***new hydropower can be managed in a trans-boundary context while working to reduce evaporative losses from reservoirs, and coordinating filling and operation.*** Countries, however, need to:

  - Put in place the conditions necessary to realize the potential of generated hydropower, facilitate power trade and expand transmission at regional level – which includes strengthening of national grids to better absorb and distribute power to various demand nodes, convene national utilities to examine demand and distribution capabilities, identify missing aspects for capacity building and new investments (to ensure that this new power can get to all the users), etc.
  - Carry out feasibility studies for new transmission linkages, e.g., from Ethiopia to South Sudan.
  - Establish a coordination mechanism for dam operations to ensure that cascades are coordinated to reach full potential and that filling takes into account flow rates and reservoir volumes (in order for dams to be beneficial regionally and to minimize the impact on regional water resources)

- Ensure that cascade development is well sequenced, and that investments in future dams and ancillary activities are undertaken for maximum regional benefit
- Design national and regional programs to minimize dam safety risks
- Ensure better sediment management (e.g., through watershed management and sediment monitoring programs) to optimize returns from hydropower
- Undertake full and regional-level environmental and social impact assessments and feasibility studies of potential projects following a systematic approach

- **Where reservoirs are used for hydro-power and irrigation, water availability may be impacted.** However, if well-planned, there are win-win development opportunities. This is therefore a critical area for taking a regional and multi-sectoral approach to identify the right opportunities, based on a detailed analysis of social, economic and environmental impacts of proposed investments across sectors.

- **Choice of crops, agricultural water use efficiency improvements and a regional approach to food security and agricultural markets** should be explored further and developed. Taking a regional approach can help to

  - Support crop zoning initiatives (so that the most suitable crops are grown in every agro-climatic zone); irrigation efficiency improvements (which can be targeted to specific crops and zones); and special measures to improve the sustainability of important livelihood sectors in the Eastern Nile Basin such as livestock (e.g., demarcation of routes, water points, etc.), fisheries and rain-fed agriculture
  - Better understand and thus optimize the trade-offs between agriculture and livestock
  - Develop regional food and agricultural markets in order to support crop zoning and prevent sub-optimal water use in agriculture - e.g., by growing crops unsuited to local agro-climatic zones, instead of growing produce that is best suited to the local areas and trading for produce that is needed but better grown in another agro-climatic zone

- **Other areas to be further explored to reach favorable win-win development outcomes for all** include the following:

  - Potential savings and effects or development on other water users such as urban peri-urban and small town residents, industries, rain-fed farmers and those dependent on forests, fisheries and livestock for their livelihoods
  - Improvements in groundwater management and utilization, salinity control, flood forecasting and management and drought mitigation.
  - Joint action on ecology and conservation within the basin, in particular, on trans-boundary parks, tourism related water management, and wetlands preservation
  - Climate change, across all sectors, and the basin as a whole.

- **Multi-sector coordination and analysis are critical** to identify sustainable development and feasible investments . There is thus a need for countries to:

  - Undertake basin-level hydrological studies to understand the impacts of future water resource use and improved management, spanning areas such as hydro-meteorological (hydro-met) monitoring and analysis, catchment management and consumptive versus productive uses of water.
  - Undertake more multi-sectoral planning at all levels, in order to be aware of tradeoffs between new irrigation, irrigation rehabilitation and modification, and new hydropower investments across the basin.
  - Follow a coordinated approach to manage floods, including updating the regional flood forecasting program to include daily flow reports on Blue Nile, revised modeling for Sudan on the Blue Nile, expanding the model to include Tekeze – Atbara and the Baro-Akobo/Pibor-Sobat river systems.
  - Prioritize the maintenance of environmental flows in the Nile, including initiating a

delta management program to address salt water intrusion and salinity, as these are critical aspect of basin health, especially in the context of climate change

- **There are huge information gaps in the basin**, which need to be plugged urgently in order to improve the basis for decision-making on critical resource management issues. Accordingly, countries need to gather and share more information about water utilization, management and efficiency, groundwater, salinity, environmental flows, new irrigation and hydropower developments, existing irrigation efficiencies, sediment flows and evapo-transpiration rates, etc, focused on improving basin-wide water resource development, management and use.

3.2 Implications for Development Strategy

The objectives of the Nile Basin Sustainability Framework(NBSF) already provide the context for the overarching strategic objectives that must underlie the investment strategy. The NBSF objectives include reference to:

- ***"socio-economic development, poverty reduction and improvement of livelihoods*** of riparian communities through ***equitable utilization and sustainable development*** of the common Nile basin water resources"
- ***efficient management of the Nile water resources*** drawing on principles of integrated water resources management (IWRM), and good practices in trans-boundary water resources management;
- ***wise use and sustainable management of the environment*** and water-related natural resources of the Nile Basin;

Consideration of all of these has led to four overarching objectives:

- Socio-economic development and poverty reduction
- Food security
- Efficient management of NB (including EN) water resources
- Sustainable management of the environment and water-related natural resources

Given these, the MSIOA study points to the following directions for development strategy in the ENB:

- **Prioritize most deserving (hydropower and irrigation) infrastructure projects:** The Investment strategy should ensure that infrastructure, hydropower and irrigation projects on which there is consensus are prioritized on the basis of economic feasibility, environmental sustainability & social equity, and prepared for implementation to meet identified needs at least in critical areas (based, for e.g., on electricity and food demand projections).
- **Optimize operational rules for reservoirs for better performance:** Apart from creating new water resource infrastructure, a key activity will be to modernize and synchronize their operating systems. Dynamic reservoir management for large dams in a cascade, based on improved hydro-meteorological systems of weather prediction, for instance, can not only optimize dam capacities and releases, but can also provide advance information downstream in case of flash floods in upstream parts of the Basin. Such synchronized operations can also improve dam safety along different cascades within the Basin.
- **Select the most economically-viable irrigation schemes:** Since the potential for uncoordinated irrigation expansion is limited, the irrigation schemes selected for implementation should be the most economically viable. Three criteria suggested for a preliminary screening are: (1) a positive internal economic rate of return; (2) positive net present value of net benefits; and (3) a benefit-cost ratio of more than 1. A final screening of the list of selected projects could be (1) their ranking according to economic viability; and (2) their feasibility with regards

to water availability (i.e., they should fit within the 'water envelope' described earlier).[24]

- **Ensure that crops most suitable to the agro-climatic zone are grown:** Since the sum total of currently planned Irrigation schemes – and possibly even those that pass the primary screening suggested above – may not be feasible given the limited availability of water, all possible options to improve their water efficiency should be considered, a primary one being their suitability for a particular agro-climatic zone.

- **Follow a regional approach to markets and food security:** Another option to optimize irrigation water use within the basin would be to promote regional trade of agriculture-based products - that are grown in the most suitable agro-climatic zone but made available to other areas where there is demand but which may be unsuitable for its production. Calculating 'water footprints' for these products and analyzing 'virtual water' movements will also help identify the dimensions and locations of such regional markets, especially to promote food and nutrition security within the Basin.

- **Continue improving and updating tools and data to support future decision-making**: There is now a useful suite of planning tools in place to support the making of the best choices in the future. The detail and applicability of these tools will be enhanced by water resources models that will be set up at the sub-basin level as part of planned studies. It is important that ENTRO retain the capacity to use and update these models so that new development states can be investigated as and when required. Those in which ENTRO has a key role to play should be highlighted and measures should be taken to ensure that ENTRO has the capacity to move them forward in collaboration with the EN countries.

- **Take forward 'no or low regrets' opportunities urgently:** There are many "no or low regret" initiatives that should be taken forward as a matter of urgency. Ten such initiatives have been identified and endorsed by country stakeholders at a workshop in Addis Ababa on 31 October 2016, and are detailed further in the next chapter (Chapter 4 below).

[24] See Annex 7 for details

Chapter 4

Next Steps

4. Next Steps

4.1 Strategic Interventions

As agreed by the key country-level stakeholders assembled for the final workshop of the MSIOA study, where the study conclusions, suggested actions and implications for development strategy were presented, it is clear that some strategic interventions are urgently needed. ***The MSIOA analysis unequivocally underscores that given the risks that the river is facing, a hydrological-unit based river basin approach is needed – and it can be achieved only with cooperation.*** Hence the strategic interventions presented below assume a cooperative approach, with each Eastern Nile Bain country supporting a regional approach to priority areas. Ten specific 'no-regret or low-regret' actions have been identified, some management-related and some investment-related have been endorsed for further action by key country stakeholders.

1. ENB energy sharing arrangements
2. Coordinated water infrastructure operations
3. Efficient irrigated agriculture
4. Watershed management to rehabilitate degraded catchments & improve natural resource-dependent livelihoods
5. Environmental and social assessments & safeguards
6. Water re-use and salinity management
7. Water quality & sediment monitoring & management
8. Groundwater monitoring & management
9. Climate change adaptation capabilities
10. Coordination and phasing of win-win-win ENB development packages

None of these involves any substantial investment activities but aim to facilitate discussions and improve implementation (e.g., where implementation has started, to bring in factors such as climate change), fill data gaps and develop the understanding of underlying issues that is necessary to take these forward into concrete investment actions.

Each of these is briefly discussed below, and are being developed into concept notes for funding.

4.1.1 Eastern Nile Energy Sharing Arrangements

Regional interconnection projects: The 2008 Eastern Nile Power Study commissioned by ENTRO showed an urgent need to supply electricity for socio-economic development and poverty reduction within the Basin as a whole. More specifically, it showed that It is possible to have profitable export of power from Ethiopia to Sudan and Egypt through high voltage transmission lines (BC ratio 2.7 – 4.0; payback <10 years). Based on this, the following need to be done:

- Immediate updating of power trade feasibility study is needed, not just to update data but also to include South Sudan in the power sharing arrangements.
- Immediate implementation of transmission line from Ethiopia to Sudan & Egypt. But need to include South Sudan in revised design
- Conditions must be put in place to facilitate power trade – e.g., expansion of transmission at regional level, strengthening of national grids to better absorb and distribute power to various demand nodes
- National utilities to be convened to examine demand and distribution capabilities, identify missing aspects for capacity building and new investments (to ensure that this new power can get to all the users?)

Many other projects could also be considered but these can only be specified after the integrated water resource management (IWRM) studies have been completed for the concerned sub-basins.

4.1.2 Coordinated Water Infrastructure Operations

Every cascade needs to be coordinated to reach its full hydropower generating potential, to maximize water savings and to realize other regional benefits such as better flood (and drought) management downstream. These in turn require, among others, the following:

- Coordination mechanisms for dam operations
- Revised dam filling schedules that take into account flow rates & reservoir volumes and reliable hydro-meteorological (hydro-met) data
- Updated flood forecasting program e.g., with daily flow reports on Blue Nile, revised modeling for Sudan on Blue Nile, etc.
- Drought forecasts - to make recommendations for operation of infrastructure
- A system optimization study to see where water may be saved
- National and regional programs to address dam safety and minimize dam safety risks

While the findings of the ENTRO cascade operations road map will be useful to outline further next steps, especially the critical issue of sequencing cascade development, there is also a need for a new study to identify next dams in a regional context, along with ancillary investments

4.1.3 Efficient Irrigated Agriculture

There is scope for optimized new irrigation for more sustainable development, but this needs the following:

- More information on water management and water efficiencies of different existing irrigation schemes from countries
- Countries to re-examine water requirements for irrigation projects under consideration & design new irrigation schemes that are economically viable and efficient
- Rapid implementation of irrigation efficiency program from Cooperative Regional Assessment (CRA) of Irrigation in the Eastern Nile Basin in 2007.
- Major new regional water savings program for rehabilitation of existing schemes and improved drainage, beyond the CRA project identified
- Water balance monitoring program including hydro-met networks, evapo-transpiration and sediment monitoring, etc.
- Countries to undertake improvements to national planning processes, to ensure that private sector water use in agriculture is part of national plans.
- More project information sharing for new irrigation developments, with basin hydrological analysis for better water savings/optimization

ENTRO can facilitate all of these by working with national governments, donor agencies and consultants and addressing each of these issues, in a coordinated fashion.

4.1.4 Watershed Management for Climate Resilience

Apart from the many well-known reasons for undertaking watershed development and management - such as arresting degradation of the natural resource base, reducing poverty, improving food security, flood & erosion control, conserving biodiversity and sensitive habitats & enhancing local and regional livelihoods and socio-economic development - better sediment management will also improve returns from hydropower infrastructure.

As the CRA for Watershed Management (ENTRO, 2007) and other studies indicated, there is a dire need for the next round of watershed management projects (e.g., in Baro-Akobo Sobat & Dinder-Rahad) that

- Learn from international & regional ‘best practice’ & lessons
- Review current status baseline data & address data gaps
- Implement effective community-based participatory planning
- Use participatory monitoring & evaluation for better effectiveness

- Studies potential savings & effects or development on other water users (urban), rain-fed agriculture, fisheries
- Analyses trade-offs between agriculture and livestock

Such watershed management projects, focused on 'hot spot' areas, should not only include well-designed and sustainable livestock management (e.g., demarcation of routes, water points, etc.) and fisheries management, but also address the key issues of rain-fed farming – which is the predominant source of livelihood within the Eastern Nile Basin – all within the context of the looming challenge of climate change.

4.1.5 Environmental and Social Assessments and Safeguards

While all future basin studies must also include climate change, it is vital that environmental flows are seen to be critical aspects of basin health, while designing and planning water infrastructure and irrigation projects. Ecology and conservation are an area for joint action, and this needs:

- A regional program to examine livelihoods, environmental flows, salinity, etc. to understand effects of increased upstream irrigation on downstream water quality
- The establishment of trans-boundary parks – with Steering Committees to conserve and manage internationally-important biodiversity areas, develop Integrated Catchment and Wetlands Management Programs, reduce NR-based conflicts
- Tourism-related water management for local & regional economic development
- Wetland studies and preservation program e.g., to establish new Ramsar sites

Further, there is a fundamental need to understand and consider the linkages between the natural environment, those who inhabit and derive a livelihood from these areas, and those who take decisions that affect them. To this end, it is necessary to have:

- Studies to understand social issues and consultation with local communities who stand to be affected by projects and development programs – by reviewing social assessment legislation, standards guidelines – and developing a standard set of guidelines
- Programs to make technical and scientific information available in a format that is accessible to the general public and decision-makers

One proposal to do this is to establish an **Eastern Nile Climate Change Detection and Advisory Services** at Watershed Level to understand linkages between environment and (traditional) livelihoods, and to promote cooperation between the EN countries.

4.1.6 Water Re-Use and Salinity Management

Water reclamation and re-use are vital to make more water resources available to address rising water demand within the entire Basin. Reclaiming and re-using wastewater, particularly from urban areas, and protecting groundwater from salinity (whether from the sea or from soil) are important parts of such efforts. Currently, however, there is a dearth of information and data on these aspects and there is therefore a basic need for:

- A delta management study and program to study delta water problems (e.g., salt water intrusion, salinity, etc.) and potential impacts of climate change
- A salinity monitoring program

4.1.7 Water Quality and Sediment Monitoring and Management

Water quality is a major issue in the sub-basin, particularly in Egypt, and is set to become critical in other urbanizing and industrializing areas of the Basin. Since pollution further reduces the scarce water resources in the basin, it is imperative that the available water is protected as best as possible from pollution – whether it is domestic sewage, agricultural chemicals or industrial effluents. There is, however, little information outside Egypt on the nature of different types of pollutants, their spread and impact and their growth over time. An urgent need, therefore, is to build up the information base and here the work done by Egypt could serve as a useful model for other parts of the Basin.

Currently projected returns from hydropower assume better rates than what currently achieved in the basin through sediment management. Apart from watershed management, there is an urgent need for a **regional sediment monitoring program**.

4.1.8 Groundwater Monitoring and Management

As in the case of water pollution, there is insufficient information on GW use in the Eastern Nile Basin, preventing any examination of sustainability, optimization of benefits, conjunctive use of ground and surface water, actions to control overdraft, etc. As groundwater is a critical part of overall basin water resources, and one that is likely to get stressed and over-exploited with an expansion in irrigated agriculture and increasing climatic variability, there is a need for:

- Groundwater studies to understand rate of withdrawal, 'hot spots', international 'best practice' in addressing groundwater over-draft, possible regulations, etc.

- A greater network of groundwater monitoring stations, observation wells, potential role of remote sensing in groundwater monitoring

4.1.9 Climate change adaptation capabilities

While it is imperative that all future studies of the Basin must include climate change, there is also a need to study potential climate change impacts, design and implement mitigation and adaptation mechanisms, monitor progress and change, and revise all planning and implementation processes to consider the potentially disruptive influence of climate change. There is therefore a need for

- Studies on the implications of increasing climatic variability (e.g., more flooding and drought disasters) and their impact on vulnerable populations in the basin

- Adaptation actions to 'climate proof' water resource infrastructure – which must be identified and implemented[25]

- Studies of local-level adaptation measures, especially to protect poor and vulnerable populations – which need to be identified and implemented

- Sharing global and regional lessons learnt in adaptation actions to protect against short-term climate variability (increased frequency and intensity of floods and droughts) and longer-term climate change impacts (e.g., temperature and rainfall changes) in different agro-ecological zones in the basin

4.1.10 Coordination and phasing of win-win-win ENB development packages

There is much to be gained by planning basin investments in a sequenced way. The need therefore is for Basin countries to plan investment using criteria to:

- Prioritize projects e.g., economic returns, social, environmental, regional significance, etc.

- Benefit sharing

- Sequence investments over time e.g., project readiness, institutional readiness, policy environment, etc.

Also, more multi-sectoral planning is needed at all levels. Countries should be aware of tradeoffs between new irrigation, irrigation rehab and new hydropower investments. This, in turn, needs:

- Coordinated multi sector packages which are critical for sustainable development and feasible investments in the basin

- Information sharing process on national investments - to analyze water use at basin level and implementation progress

25 See for instance, Cervigini et al., 2015) *Enhancing the Climate Resilience of Africa's Infrastructure*, World Bank,

- National level committees to discuss water use, culminating in regional-level management discussions on water use across sectors

4.2 Further Action

Following the acceptance of this report by the ENB countries, the following steps may be taken:

- Present the Report to national governments within the Eastern Nile Basin for their formal acceptance and endorsement
- Discuss the Concept Notes prepared with governments and potential funding organizations
- Convert Concept Notes into full-fledged project proposals, with the assistance of ENTRO
- Implement initiatives for which funding has been secured, with the help of ENTRO

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ANNEX

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Annex 1

The Eastern Nile Basin: **River System and Sub-basins**

Annex 1: The Eastern Nile Basin: River Systems and Sub-basins

A1.1 Eastern Nile Basin

River System

The Blue Nile (or Abbay as it is known in Ethiopia) river begins its long journey to the Main Nile from Lake Tana at an elevation of 1,800m in the highlands of the Ethiopian plateau and flows through Ethiopia and then into Sudan before making its confluence with the White Nile in Khartoum at an elevation of about 350 m. The combined flow, i.e., Main Nile, flows northwards through Sudan towards Egypt. Below the confluence at Khartoum, the only major tributary of the Main Nile is the Atbara River. Before reaching the Sudan-Egypt border the Main Nile reaches the reservoir of the High Aswan Dam (HAD) before flowing on through Egypt and making its outfall into the Mediterranean sea.

The Eastern Nile accounts for almost half of the 3.4 million square kilometer catchment area of the Nile River Basin. The Eastern Nile Basin can be divided into four sub-basins based on the hydrology of the basin:

1. The Abbay-Blue Nile sub-basin
2. The Baro-Akobo-Sobat sub-basin
3. The Tekeze-Setit-Atbara sub-basin and
4. The Main Nile sub-basin

Water Resources

Run-off: It contributes much more than half of the runoff to the Main Nile since the White Nile, which flows from Lake Victoria, makes a much smaller contribution (due largely to the fact that most of 100 billion cubic meters (BCM) of rainfall that falls annually on Lake Victoria evaporates). Similarly, the other lakes in the Equatorial Lakes Region of the Nile basin contributes relatively less additional runoff, and just over 30 BCM makes it to the Sudd from this upstream system. Despite being augmented by substantial flows (>11 BCM) from tributaries such as the Bahr-el-Ghazal, only about 15 BCM emerges from the Sudd (Africa's second largest wetland) to join the Blue Nile at Khartoum.

River lengths: The stream lengths and the slopes of all major rivers in the Eastern Nile basin have been calculated according to their change in elevation and horizontal chainage. The stream lengths and slope indicate that the longest river is the Main Nile (3,006 km) and the Akobo River has the highest slope (6.695 m/km). Among the major rivers, the shortest is the Baro River (280 km) and the White Nile River has the flattest slope (0.011 m/km).

Water Balance

An indicative water balance for the Blue Nile system shows that the mean annual flow at the Ethio-Sudan Border and the Roseries Dam is 51.03 BCM and 49.30 BCM respectively, indicating a loss of 1.73 BCM between the border and the Roseires station. Annually 6.3 BCM is abstracted from the Sennar reservoir for irrigation purposes while the Rahad-Dindar contributes 4 BCM and finally the annual mean flow of the Blue Nile at Khartoum becomes 48.7 BCM.

The inflow to the main Nile system at the Khartoum junction is estimated to be 74 BCM. The total Blue Nile inflow including that of the Rahad and the Dindar is 56 BCM. Accounting for mean annual abstraction of about 6.50 BCM and 0.786 BCM evaporation from the Roseires reservoir and the Sennar reservoir respectively in the Sudan Blue Nile system, 48 BCM of inflow reaches Khartoum.

The 30.5 BCM inflow of the Sobat-White Nile system at Malakal is reduced to 26 BCM downstream of the Jubel Aulia reservoir, the balance being for the abstractions in the Assalaya & Kenan sugar farms (all together 1.3 BCM), evaporation losses (estimated at 2.12 BCM) from the Gebel Aulia reservoir and losses through seepage and spillage along its route from Malakal to the Jubel Aulia reservoir. At Atbara, some 300km downstream of the Khartoum junction, the Atbara-Setite-Tekeze sub-basin contributes mean annual inflow of 12 BCM, which increases the inflow of the main Nile downstream of the Atbara confluence to be more than 84 BCM. The Sudan's abstraction downstream of the Khartoum confluence is insignificant (0.534 BCM). The mean annual inflow reaching the Aswan reservoir is estimated to be 84 BCM downstream (OSI Water Synthesis Report p. 174).

The mean annual flow of the Baro River at Gambella is 12.4 BCM (1980-2000). In its lower course, the flow spills and a large amount of spillage enters the Machar swamp. Annual spillage is estimated to be above 3.03 BCM (1980-2000). This spillage is estimated to be 3.6 BCM (1905-1955). At the mouth of the Baro River, the mean annual flow is recorded to be 9.53 BCM (1905-1955). Due to the combined flow from the Baro (9.53 BCM), the Gilo (3.2/1.12 BCM), the Pibor (0.224/1.04 billio m3) and the Akobo (3.9/0.37 BCM), the average annual inflow of the Sobat River at the Doleib hill located upstream of the Malakal station becomes 13.687 BCM (1905-1955). The mean annual inflow from the Sudd to the White Nile at Malakal has been estimated as 16.82 BCM and together with the Sobat system it is estimated to produce a mean annual inflow of 30.50 BCM to the White Nile system.

At the Jubel Aulia station, the average annual flow of the White Nile has reduced to 25 BCM. The flow loss is mainly due to evaporation from the Jubel Aulia reservoir as well as evapo-transpiration from agricultural activities. The White Nile system contributes about 30% of the Nile flow at Aswan. (ENTRO 2009b).

The Atbara River contributes 12.7 % of the total discharge of the Main Nile. The average discharge at the Kashm el Girba station (1986-2000) has been found to be 11.45 km3 . The total runoff is 52,834 m3 water per km2 per annum, compared with 169,612 m3/km2/yr for the Blue Nile and 28 833 m3/km2/yr for the Baro-Akobo-Sobat (ENTRO, 2006d).

The Blue Nile river, with a mean annual inflow of 50 BCM contributes 65% of the inflow to the Main Nile (ENTRO, 2006a) and 60% of the inflow entering the Aswan reservoir, while the White Nile and the Tekeze-Setit-Atbara contributes 25% and 15% of the inflow entering the Aswan reservoir respectively. **There are, however, inconsistencies in the data on the water balance at Aswan, which is s significant information gap with implications for the MSOIA since it is important to be able to accurately assess impacts of different development and management actions on the system downstream.**

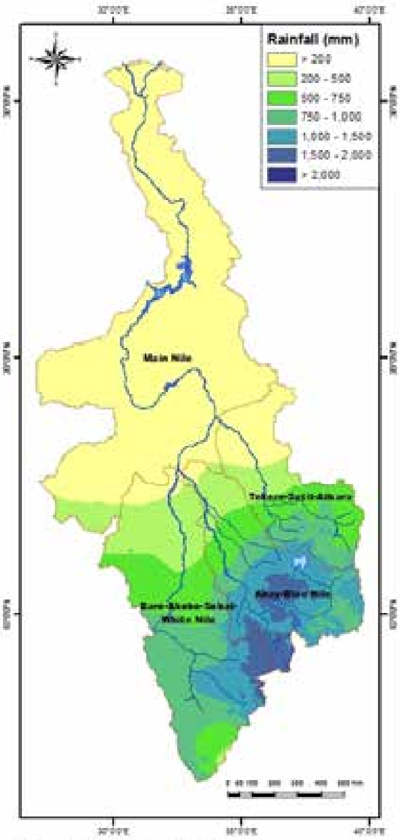
Overall Basin Perspective

The hydrological cycle in each sub-basin and the water balance of the entire Eastern Nile basin in terms of the "green water" used productively, infiltrated and evaporated and "blue water" that ends up in rivers shows that:

- The three upper sub-basins all have much more rainfall and surface water outflows than are experienced downstream in Sudan and Egypt.
- Very little of the water supply in Egypt comes from rainfall; the vast majority originates from surface water flows from Sudan.

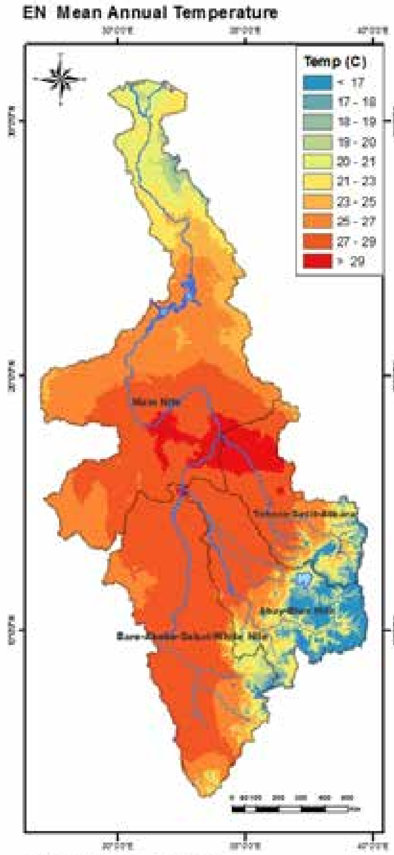
Figure A1.1: Green and Blue Waters of the Eastern Nile

Mean Annual Rainfall



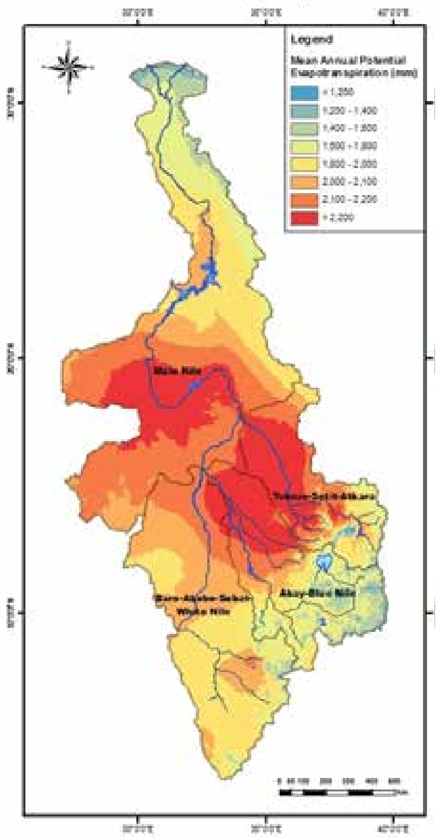
Source: WorldClim Precipitation Dataset

EN Mean Annual Temperature

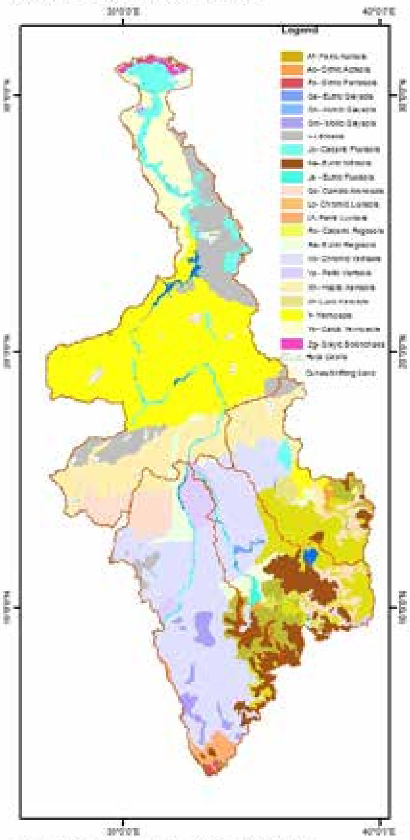


Source: WorldClim Temperature Dataset

EN Mean Annual Potential Evapotranspiration

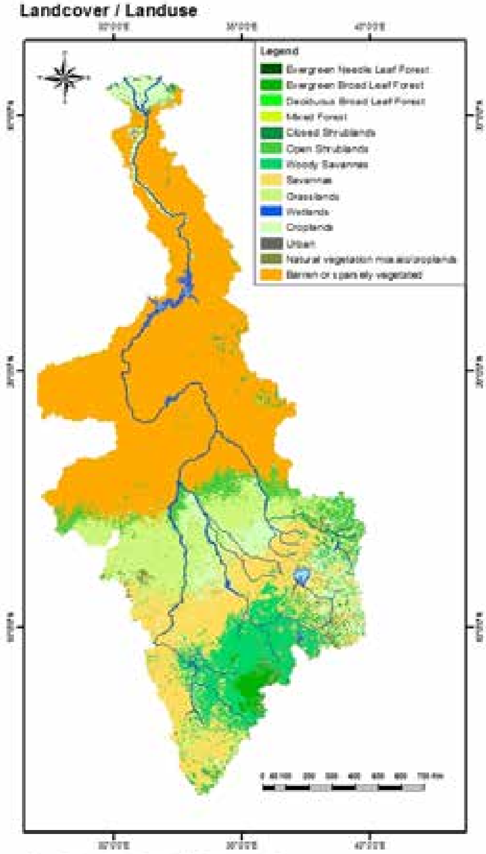


Dominant Soils of Eastern Nile Sub-Basin



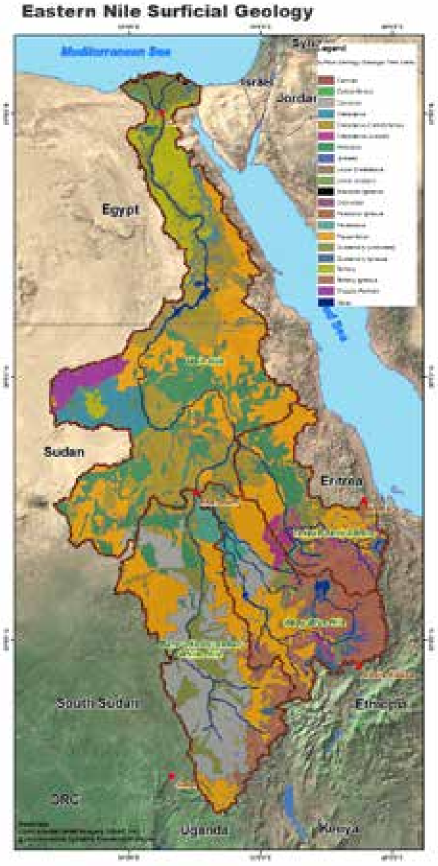
Note: Extracted from Digital Soil Map of the World (FAO of UN)

Landcover / Landuse



Source: Extracted from Global MODIS Landcover Database

Eastern Nile Surficial Geology



- Evapo-transpiration outflows in Egypt (includes crop water use, evaporation losses from reservoirs, and other system evaporation losses) is about 57 BCM annually, while another 13 BCM flows into the sea.

- Rainfall in sub-basins within Sudan plays a greater role but is still only about 30% of total inflows; evapo-transpiration there is about equal to surface water (outflows).

- In all three of the Ethiopian sub-basins the hydrology is dominated by rainfall. However, evapo-transpiration losses still far exceed surface water outflows. Of about 580 BCM of rainfall in Ethiopia annually, only 14% (about 80 BCM) makes it to a surface watercourse that flows to South Sudan or Sudan. Specifically, net amounts that reach the rivers are 12, 54, and 13 BCM for the Atbara, Blue Nile, and Sobat rivers respectively.

- The Sudd Swamps contribute approximately 15 BCM to the White Nile.

- Abstractions from the Eastern Nile system (approximately 60 BCM for irrigation) occur in the form of net consumptive use, net groundwater loss, and further losses (e.g. reservoir losses, conveyance losses in rivers, canals, irrigation systems, and through crops).

- Evaporation losses from man-made reservoirs in the system are high, both as a result of manlade reservoirs and naturally from lakes, wetlands and river channels. Annual evaporation is estimated to be almost20 BCM.

- Annual conveyance losses directly from the river channel, floodplains and associated wetlands are estimated at 20 – 23 BCM.

- There is high variability in flow in most part of most tributaries coupled with low per capita storage

- Erosion is very high in many parts of the up and areas and this results in high rates of sedimentation of reservoirs, reducing yield and lifetime

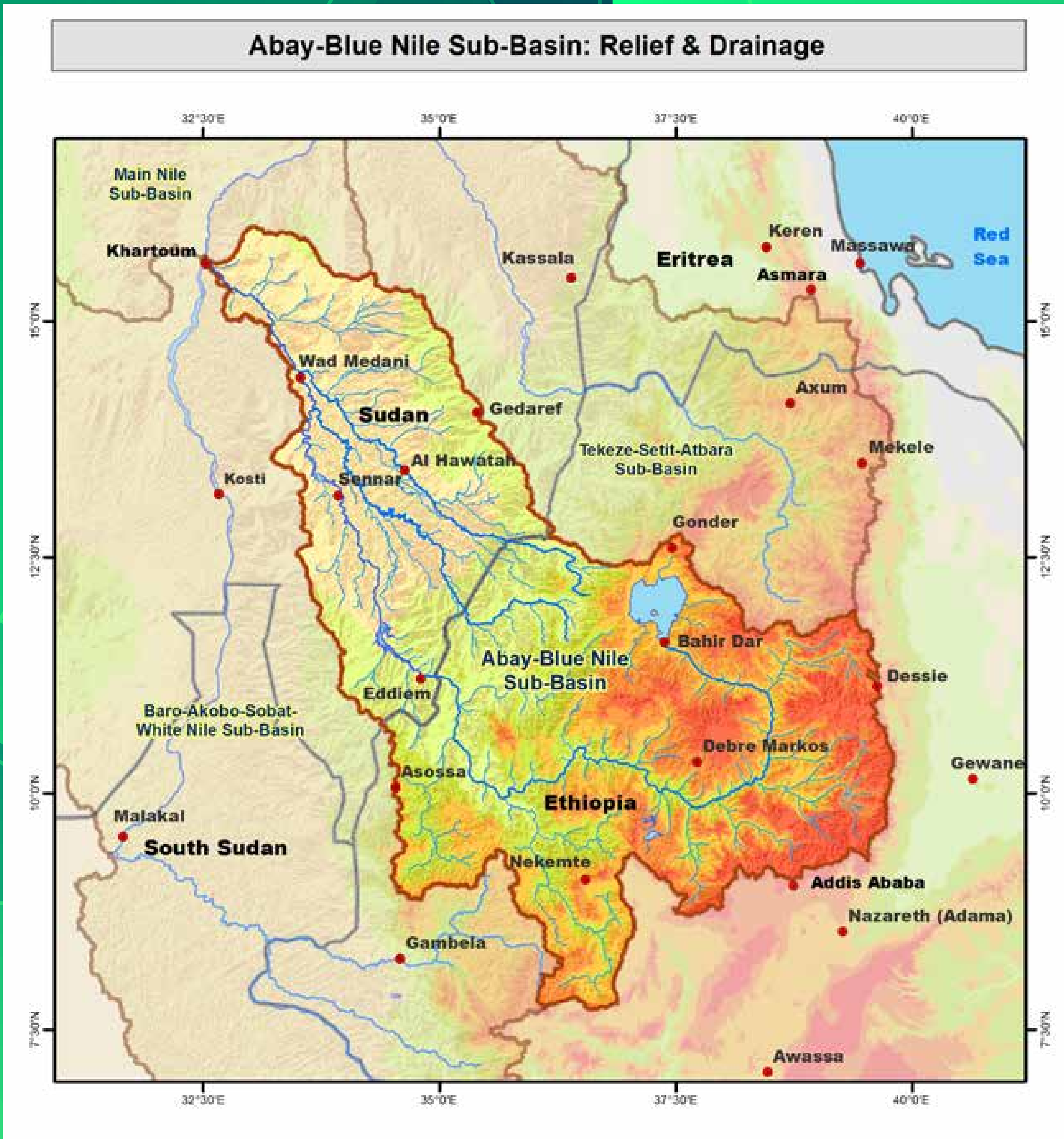
Overall it is also true that the understanding of the hydrology in many parts of the sub-basin is limited and there is a need to improve knowledge in these areas through further studies and improved data collection.

A1.2 Eastern Nile Sub-Basins

The Abbay-Blue Nile sub-basin

Catchments and river system: The Blue Nile (or Abbay as it is known in Ethiopia) river begins its long journey to the Main Nile from Lake Tana at an elevation of 1,800 meters above sea level (MASL) in the highlands of the Ethiopian plateau and flows through Ethiopia and then into Sudan before making its confluence with the White Nile in Khartoum at an elevation of about 350 MASL. It is fed by the Gilgil Abbay (the "little" Abbay, considered to be the start of the Blue Nile system). The Blue Nile derives its name from the relatively dark colour of the sediment-laden water when it meets the clear White Nile at Khartoum.

Area and Population: The sub-basin has an area of over 310,000 km2. With a population of 39 million, this sub-basin accounts for around 26% of the total population of the Basin and is the second most populous of the four sub-basins after the Main Nile sub-basin. Most of its population, around 25 million, lives inthe Abbay sub-basin, which is largely located within the Benishangul-Gumuz and Amhara Regional States of Ethiopia, with a small area in the Oromia Regional State. The remaining 14 million live in the Blue Nile sub-basin, which starts where the Abbay enters Sudan from Ethiopia and is divided into the southern and northern zone. The southern zone stretches from the Sudan-Ethiopian border to Khartoum State, and includes the states of Blue Nile, Sennar, Geziera, and Khartoum.



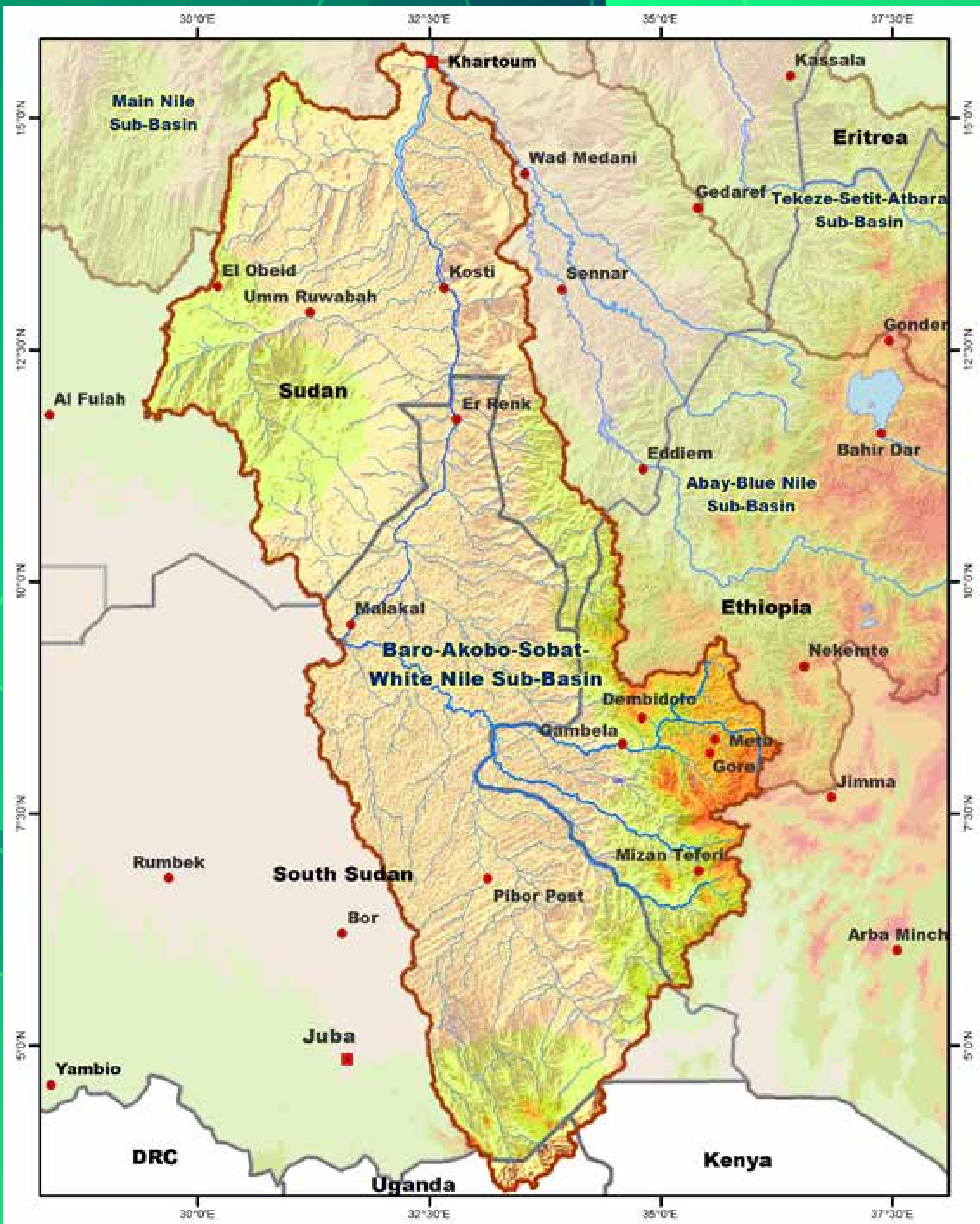
Water Resources: The mean annual runoff and other water resource parameters at different points in the sub-basin are summarized below (see Table A1.2)

Table A1.2: Mean annual runoff and other water resource parameters in the Abbay-Blue Nile sub-basin

Location / Parameter	Annual volume (1000xMm3)
Lake Tana outflow	4.079
Abbay upstream of Mandaya	26.260
Abbay at Ethiopia/Sudan border (Diem)	49.674
Blue Nile downstream of Sennar Dam	41.017
Blue Nile at Khartoum	43.661
Mean annual evaporation from lakes and wetlands	2.179
Reservoir storage including Lake Tana	39.16

The Baro-Akobo-Sobat-White Nile sub-basin

Catchments and river system: The sub-basin consists of the Baro River (and its tributaries such as the Birbir) and the Akobo river (with its main tributary, the Pibor). After the confluence of the Baro and Akobo, the river is called Sobat in South Sudan. The Baro, the Akobo and the Pibor rivers are all tributaries of the Sobat River which makes its confluence with the White Nile near Malakal. The Baro Originates at an elevation of 2,200 m and the Akobo at an elevation of 1,000 m. The river makes its way from an altitude of over 3000 masl in the Ethiopian hills to about 400 masl when the Sobat crosses into South Sudan on the way to its junction with the outflow from the Sudd wetlands. There are important wetland areas in this sub-basin. The seasonal rainfall pattern and large flat areas have resulted in the formation of many wetlands (e.g. the Gambella, Machar Marshes, etc.) that have been a defining influence on the activities of the people (including tribal groups) of the sub-basin. The Machar wetland is located north of the Baro River upstream of its confluence with the Pibor River. The Machar swamp has been studied by different research teams since 1950.



Area and Population: Spread over 206,000 km2, the total population of the sub-basin was 10 million in 2006 of which 7.6 million (76%) was rural. Of this total 5.5, 3.3 and 1.7 million lived in Ethiopia, South Sudan and Sudan respectively. The Baro-Akobo-Sobat-White Nile sub-basin is located in southwestern Ethiopia and eastern South Sudan and is home to four regional states in Ethiopia (Gambella, Benishangul Gumuz, Oromiya and SNNPRS) and three states in South Sudan (Jongeli, Unity and Upper Nile).

Water Resources: The mean annual runoff and other water resource parameters at different points in the sub-basin are summarized below (see Table A1.2)

Table A1.3: Mean annual runoff and other water resource parameters in the Baro-Akobo-Sobat Sub-basin

Location / Parameter	Annual volume (1000xMm3)
Baro at Gambella	12.139
Baro u/s of Machar Wetlands	12.878
Machar Spill	3.541
Baro at confluence with Sobat	9.341
Akobo upstream of Twalor wetlands	5.560
Twalor Spill	2.518
Akobo (Pibor) at confluence with Baro/Sobat	3.634
Sobat upstream of White Nile confluence	13.328
White Nile downstream of Sobat confluence	30.290
White Nile at Khartoum	26.677
Mean annual evaporation from lakes and wetlands	1.950
Reservoir storage	4.610

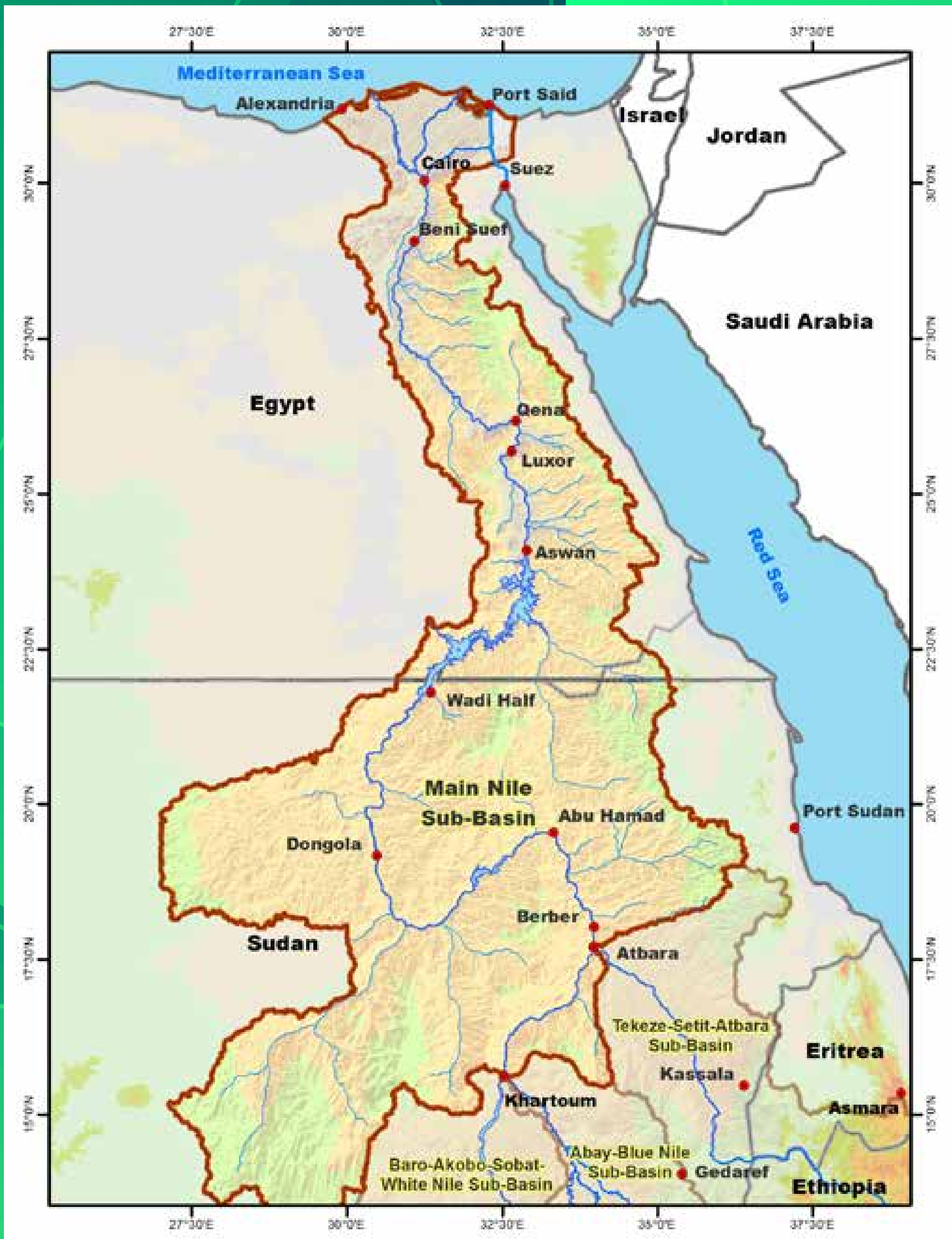
The Tekeze-Setit-Atbara sub-basin

Catchments and river system: This sub-basin is created by the Tekeze river (known as the Setit in Sudan), and its tributaries, the Goang (Atbara in Sudan) and Angereb, all of which originate in the north central highland plateau of Ethiopia. As the river makes its 1325 km journey, it falls from a height of about 3000 MASL near its origin to about 300 masl when it joins the main Nile in Sudan, about 285 km downstream of Khartoum. The sub-basin comprises two major catchments covering the Ethiopian north western highlands (Tekeze river basin) and the Sudanese eastern lowlands (Atbara river basin).

Area and Population: The sub basin crosses two national boundaries, that of Ethiopia and Sudan, and it population is made up of two groups: The first group lives in upper portion of the sub-basin located in Ethiopia and falls within the regional states of Amhara and Tigray; the second group lives in three Sudanese states of Nahr Elnil, Kassala and El Gadarif. The population of the sub-basin in 2007-08 was 13.5 million of which 9.3 million lived in Ethiopia and 4.2 million lived in Sudan. This sub basin, like the other sub basins of the Eastern Nile, extends from the Ethiopian highlands north of Lake Tana and flows westward into the Sudan, joining the Nile as its last tributary at the town of Atbara. The Tekeze River basin includes the Tekeze River, Angereb River and the Goang River.

Water Resources: The mean annual runoff and other water resource parameters at different points in the sub-basin are summarized below (see Table A1.2)


32°30'E
35°0'E
37°30'E
40°0'E
17°30'N
15°0'N
12°30'N
Berber
Atbara
Main Nile
Sub-Basin
Red Sea
Sudan
Aroma
Eritrea
Keren
Massawa
Khartoum
Kassala
Asmara
Halfa' al Jadidah
Teseney
Wad Medani
Shuwak
Humera
Adigrat
Inde Selassie
Axum
Adwa
Gedaref
Tekeze-Setit-Atbara
Sub-Basin
Mekele
Abay-Blue Nile
Sub-Basin
Ethiopia
Kosti
Sennar
Debark
Metema
Maychew
Gonder
Lalibela
Bahir Dar



The Main Nile sub-basin

Catchments and river system: The sub-basin covers the entire region from the point where the Nile River from Khartoum covering Northern state of Sudan to Egyptian-Sudanese boarder and flows north towards Cairo before ending in the Mediterranean Sea. The entire sub-basin is located within Egypt.

Area and Population: The Main Nile sub basin covers an area of 656,000 km2. and has an estimated population of 79 million in 2006. This is the most populated of the four sub-basins.

Water Resources: The mean annual runoff and other water resource parameters at different points in the Main Nile sub-basin are summarized below (see Table A1.4)

Table A1.4: Mean annual runoff and other water resource parameters in the Main Nile Sub-basin

Location / Parameter	Annual volume (1000xMm3)
Nile downstream of Blue Nile and White Nile confluence	70.338
Nile upstream of Atbara	69.714
Nile downstream of Atbara	81.067
Nile upstream of Aswan Dam	78.501
Nile downstream of Aswan Dam	63.651
Nile at Baladela	43.088
Nile Outflow to Mediterranean	12.573
Mean annual evaporation from all lakes and wetlands	15.270
Mean annual evaporation from Aswan Dam	13.318
Reservoir storage	181.870

Annex 2

Photo istock/NBI

The Eastern Nile Basin: **Water Management Issues**

Annex 2: The Eastern Nile Basin: Water Management Issues

A2.1 Soil Erosion And Sedimentation Control

The scale of the problem

Soil erosion by water and its complement high sediment loads in streams and rivers together with soil nutrient depletion are the two major land degradation processes. These have major impacts on agricultural production and thus on peoples' livelihoods. Agricultural production forgone is caused by soil erosion, dung/crop residue burning and crop removal through:

- Reduced moisture-holding capacity and nutrient loss from soil erosion.
- Nutrient breaches due to the burning of dung and crop residues and grain removal.

The total amount of soil eroded each year in the Eastern Nile Basin is estimated at 447 million tons with 68 %, 22 % and 10 % eroded in the Abbay, Atbara-Tekeze and Baro-Akobo Sub-basins respectively. Of the total, 151 million tons (33 %) is from cultivated land and 201 million tons (76%) is from mainly communal grazing and settlement areas. The area of cultivated land whose use is considered to be unsustainable is estimated at 4.7 million ha.

With the natural increase in population the area under cropland will increase. Whilst some of the expansion will occur as infilling on suitable land, much will take place on land marginal for crop production because of shallow soils and steep slopes. In the absence of substantial watershed management interventions it is estimated that by 2025 cropland will expand by some 2.93 million ha in Ethiopia in the Eastern Nile Basin (Benefits of Watershed Management in the Context of JMP, July 2007). The potential for increased erosion and soil loss in the EN Basin, specifically the Abbay-Blue Nile sub-basin, is therefore substantial.

Based on these figures it is clear that the Abbay sub-basin has the highest levels of soil erosion in the EN Basin, more than three times higher than the Atbara-Tekeze sub-basin. This is not surprising given that the Abbay sub-basin also has the second highest population after the Main Nile sub-basin. The population of in the Ethiopian highlands is also projected to increase significantly over the next 15-20 years. Therefore in terms of priorities, the focus of catchment management programmes should therefore be in the Abbay sub-basin, followed by the Atbara-Tekeze and the Baro-Akobo-Sobat sub-basins.

Addressing the problem

Research has shown that watershed management interventions can have a substantial impact on arresting degradation of the natural resource base both on cropland and also on non-cropland. This is a vital entry point in breaking the cycle of poverty and resource degradation and attacks one of the root causes of poverty in the Eastern Nile Sub-basin.

The majority of the sediment load generated in the EN Basin is from the Abbay sub-basin, which accounts for almost 68% of the total sediment load. Addressing soil erosion at its source, namely in the Ethiopian Highlands, would therefore have significant trans-boundary benefits. In addition, combined with other elements, the programme would also assist Ethiopia to address rural poverty in the Ethiopian Highlands. The other area for investment is the Baro-Atbara-Sobat sub-basin. The quantifiable benefits of reduced erosion in the Ethiopian Highlands and sediment loads in the Eastern Nile river system include reducing costs in Sudan associated with dredging of power intakes and irrigation canals and improved power generation potential. A reduction of Abbay-Blue Nile and Tekeze-Atbara River systems' sediment load could also contribute to a reduction in the rate of loss of live storage in dams in Sudan and Egypt and the loss of potential irrigation water and power generation for Egypt and Sudan.

Reduced sediment loads in the Rahad and Dinder Rivers could also reduce siltation of the maya'a wetlands in Sudan and thus reduce the incidence and extent of flooding and the damage this causes to crop production. They could also contribute to a reduction in the sedimentation of the Meroe

Dam and to an increase in its economic life. However, in the Baro-Sobat-White Nile River systems, the quantifiable benefits to reduced erosion in the Ethiopian Highlands are limited.

Some water management issues such as salinity and deteriorating water quality are also described as part of 'Environmental Issues', detailed in Annex 3.

A2.2 Flood Management

The scale of the problem

The Eastern Nile region is characterized by highly variable climate and river flows, making it prone to consequences of extremes of droughts and floods. A significant proportion of the annual runoff volume occurs during a few high rainfall months in the year, thus, requiring adequate regulation to maintain required flow during dry periods. During high rainfall periods major rivers in the region often give rise to large scale riverine flooding, particularly in floodplain areas in Sudan and Ethiopia. Severe flooding along populated areas, can have devastating effects on lives, livelihoods, and property. Infrastructure, agricultural land, and other resources at risk from floods can be vast, and include residential, commercial and industrial property, and public service infrastructure, including water supply. The Eastern Nile region is particularly vulnerable to these frequent and damaging floods, causing significant loss of life and economic damages.

Flood events originating in the Blue Nile River and its tributaries are of concern to the EN riparian countries of Ethiopia and Sudan. Flood events along the EN are typically caused by heavy rainfall in the Ethiopian highlands. Flood flows then concentrate in Ethiopia and Sudan before traveling downstream into Egypt. Each of the four countries is interested in being able to forecast river conditions, but the unique characteristics of the river regime in each country yield a different focus for each country with respect to forecasting needs:

In Ethiopia, localized, flash floods along Nile tributaries are of greatest concern. Example flood prone areas are Lake Tana and the Gambella plains. The Blue Nile River gorge is well entrenched, so that high flows in the gorge are generally not a safety concern. With the development of hydropower, however, there may be increased interest in hydrologic forecasting for reservoir operations.

In Sudan, the main riverine flood risk areas are located along the Blue Nile and the Main Nile. In addition, localized and flash flooding affects areas along tributaries to the Nile, such as the Atbara, Dinder and Rahad Rivers. The effects of these flash floods can be more severe when they coincide with flood flows on the Blue Nile.

In South Sudan, flood prone area in the Sobat river system due to both localized and flash flooding affects as well as river bank overtopping along the tributaries of the Sobat river cause devastating impact to the local communities.

High flows in the Nile River in Egypt affect mostly the operations of High Aswan Dam (HAD), which must be operated to prevent flood damage downstream while also preserving volume from year to year for hydropower and downstream agricultural production and water supply.

Major Flood affected Communities in the Eastern Nile Basin

Around Lake Tana, Ethiopia: The flood impacted communities around Lake Tana include 3 administrative zones as part of the Amhara region. These are mainly the Fogera and Dembia floodplains which are part South Gonder and north Gonder administrative zones. The Amhara National Regional State (ANRS) is located in north-central and north-western Ethiopia, occupying a land mass of approximately 170 152 km2. The region is divided into 11 administrative zones, which are further subdivided into 106 woredas. The 11 administrative zones are: North Gonder, South Gonder, West Gojjam, East Gojjam, Awie, Wag Hemra, North Wollo, South Wollo, Oromia, North Shewa and Bahir Dar City special zone. Table A2.1 profiles the woredas and kebeles that have been identified as most at risk from flooding in the Amhara Region:

Table A2.1: Flood-Prone Woredas around Lake Tana

Zone	Woreda	Population		
		Rural	Urban	Total
South Gonder	Fogera	49 224	464 071	513 295
North Gonder	Dembiya	274 756	31 915	306 671
Bahir Dar	Bahir Dar City	--	159 955	159 955

Source: Annual Statistical Bulletin, BFED, 2003

The general assessment of flood exposure and vulnerability in Lake Tana reveals the following:

- Flooding in urban areas around lake Tana is mainly derived from heavy rainfall and stormwater runoff. Lack of adequate drainage system is the main cause of flooding.

- Most communities at risk from flooding in rural Amhara are located in low-lying flood plains. Floods are a necessary annual occurrence and, for the most part, communities have adequate knowledge of how to live with, and benefit from them. There is less capacity in these communities to deal with serious floods, however.

Gambella, Ethiopia: The Gambella plain lies in south-western Ethiopia and is part of the Baro-Akobo river basin. The Gambella plain, which makes up the western half of the Baro-Akobo basin, is characterized by rivers that originate from highlands around Gore and Masha in the east. Major rivers in the areas are Baro, Akobo, and Gilo. The two most important causes of flooding in the Gambella area are flooding resulting from rivers overflowing their banks and flooding due to inadequate drainage. Riverine flooding is further aggravated by backwater effects from the Pibor and Sobat rivers. The city of Gambella is subject to occasional flooding caused by overflow of the Baro river and some of its tributaries. There are also other cities located on the north of the Baro river that are occasionally flooded (see Table A2.2).

Blue Nile and Main Nile, Sudan: Over the last years, heavy flooding was experienced in Sudan in 1998, 1999, 2001, 2002 and 2003. Socioeconomic impacts of these floods included the displacement of large communities, the loss of agricultural crops, damage to agricultural inputs such as seeds and pumps, deterioration of health conditions due to the increased incidence of malaria and diarrhoea diseases, and disruption of social services such as education and health. It is estimated that a total of 256 local communities adjacent to the river banks of the Blue and Main Nile are flood prone areas (see Table A2.3)..

Table A2.2: Flood Damage to the Gambella Area

Woreda	Year	Population affected	Woreda	Year	Population affected
	1993	6 157		1993	28 431
Gambella	1995	27 207	Itang	1995	33 906
	1996	10 000		1996	24 267
	1993	500		1993	27 236
Abobo	1995	33 906	Jikao	1995	19 910
	1996	-		1996	10 000
	1993	9 000		1993	12 921
Gog & Jor	1995	8 510	Akobo	1995	17 641
	1996	22 500		1996	18 000

Table A.3: Summary of high risk flood prone areas in the Blue Nile and Atbara Rivers

State	Locality	Target Community	Target population estimates
Blue Nile	Gissan	Seven villages	22,440
	Damazin	Azuhur Extension	13?900
Sinnar	Singa	Elsabounabi village Umbaneen village	10,000 11,000
Khartoum	Khartoum	Tuti Island	18?000
	Khartoum North	Wawoosi village	6,000
River Nile	Addamar	Seedon	9,300
		Abaka	7,000
Total			**97,640**

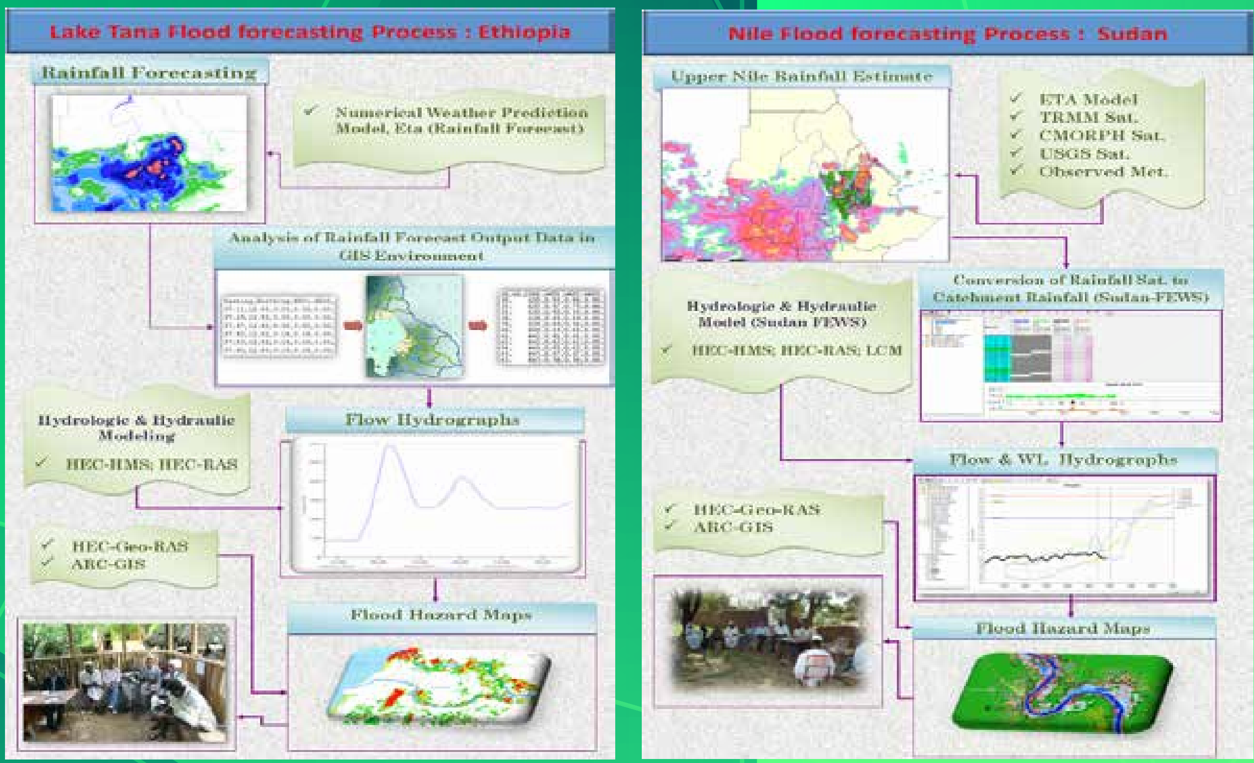
Tuti Island, Khartoum State: As an island, Tuti Island has always been threatened by floods. The floods of 1946, 1975, 1988, 1994, 1998 and 2001 were particularly severe. What sets Tuti Island apart is the way in which the community has mobilized their own resources and capacities to manage floods. The island has become a model case for resisting resettlement as a flood mitigation measure. At the beginning of the rainy season (from late June) people will reinforce all sand levees with sand bags. All openings that are used as access roads to the river's edge during the dry season will be closed and fortified. In a normal year, the water level will inundate up to some 80 m from the bank. It will inundate lower ground and can remain there for up to 3 months. Water-logging, with its associated problems of malaria, flies and other water-borne diseases, is considered one of the main problems of flooding on the island.

Addressing the problem

The Flood Preparedness and Early Warning Project FPEW I is one of the fast-track projects identified for priority action under ENSAP. The project ended in 2010, but it established the relationships for joint action through its strong focus on networking, communication, information management, capacity building, and institutional strengthening in flood preparedness. The approach is highly cooperative. FPEW brought together relevant national government offices in Ethiopia and Sudan, local governments, relief agencies, and community members. The established national flood coordination units (and regional units in flood-prone areas in Ethiopia) strengthen communication and ensure coordination of flood-related activities across the eastern Nile.

After the completion of FPEW I project ENTRO continue with Flood forecast and Early Warning activity starting from 2010. Every flood season ENTRO conduct this activity to conducts daily monitoring with three-day lead-times to produce forecasts for Lake Tana, Blue Nile in Sudan and BAS sub basin flood prone areas. The project utilized already available knowledge in the region to develop Numerical Weather Prediction (NWP) models, and flood forecasting models. This has created link among Ministry of water affairs, universities, meteorological agencies and ENTRO which created common ground to work together. Daily, weekly, and seasonal flood forecast reports are generated and disseminated to different users at different levels through the ENTRO web portal, email, and mobile phone messaging. The results of this program were found to be very encouraging to be taken over beyond the pilot phase as well as to replicate to other flood prone areas in the region.

Figure A2.1: EN Flood Season Monitoring and Operationalization of Flood Forecasting Tools



Annex 3

Photo istock/NBI

The Eastern Nile Basin:
Social and Environmental Issues

Annex 3: The Eastern Nile Basin: Social and Environmental Issues

Socio-economic and environmental contexts are intertwined and this is especially true when the livelihoods of a large proportion of the population are directly dependant on natural resources, as is the case in the Eastern Nile. With this understanding, however, these two aspects are treated separately below.

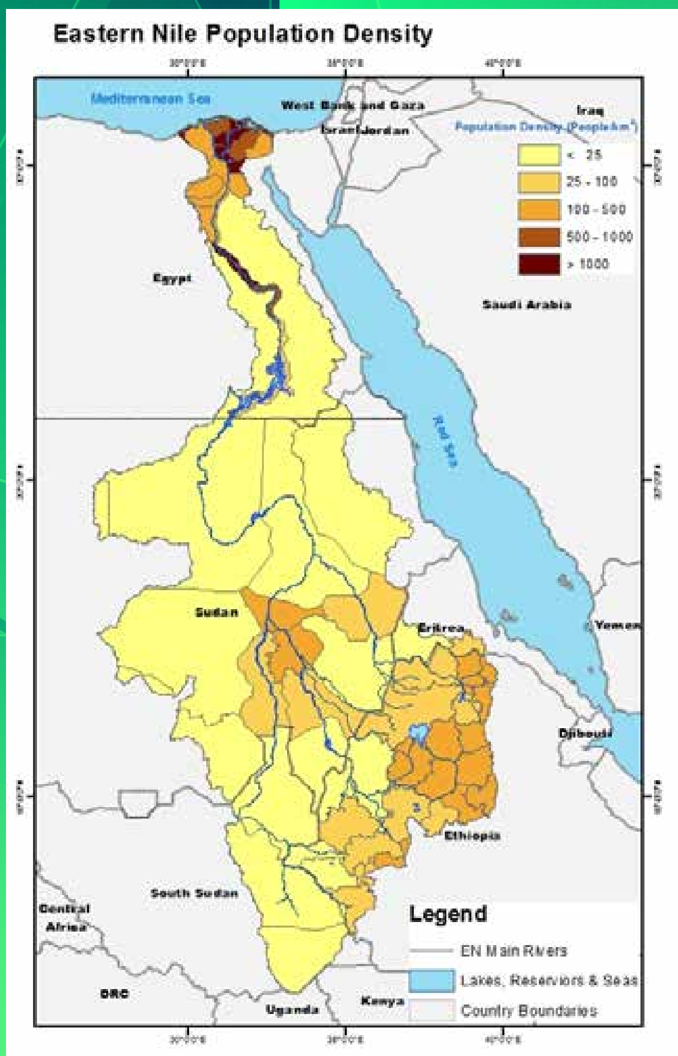
POPULATION AND SOCIAL DEVELOPMENT

The population of the ten Nile countries was estimated at 424 million in 2010,[26] and 54% – 232 million – live in the four countries of the Eastern Nile basin (see Figure). Ethiopia has the largest total population, closely followed by Egypt. But while most Egyptians live within the basin, the proportion is lower in Ethiopia. A large percentage of the populations of South Sudan and Sudan also lives within the basin. Settlement patterns in the lower riparians clearly follow the river. Population density is therefore very high in the Nile Delta and Nile valley in Egypt, which represent 5 per cent of the country's total land, while vast stretches of the desert are unoccupied. This pattern continues in the north of Sudan, with most people living along the River Nile, in the Khartoum area, and in the irrigated areas south of Khartoum.

- Egypt: 84.5 million, of which 82.9 million live in Main Nile Basin;
- Ethiopia: 85 million, of which 34.1 million live in EN sub basins
- Sudan: 34 million, of which 32 million live in EN sub basins
- South Sudan: 11 million, of which 3.5 million live in the EN sub basins.

The medium population growth projections for the EN Basin indicate that the population of Ethiopia will grow to 132 million by 2030, Egypt is projected to increase to 111 million, Sudan to 46 million and South Sudan to 17 million. Significantly, the population of Ethiopia is projected to increase to 186 million by 2050, while the population of Egypt projected to increase marginally from 111 to 114 million. This is due to the continued existence of a large, rural population in Ethiopia.

Of the total population the majority of the population in Ethiopia (82%), Egypt (57%), South Sudan (83%) and Sudan (55%) were rural in 2010. However, there is a move towards urbanisation, with the rural population in Ethiopia, Egypt and Sudan projected to decrease to 73%, 50% and 39% respectively by 2030. No information was available for South Sudan. However, given the limited level of infrastructure development the majority of the population are likely to remain rural.



[26] United Nations Population Division

With a large proportion of the population living below the poverty line, the Nile countries are facing serious socioeconomic challenges. This condition is reflected by their ranking in the Human Development Index (HDI).

AGRARIAN NATURE OF BASIN ECONOMIES

The agricultural sector makes a substantial contribution to national economies, but has an element of insecurity: Economic growth in wet years tends to alternate with contraction in drier periods. Agriculture provides food for rural people, mostly through small-holder, rain-fed subsistence farming. In the upper Nile countries, agriculture employs almost all the workforce, but is increasingly unable to meet the needs of growing populations.

- Ethiopia: Agriculture contributed 43% to the total GDP and accounted for 85% of the total labor force
- Egypt: Agriculture contributed 14% to the total GDP and accounted for 32% of the total labor force
- Sudan: Agriculture contributed 32% to the total GDP and accounted for 80% of the total labor force

The State of the River Nile Basin Report (2012) notes that the rapidly rising population in the Nile Basin presents enormous challenges for the region and the riparian governments, placing increasing pressure on regional natural resources, infrastructure, and services.

Most people in the rural areas are intimately dependant on the agricultural economy and as such, the natural resource base, for their livelihood and food security. The agricultural sector therefore plays a key role in the economy the EN region. Sustainable development therefore requires the implementation of effective and appropriate rural development policies coupled with the sustainable use of the regions natural resources.

The State of the River Nile Basin Report (2012) notes that the increasing population pressure and demand for land will result in encroachment into natural areas and national reserves, which will in turn impact on the functioning of natural ecosystems. Population growth will also result in the fragmentation of agricultural holdings, settlement on marginal lands, and rising landlessness. As a result tension over access to and use of natural resources, such as water, arable land and grazing, is likely to intensify and create the potential for local conflicts. In the EN Basin resource related conflicts are already widespread. Local authorities will also be placed under growing pressure to provide clean water and improved services, such as sanitation, to scattered rural settlements. Failure to improve rural livelihoods will perpetuate poor living conditions and accelerate rural to urban migration, with marginalized and landless people moving to the larger towns and cities in search of work, better services, and better education opportunities. This will in turn place growing pressure on the services in these cities.

GROWING URBANIZATION

In this regard rapid urban growth poses specific challenges to city administrators with regard to high unemployment and provision of key services, such as housing, water, sanitation, health care, schooling and waste management. Urban growth in the EN Basin is typically not well planned, with many urban poor living in informal settlements.

Despite the challenges, there have been improvements in the access to water for urban populations in the EN Basin. With Egypt and Ethiopia having 100% and 98% of their urban population respectively having access to improved drinking water in 2008.

The growing population in the Eastern Nile Basin will in turn increase the demand on water resources. The impact of population growth on food security is amplified in the Basin given that the majority of the large rural population cannot afford food imports. Their food security depends on local produce for food security, mostly grown in close vicinity to the actual consumers.

CHALLENGES

The State of the River Nile Basin Report of 2012 summarizes the challenges and opportunities as:

- Rising populations put increasing pressure on natural resources, underlining the critical importance of managing natural resources in a sustainable way;
- Most basin countries will continue to have predominantly rural populations until at least 2030, leading to land fragmentation and serious environmental degradation;
- Lack of opportunities in rural areas is causing people to migrate to cities;
- Governments need to intensify efforts aimed at rural development and at making rural areas more productive;
- Unplanned urbanization is posing major challenges for city governments in terms of the management of pollution and traffic congestion, and the provision of social services, housing, and essential infrastructure;

The State of the River Nile Basin Report concludes, "given the economic conditions and natural resource limitations in the Nile Basin, the challenges posed by the rising population currently outweigh the likely benefits". In order to address these challenges the Report suggests two distinct policy focus areas, namely:

- Foster rural development and efficient resource management for the large rural populations
- Accommodate and manage rapid urbanization.

OPPORTUNITIES

The EN Basins growing population Basin also creates opportunities for economic development and growth including opportunities for local and foreign investment in large-scale production of goods and services. An expanding population increases the availability of labour, and creates growing demand for food produce, manufactured goods, and services. However, a number of conditions will be required to achieve sustained economic development. These include provision and maintenance of effective services and infrastructure, such as water, sanitation, housing, education, health care, roads and transportation (State of the River Nile Basin Report, 2012).

THE ENVIRONMENTAL SITUATION IN THE EASTERN NILE BASIN

The area of the Eastern Nile basin reaches 1, 787,624 km^2, of which the main Nile alone covers about 45 %. For the rest of the basin, the share of area coverage goes in the order of Baro-Akobo-Sobat and White Nile (26.3 %), Blue Nile 17.2 %) and Tekeze-Atbara-Setit (12.9 %). About 46 % of the Eastern Nile basin falls in the altitude range of 200-500 masl and can be considered as desert. The mid altitude (1500 – 2300 masl) covers 13 % of the whole basin. The highlands in the upper part of the eastern basin constitute only 5 % of the total area.

Analysis of the physiography data shows that about 84 %% of the basin's land area has a slope gradient below 5 %, corresponding to very flat-to-flat relief. The largest part of the flat topography lies in the middle and lower part of the basin. This portion is characterized by floods and sediments originating in the uplands constituting only 10 % of the whole basin area.

According to data from the FAO and the Woody Biomass Inventory and Strategic Planning Project (Ethiopia), 35 % of the basin's area is covered by tree crops, followed by croplands, and deciduous woodlands, covering 14 % and 12 %, respectively. Grassland occupies close to 11 %, while forestland coverage is estimated below 2.5 % of the total area.

Approximately 63 % of the basin's area receives a mean annual rainfall below 600 mm. Areas belonging to the humid and peri-humid zone in the Upper part, covering 25 % of the eastern basin area, receive over 900 mm a year. Around 60 % of the basin (middle and lower regions of the basin) has a mean temperature of over 25 0C. .

Poor land cover, high rainfall and steep slopes in the upper part of the basin are believed to cause severe soil erosion hazard. This concerns more than 38 % of the basin.

Large areas of forest have been altered by some form of clearing or tree removal. Many of these areas have been given over to human settlement and agricultural use. Some disturbed forests remain in few areas as National Priority Forest. Nevertheless, the situation has become critical with exploitation and uncontrolled burning exceeding the rate of forest growth. Very few primary forests remain on the steepest slopes where agriculture is not feasible.

With the high rate of increase in both human and animal populations, remnant woodlands and bush lands continue to be under pressure. A number of factors have contributed to this, including:

- population growth which induces both an increased demand for agricultural land and pasture and results in increased fuel wood harvesting exceeding regenerative capacity,
- long droughts,
- flooding and high winds.

Seedlings, whether from natural regeneration or plantation, usually suffer abrasive dust, sand storms, drought, browsing and animal trampling. As a result, much of the vegetation in the sub basins has disappeared and very little of the original vegetation remains.

Populations of the wide variety of wildlife in part of the Abbay/Blue Nile sub-basin, including the Walia Ibex, Key Kebero (Ethiopian wolf), the Gelada Baboon and the Mountain Nyala, are on the decrease due to anthropogenic pressures.

In the vast plains of the lower altitudes, trees and shrubs are usually gathered for domestic animals. Most of these areas have been deforested for rain-fed mechanized agriculture, which led to the rapid disappearance of the natural vegetation. Over-grazing, especially during the rainy season, has become the main hazard to plant density. More than half of the areas in the plains are drought-prone as they lie in the semi-desert belt.

Another threat is the hazard of fire. Expansion in mechanized rain-fed agriculture for food production has been at the expense of the natural ranges; and the balance between the numbers of livestock and grazing has been disrupted. There has been illicit felling of trees for domestic and commercial purposes especially in the remote and inaccessible parts of the plains. Lack of clear land use policies has also been an additional constraint to forest conservation. Furthermore, war conditions have led to the destruction of plantations owing to unauthorized felling of trees for commercial logs. Official figures on government plantations in the lower altitudes, for instance, illustrate that 80 % of the teak plantation has been damaged.

In general, there has been severe reduction in wildlife habitats and due to the conversion of large areas of land for agricultural use. This has particularly affected the more densely populated higher and cooler altitudes where few large animal habitats remain intact.

In the upper part of Blue Nile, there are limited fish reserves in both lake and riverine systems. Lake Tana has the largest fish resources. Fishing is carried out on a subsistence basis and for limited commercial purposes both in the main river channels and the floodplains. Virtually, every family that lives near water fishes to supplement their diets. Nile perch (Lates niloticus) Nile tilapia (Oreochromis niloticus), Catsish (Clarias sp), Bargrus, Barbus and Labeo species are known to be important both in ecological and commercial terms. However, there is little information on fish species and no systematic fish identification has been done. Similarly there is no information available on fishing and catches.

With regard to water quality, apart from high sediment loads, the water quality of all rivers that are distant from urban centres appears to be adequate for most uses. Lake Tana with a surface area of 3,042 km2 is the largest freshwater inland lake in Ethiopia and remains an important regulating feature in the upper part of Blue Nile. The lake's water quality seems to be satisfactory and is used as a minor source of supply for the town of Bahir Dar.

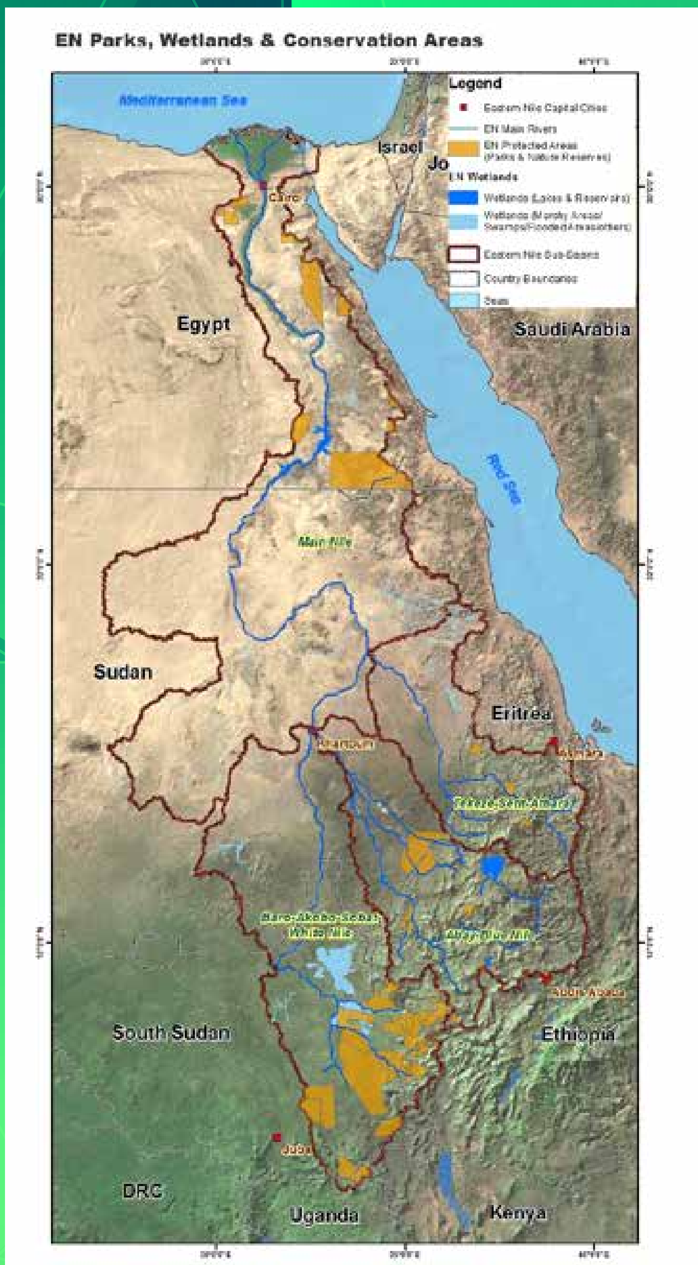
Water Hyacinth: The neotropical aquatic weed Eichhornia crassipes was recorded from Sudan since 1955. First noted as a serious weed in the white Nile System in 1958, it spread rapidly throughout the Sudd region from Juba , over a distance of 1700 km , to Jebel Awlia Dam 40 km south of Khartoum . The Jebe Awlia Dam serves as a barrier and with the continuous monitoring and control by the Sudanese authorities, water hyacinth have not been observed downstream of the dam. The serious effects caused by this weed on the White Nile system include, interference with river transportation causing high operation and maintenance cost for ships, blockage of irrigation canals and pumps, water loss by evape-transpiration, fishing losses, and the high cost of chemical control programs and its impacts on human health.

Dinder National Park with its area of about 890,000 hectares preserves natural wildlife migration corridor. The park is the last remaining wildlife sanctuary in the clay plains. It supports a population of Tiang, Reedbuck, waterbuck, bushbuck, Pribi, roan antelope, warthog, buffalo, greater kudu and red fromted gazelle. Many birds are found in the park such as ostrich, marabou stork, Clappertoni francolin, cattle egret, crowned crane, grey heron, sacred ibis, hooded vulture, pink backed pelican, bee-eaters, starling and guinea fowl. The annual reports on the park show continuous decline in the population size of nearly all species.

ENVIRONMENTAL STATUS AND THREATS

The causes of environmental threats are interconnected. Land degradation is the result of deforestation and inappropriate agricultural practices. As mentioned earlier, the main cause of deforestation in those regions is the increasing need for forest products by the rapidly growing rural and urban populations. Soil loss, due to removal of the vegetation cover, is an ever-increasing problem. As a result, in the upper parts of the sub basins (largely in Ethiopia) up to 400 tonnes of fertile soil per hectare is lost annually from degraded lands due mainly to lack of adequate soil conservation practices. About 130 tonnes of soil per year is lost within the upper part of Blue Nile sub-basin alone.

In the lower parts of the sub basins (largely Sudan) environmental degradation and floods remain the major environmental problems. Sudan was ranked among the 10 bottom countries in the 2005 Environmental Sustainability Index (ESI). This reflects a low environmental performance taking the five standard measurement components (Environmen-



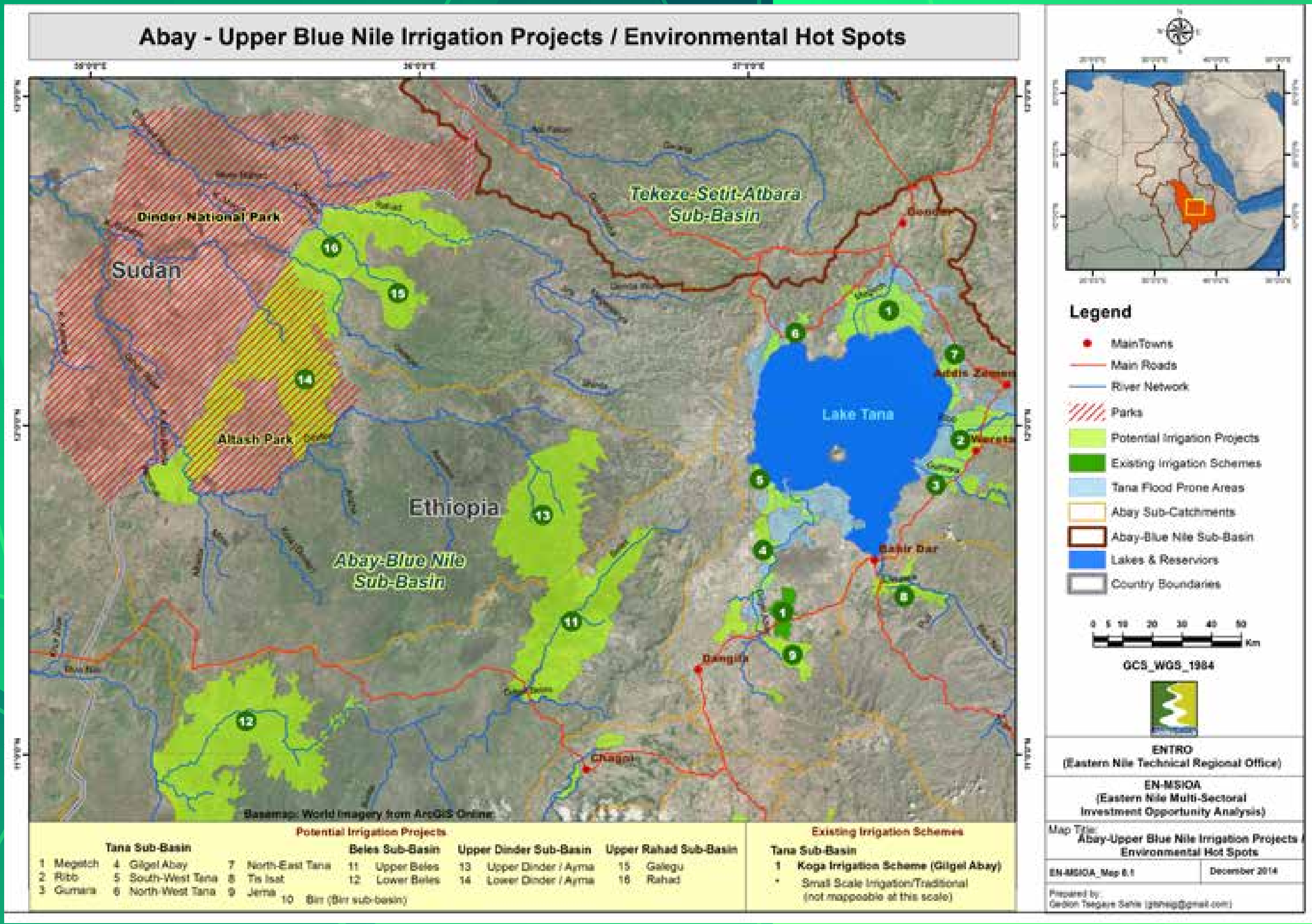
tal System, Reducing Environmental Stresses, Reducing Human Vulnerability, Social and Institutional Capacity, Global Stewardship levels that cause no serious harm.)

The key driving forces of environmental degradation in the lower parts of the sub-basins include climatic variability and change, which is revealed in the form of severe drought and occasional floods. Climate change is expected to increase the frequency and severity of climatic variability.

In general, the following conditions characterize the environments in the EN sub-basins:

- **Land degradation** happens as the result of many factors such as ad hoc government policies regarding the use of natural resources, horizontal expansion of rain fed mechanized and traditional farming, heavy reliance on forest biomass energy, overgrazing, bush fire, etc.;
- **Unsuitable agricultural practices** are manifested in the form of reliance on seasonal bush and grassfires for purposes of preparing land for cultivation, pastoralism, overgrazing in some regions and limited extension services;
- **Wetland loss and degradation** results through direct drainage for cultivation, grazing, etc., or indirectly through sedimentation and pollution;
- **Loss of soil nutrients** becomes a phenomenon due to mono-cropping farming systems, years of extensive cultivation practices by the mechanized and traditional rain feed sectors, with limited or no access to fertilizers and improved farming techniques compounded by wind and water erosion which has left most soils depleted of nutrients;
- **Deforestation** has continued as a result of encroachments, agricultural activities and urbanization. Forest resources have also depleted as a consequence of uncontrolled felling of trees;
- **Desertification** has become a growing challenge affecting significant parts of the regions' land area. In the lower part, the largest portion ranges from light to severe desert. 13 of the 26 states in Sudan could be classified as desert or semi- desert;
- **War and civil strife** has had a major impact on the natural resources and the entire environment; and
- **Increased population pressures and urbanization** resulting in more demand on resources and services.

In conclusion, soil erosion, land degradation, sedimentation, extreme floods, deforestation, desertification, the movement of sand dunes, water quality and pollution, agrochemicals, conservation of sensitive ecosystems (protected areas, wetlands, forests etc) are major environmental issues that need to be carefully considered at the different development stages.



SUB-BASIN-SPECIFIC ENVIRONMENTAL ISSUES: ABBAY-BLUE NILE

Agricultural soil loss and land degradation

The main area of sheet erosion is within the Ethiopian Highlands. Gulley erosion occurs in both Ethiopia and Sudan. On the large Semi-mechanized and small traditional farms the key soil degradation problem is nutrient mining. They are located on the clay plains north and south of the Blue Nile. The main locations for sedimentation are the Roseires and Senner dams, and the irrigation canals within the Geizera-Managil and Rahad Irrigation Schemes. High suspended sediment loads affect pumps for irrigation and increase costs of water purification for domestic and industrial water supplies. Sedimentation is negatively affecting the wetlands of the Rahad and Dinder River systems, in turn affecting human and livestock water supplies and biodiversity.

Water Quality

Apart from high sediment loads, the water quality of all rivers that are distant from urban centers appears to be adequate for most uses. Lake Tana with a surface area of 3,100 square kilometres is the largest freshwater inland lake and remains an important regulating feature for the Blue Nile River at its head. The lake's water quality seems to be satisfactory and is used as a minor source of supply for the town of Bihar Dar. The remainder of the town's water supply is being pumped from shallow groundwater bores.

Soil Erosion

A key issue of soil degradation within the sub-basin is declining soil fertility, the immediate cause of which is soil nutrient "mining". Whilst some of the underlying causes may be nationally specific (e.g. land policy) the impact on the rural population of the Sub- basin is the same: declining livelihoods and increasing rates of poverty. For this reason it is considered a basin-wide issue.

- **Sheet erosion**

  Key areas: Most sheet erosion in the Sub-basin occurs in the Ethiopian Highlands. Some sheet erosion occurs within Sudan, mainly on and around the rock hills (Jebels), which have become devoid of vegetative cover. Most of this is deposited on the footslopes and does not enter the drainage system. Four main areas of high sheet erosion are found in the Abbay Basin. The steep slopes around Mount Choke in East and West Gojam stand out as a significant area with a high sheet erosion hazard. This is an area with high rainfall causing problems in developing physical soil conservation structures because of the problems of providing effective water disposal structures. The second widespread area of high erosion hazards occurs north and east of the Abbay River in the Lake Tana Basin. This area includes the steep cultivated slopes around Mounts Guna (South Gonder) and Molle (South Wello). A third more restricted area is found in the upper Jema sub-basin in South Wello on the high hills north and west of Debre Birhan. A fourth area is found south of the Abbay and encompasses the upper and middle steep and cultivated slopes of the Middle Abbay Gorge Sub-basin in East Wellega. Two subsidiary areas with a high erosion hazard can be seen in the Upper Didessa Valley and along the escarpment hills to the west of Lake Tana in the upper Dinder and Beles valleys.

  Total soil eroded: The total soil eroded within the landscape in the Abbay Basin is estimated to be 363.4 million tons per annum and that from cultivated land is estimated to be 122.2 million tons per annum. Thus about 66 percent of soil being eroded is from non-cultivated land, i.e. mainly from communal grazing and settlement areas.

  Impacts on agricultural production: The current annual crop grain production for the Abbay Basin is 4.35 million tons. The annual loss due to soil erosion as a proportion of total production is 0.6 percent in the Abbay Basin. However, after 10 years this rises to 6 percent and after 25 years to 15 percent of annual crop production.

- **Gully erosion**

  Ethiopia: Although some work has been undertaken on gully formation and extension (Billie & Dramis, 1993), (Shribrus Daba et al., 1993), there is no information on gully distribution, density, erosion rates and sediment delivery ratios. Very recent research by the Universities of Makelle, Ethiopia and KU Leuven, Belgium in Tigray (Nyssen, J et al., 2005) have provided information of gulley erosion rates, sediment yields and sediment delivery ratios in northern Ethiopia. They report that gullies were initiated by a variety of changes in environmental conditions: removal of vegetation between fields, Eucalyptus planting in valley bottoms and new road construction. Where soil conservation measures have been introduced and gullies are relatively stable they contribute approximately 5 percent to sediment load. Where there are no conservation measures the average rate is 32 percent.

  Sudan: The main erosion problem in the Blue Nile Sub-basin is the gully erosion along the Blue Nile and Dinder Rivers producing kerib land. The plains are overlain with Vertisols (black cracking clays). The Vertisols develop very wide cracks during the dry season. At the onset of the rains water enters the cracks. Whilst the soils are covered with deep rooted vegetation there is no problem as roots take up any excess sub-soil water. However, once this vegetation is removed there is excess water in the subsoil and tunnels develop in the subsoil. These eventually collapse leaving an incipient gulley. These gradually extend back into the plain stripping the soil away from the underlying weathered rock of unconsolidated sediments, which are extremely soft and erodible. The weathered rock is quickly gullied. The Dinder is gullied for about 50 kilometres upstream from its confluence with the Blue Nile. The Rahad River does not appear to be affected except very locally near its confluence with the Blue Nile. However it is not as extensive nor has it gullied back to the same extent as it has along the Atbara. Most the kerib land along the Atbara has gullied upto 2.5 kilometres from the river, whilst along the Dinder it about 500 meters. It is possible that the Dinder is not as incised as the Atbara River. An interpretation of 2,000 Landsat TM imagery gave an estimate of 337,640 feddans (141,810 ha) of land that is affected. Some kerib land adjoins rainfed and some irrigated cropland. As no information is available on erosion rates it is difficult to estimate the impact on loss of cultivated land.

- **River bank erosion:** Possibly a bigger problem in terms of sediment delivery to the river is bank erosion, particularly along the Blue Nile. Much of it is a natural phenomenon caused by river meandering over flat flood plains and subject to a complex array of hydraulic factors. Along the Blue Nile bank material is mainly clay and silt. Human influences can alter the very delicate balance of hydraulic forces and set in chain accelerated bank erosion. Excavation of soil for brick making and building, the removal of tree vegetation along the banks, different cropping patterns and dumping of material into the river can all causes accelerated bank erosion. A change from deep rooting fruit trees to shallow rooting bananas is reported to have caused accelerated bank erosion along the Blue Nile (Mekki Abdel Latif, 2005).

- **Soil Degradation and loss of agricultural productivity:** A key issue of soil degradation within the Sub-basin is declining soil fertility, the immediate cause of which is soil nutrient "mining". Whilst some of the underlying causes may be nationally specific (e.g. land policy) the impact on the rural population of the Sub- basin is the same: declining livelihoods and increasing rates of poverty. For this reason it is considered a basin-wide issue.

  Ethiopia Highlands: In the Ethiopian Highlands the immediate causes are the burning of dung, removal of grain and soil erosion. Within the Abbay Basin some 1,751,600 tons of dung collected from crop fields (about 40% of total dung produced) and some 3,207,046 tons of crop residues were burnt as household fuel. This resulted in a loss of some 44,060 tons of N and 9,250 tons of P. The rate of loss of nutrients is nearly 2.5 times the rate of loss occurring in the Tekeze Basin, confirming the work of other workers (e.g. Desta et al, 1999, World Bank, 2004) that soil nutrient breaches and decline in soil nutrient status is major problem in the higher rainfall areas. It is noticeable that in contrast to the Tekeze Sub-basin where the greatest losses are from burning dung and residues, losses from grain removal make the largest contribution to total losses in the Abbay Basin.

  Sudan: Semi-mechanized Farms: Within the Abbay-Blue Nile Basin in Sudan, the Africover mapping of rainfed cropping with large to medium size fields suggest that there are approximately 7.454 million feddans (3.131 million ha) of large to medium semi-mechanized farms (SMF). However, a proportion of this land has gone out of production and in some cases has been abandoned. The FAO/WFP crop survey for 2005 estimated cereal production from the SMF Sector for Gederef State as 589,000 tons. Average yields are 0.36 tons per ha, which suggests that approximately 1.636 million hectares were under crops. The Africover estimate for land under SMF's in Gederef State (in 2000) was 3.1 million hectares. This suggests that in 2005 (a good rainfall year with high sorghum prices) only 50 percent of the SMF land was cropped. During the 1990's the area harvested on the SMF's contracted by 2.4 percent per annum whilst yields declined even further by 5.1 percent per annum (World Bank, 2005). This resulted in a decline of GDP from SMF sector of 7 percent. These reductions in yield are partly due to a decline in soil fertility in the absence of fallowing or fertilizer application. There has also been a decline in productivity partly due to the build-up of weeds (including striga) and partly to an expansion onto marginal land resulting in destruction of soil structure, soil erosion and soil fertility. The removal of natural predators (snakes and cats) has led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage. With only approximately 50 percent of the land being cropped and yields declining at just over 5 percent per annum this represents a substantial waste of natural resources.

Sudan: Small-scale Traditional Farm Sector: There are approximately 1,129,240 feddans (474,282 ha) of small-scale rainfed cropping. Spatial expansion of the traditional sector is severely constrained by the SMF's and the State Forest reserves. This is resulting in shortening fallow periods and thus declining crop yields. Sorghum yields in the traditional crop sector have declined in line with those in the SMF sector and are currently about 0.4 tons/ha, down from about 0.9 tons/ha in the 1970's.

- **Dam and Reservoir Siltation:** The most important off-site negative impacts of soil erosion are sedimentation of streams and water storage infrastructures. High sediment loads in streams pollute water supplies, and cause siltation of dams, reservoirs, water-harvesting structures and irrigation canals, reducing their effective capacities, shortening their service lives, and incurring high maintenance cost, at national, community and individual levels.

  The two main dams in the Blue Nile Basin are Roseires completed in 1966 with a storage capacity of 2.4 cubic kilometres and the Sennar completed in 1925 with a capacity of 0.7 cubic kilometres. The hydro-electric facilities at each of the dams have installed capacities of 250 MW and 15 MW at Roseires and Sennar respectively. Both dams are affected by siltation.

  The Sudan Ministry of Irrigation and Water Resources report that sedimentation in the Roseires Dam rose from 300 million m^3 in 1970 to 1,264 million m^3 in 2000 resulting in a loss of 38.3 percent of its designed capacity. Sedimentation is now reducing the live storage. As well as the loss of storage impact on crop area that can be irrigated there is also a reduction of hydro power generation. High sediment loads in the rivers used as sources for domestic and industrial water supplies cause problems and additional expenditures for water treatment plants.

Deforestation and Degradation of Woody Biomass

Deforestation and degradation are two different processes that cannot be directly compared. Clearing woody biomass for agriculture is a sudden and complete process. The "degradation" of woody biomass stocks caused by wood removal for fuelwood and charcoal is gradual and partial. The conversion of forest land to crop land and then grazing land has implications for hydrology. Although there is much debate at present about the role of forest land in affecting the volume of flow, due to evapotranspiration by trees, there are clear implications of forest loss upon the moderation of stream flow, especially the storage of water from the rainy season into the dry season. Hence, linked to the loss of forest are trends towards higher floods and lower dry season flows.

- **Ethiopian Highlands:** In the northern Highlands in the Abbay-Blue Nile Basin there is little or no potential for expansion of agriculture except in very local situations. However, south of the Abbay River in Oromiya Region there is some potential for agricultural expansion and this taking place into areas covered by shrubland, woodland and forest. In the western lowlands, mainly encompassing Beneshangul-Gumuz Region there remains considerable areas for agricultural expansion. Hitherto settlement and expansion of agriculture in these areas have been constrained by the presence of human diseases (particularly malaria) and cattle diseases (particularly trypanosomiasis). In the late 1970's a large-scale mechanized farm of 96,000 ha was cleared and developed in the lower Didessa and Anger Valleys. It experienced continued declining yields and following the fall of the Derg it was abandoned. Such was the efficiency of the clearing of the original woodland that even after 10 years it remains grassland with no woody vegetation. Since 1991 a new voluntary resettlement programme is being implemented in Oromiya region and to a much lesser extent in Amhara region. The main areas for resettlement are in the Didessa and Anger valleys. The Pawi scheme has also continued to receive settlers. In BSG Region some 128,000 ha have been allocated for medium-large scale agricultural investment. By 2015 some 56 percent of forests, 61 percent of woodlands and 43 percent of shrublands will have been cleared for agriculture and settlement as a result of natural population increase. No account is taken of resettlement and migration, or of expansion of large-medium scale commercial agriculture.

In BSG given its low population densities the rates of clearing are much lower and only some 5 percent of Acacia-Commifera woodland and 27 percent of shrubland are estimated to be cleared for agricultural expansion due to natural population increase. Again no account is taken of expansion of agriculture for irrigation (e.g. the Beles scheme), resettlement for rainfed agriculture or large-medium scale commercial agriculture. The pattern of weredas consuming in excess of sustainable yield mirrors that of the weredas with high proportions of their area experiencing moderate to severe soil erosion.

Most weredas that are consuming more wood than the sustainable yield are located in the highlands a clear reflection of the low population densities in the lowlands.

Sudan: Semi-mechanized farms: Substantial areas in the Abbay-Blue Nile Sub- basin have been cleared to make way for the Semi-mechanized farms. These now cover some 1.32 million hectare. This was formerly woodland and shrubland. The clearing has been particularly severe in the west of the Blue Nile and towards the Ingessena Hills. Map 19 indicates the encroachment of these farms towards the Ingesenna Hills (near to Bau). An unknown area of Semi-mechanized Farms is abandoned each year because of falling crop yields. Because the land is totally cleared of all tree cover and combined with years of constant harrowing and disking the tree seed bank in the soil has been completely destroyed.

The abandoned areas are a waste land with no tree cover. The quality of the grass cover is very poor because of the very low levels of soil fertility.

The remaining woodlands are under severe threat from fuelwood harvesting and charcoal production. The latter is mainly for export to the urban centres as far away as Khartoum. It can be seen on Map 19 that there are large areas of grassland (mainly fallow land with scattered cultivation) where the tree cover has been removed. In addition to the local population the area has received considerable numbers of IDP's. Collecting fire wood and charcoal production has become an important livelihood strategy in the area.

National Parks

Dinder National Park: This Park has a high level of biodiversity with over 160 species of birds, 27 species of large mammals and unknown number of small mammals. It comprises the last extensive tract of woodland in eastern Sudan. Its importance to conservation can be summarized as follows (ArabMAB, 2006):

The proximity of the Park to the desert and semi-desert makes it an important buffer zone for the vegetation cover of central Africa in addition to its significance in providing genetic material for the rehabilitation in the semi-arid and arid areas. The Park is an important watershed area protecting the most important feeders of the Blue Nile, the Dinder and Rahad Rivers. The Park, together with the south-western corner of the Ethiopian Plateau make a complete Ecosystem for wild animals, for which the Park is the dry season habitat for migratory species. The Park supports a high diversity of fauna and flora, including animals of international conservation importance (the African elephant, African buffalo and lion).

Three groups of people with interests in the park are:

- The first is the original inhabitants of the areas - a small group of Maganu people who continue to live in the south-eastern part. They depend on subsistence farming in the rainy season and supplement their diet by collecting fruits and wild honey. In the dry season they move to the Dinder for fishing.
- The second group are pastoralists and agro-pastoralists who enter the Park in the Dry Season looking for forage and water because much their rangeland has been converted into semi-mechanized farms. They burn the tall

grasses in the dry season to make green grass available, but in doing so eliminate susceptible herbs and shrubs.

- Around the Park are a considerable number of Internally Displaced Peoples taking refuge from the war in Dafur in the 1970's and are settled along the Dinder ands Rahad rivers and enter the Park for fishing, fuelwood and honey collection but also for illegal hunting and present the most serious threat to the wildlife. It is estimated that 100,000 people live around the park in 36 villages.

The Maya'a: The Dinder and the Rahad Rivers and their tributaries drain the Park. They rise in the Ethiopian Highlands and are highly seasonal almost drying out in the dry season. Due to the abrupt change in gradient the rivers meandering a large number of cut-off meanders have been formed locally called Maya'as. They are generally flat and cover an area some 0.16 to 4.5 sqaure kilometer. Rain and flood water fill them during the rainy season. The maya'as provides a valuable source of water and forage for domestic livestock and wildlife, as well as unique habits rich in biodiversity. Under natural conditions there is a constant evolutionary sequence of the formation of young maya'as that are deeper with clear water. Gradually they pass through stages of becoming gradually silted up. Over long periods of time with the meandering new maya'as are being formed. The spectrum runs from young productive maya'as to old non-productive dry ones. With the accelerated erosion in the Ethiopian Highlands this gradual and long term evolutionary process has been disturbed because increased flood peaks and high sediment loads. The area is now subject to annual flooding and many of the Maya'as are becoming silted up with a consequent loss of habitat biodiversity and forage productivity.

Alatish National Park: In Ethiopia the Amhara regional Government has proposed to develop the Alatish Regional Park in Quara wereda of North Gonder Zone, almost opposite the Dinder national Park in the Sudan. The area represents the Sudan-Guinea Biome. The park has been gazetted as a Regional Park and demarcated. However, the Park lacks national legislation and international recognition (Cherie Enawgaw et al., 2006). The Park covers an area of 2,666 sqaure kilometer to the north of the Dinder River, which forms its southern boundary, and to the south of the Gelegu River that forms its northern boundary. The Alatish and other ephemeral streams drain the central area. Its altitude ranges from 500 to 900 masl. The main vegetation is woodland, shrubland and lowland bamboo thicket. Studies so far have revealed that the Park contains 48 mammal species and 180 bird species. It contains such endangered species as Loxodonta africana, Panthera pardus and Panthera leo. The area is intact with no permanent settlement, although Fellata pastoralists enter the Park in the dry season with over 10,000 head of livestock. The northern and eastern sides have a 2 kilometres buffer zone, but the southern boundary has no buffer zone as it border Beneshangul-Gumuz regional State. The Gumuz people have settled to the south of the Park and practice poaching and fishing along the Dinder River. Settlement is increasing and agriculture expanding along the northern boundary and numbers are being swelled by migrants from other parts of Amhara region. There is an urgent need to collaborate with the Beneshangul-Gumuz Regional government and with the Government of Sudan to secure the area. The Ethiopian Wildlife Conservation Organization has strongly recommended that the Alatish Park been proclaimed a National park and that in the future it should form part of a Transboundary Park with the Dinder National Park. There is also an urgent need to develop a park management plan in participation with local communities.

SUB-BASIN SPECIFIC ENVIRONMENTAL ISSUES: THE TEKEZE – SETIT – ATBARA SUB-BASIN

Water Quality

Except for its high sediment load, water quality, especially away from urban centers is suitable for most uses.

Industrial and agricultural Pollution

These include air pollution in Mekelle from the cement factory, water pollution from the newly constructed Sheba Tannery and the dyeing factories of Tigray.

Water Related Diseases

In the upper course of the sub-basin (largely confined in Ethiopia) four major vector-borne diseases, notably malaria, intestinal schistosomiasis, visceral leishmaniasis (VL) and onchocerciasis are confirmed as being endemic and pose a major challenge to socio- economic development effort in the area. The incidence of malaria and schistosomiasis will increase in areas of ongoing micro-dam construction. Most major settlements in the basin have non-extent or inadequate drinking water supply systems. Sanitation is also inadequate, piped drinking water should be boiled for use.

Mekelle already has a water quality problem due to the chemical composition of the aquifer rocks. At present Lalibela has severe water shortage with daily water cuts. The existing residential areas have few latrines. People defecate on the hills surrounding the town. This has resulted in the pollution of the land underneath the rock-hewn churches in the valley. Sample taken from the churches foundations show evidence of erosion with urine concentrations.

Soil Erosion & Land Degradation

Land degradation refers to degradation of soils and natural vegetation, resulting in a disrupted hydrological equilibrium. Erosion and/or land degradation is generally recognized as the main environmental problem in the Tekeze Sub-basin in particular in the highlands. Land degradation is virtually caused and/or accelerated due to two important factors; human and natural factors and it is related not only to the geographic distribution of natural resources but also to the historical pattern of land use.

Of the natural conditions/factors, two general features have caused high erosion hazards since ages are (1) the erosive character of the rainfall pattern, and (2) the predominantly steep relief in most of the sub-basin areas.

The high erosion is related to the high intensity of rain storms, causing damage particularly at the onset of rainy season when soils are least protected against the impact of rain. Erosion hazard turns in to actual erosion if the protective vegetation cover is depleted.

Development of habitation and land use pattern and related depletion of vegetation resources and land degradation, historically, have different levels as seen from the national and sub-basin/regional perspectives. At the sub-basin/regional level, for longer period of time(it exists even at the present) habitation in the highlands was more preferable than in the lowlands, owing to the highlands having more favourable climate and less suffering from endemic diseases like malaria. Population increase, which has resulted in an increased demand for cultivation land, which in turn has caused massive destruction of forest land and biomass. This has accelerated land degradation in the sub- basin. Sever scarcity of woodlands in the highlands and being as one of the outstanding characteristics for the lowlands today is the reflection of the then mentioned historical habitation pattern in the sub-basin. On the other hand when seen at the national/basin level, largely in the upper course, land degradation, historically, has spread from north to south. The northern highlands of the upper course of EN Basin indeed shows a state of sever degradation as compare to the highlands in the southern portion of the upper course of the EN Basin, which could be the combined effect of longer lasting pressure on resources in a more fragile (drier) environment. In the northern portion originally, the highland plateau was covered by *Juniperus*, *Olea*, and *Cordia*, alternating with mixture of *Acacia-Andropogon* savannas, and by edaphic grasslands and swamps in flat valley bottoms. By centuries of continuous abuse, these lush conditions have been converted into the almost barren plateau which exists today, where forest and natural woodland is virtually confined to small areas around churches and holy places, and destructive high winds blow over the bare lands.

As seen at the local level in the sub-basins, settlement and cultivation have first concentrated in highland plains, on plateaus and on gentle footslopes, all sites with suitable fertile soils and low erosion hazards. Sustained usage of land resources was possible because of the relative abundance of fertile soils and the possibilities of shifting cultivation and fallow periods being sufficiently long to allow regeneration of soil productivity. Fuel and timber were available in abundance and could be collected from the direct surroundings. With gradually increasing population, both the possibility of shifting cultivation within areas of low erosion hazard and the length of fallow periods have decreased. At present, highland plateaus and plains are fully under cultivation (or grasslands and are completely deforested. Fuel and timber have to be collected from other areas with a much higher erosion hazard, notably, steep hill sides and valley sides bordering plateau.

Soil degradation in terms of fertility loss and erosion has come into the picture in the process and decrease in productivity could be compensated for by expansion of the cultivated land area and by increasing management inputs such as weeding and more frequent cultivation/ploughing. Consequently, initially low but gradually increasing land degradation rates, i e. in the form of erosion, probably remained unnoticed.

Factors underlying land degradation

In the Tekeze Basin, food production, livestock feed and fuel requirements put competing demands on scarce and vegetation resources. The Tekeze Basin has been a process of gradual degradation of land and vegetation under population pressure and inadequate management of natural resources. An analysis of scarcity and degradation of resources in the studied 42 PAs showed that pressure on resource is strong or critical in 31 PAs and low or moderate in 11 PAs. Most of the latter are situated in the western lowlands of the basin. (OSI Water Synthesis Report, Forest Land, p. 146)

Two important phenomena must have been the main causes for crossing critical thresholds of natural regeneration of resources: (1) the increasing demand for land that has forced the farmers to expand cultivation onto steeper land being much more susceptible to erosion; and (2) the increasing demand for fuel and timber, which has caused large scale deforestation at a rate increasing beyond natural regeneration and the indiscriminate cutting has long been coupled with very little replacement effort.

Shortage of land has also had its repercussion on livestock husbandries. Most of the suitable land is reserved for crop production. Grazing of cattle is limited to hydromorphic valley bottom lands to marginal deforested hill slopes and to a limited number of enclosures within the cropland reserved for grazing.

Land degradation in the Tekeze Watershed is distinguished between physical, chemical and biological soil degradations, water and wind erosion, and mass movement (Barber,1984). Chemical degradation refers to the leaching and removal of nutrients and the buildup of toxicity other than those due to excess salts. Physical degradation includes those processes which adversely affects soil physical properties such as infiltration rate, structural stability, root penetrability and permeability. Biological degradation refers to processes which accelerate humus mineralization rates, and reflect the moisture/temperature regimes of the environment and land use practices.

Water erosion in the form of sheet, rill and gully erosion is the most intensive and widespread form of land degradation and also recognized as the main environmental issues in the sub-basin. Rill and gully erosions are more spectacular because more evident features are formed during much shorter periods, generally during one season, and even as a result of one exceptional rain storm or a few storms at short intervals.

Stream bank erosion is one of the striking features of the land degradation in the sub- basin. By far the greatest majority of natural drainage routes in the areas are actively eroding. Highly variable rainfall (high hydrologic variability, due to sever environmental degradation) that produces seasonal high peak river flows exceeding the channel capacity of the drainage routes; destroy the protective role of vegetation. Intensive deforestation actions within the watershed, that causes the depletion of riverine forest or bushes also eliminates the protective capacity of vegetations, is the other factor enhancing stream bank erosion in the watershed.

Above all land topography plays important role for land degradation in the watershed. Nearly 30% of the upper course of the Sub-basin is identified to have land slope exceeding 30% and about 25% has land slope that ranges from 15% to 30%. Due to cultivable land shortage resulting from land degradation and population pressure, these steeply sloping areas are intensively cultivated, aggravating land degradation events in the Sub-basin. Research activities in soil loss are rare in the Sub-basin. Very few attempts indicate soil loss in the watershed ranges from 17 tones/ha per year to 33tone/ha per year. Landownstreamoil degradation in the watershed has caused an average loss of 3% in agricultural produces (Tekeze Master Plan Studies, May 1998).

Pests and Weeds

Regular crop yield loss caused by various pests such as weeds, diseases, insects, rodents and birds are common. The existing weed control measures are limited to hand weeding, commonly performed quite late after crop emergence. Farmers do not use herbicides. Single weeding is the common practice in all cereals, except teff, which gets more attention. Diseases such as rust, smut, scald and blotch are reported to cause damage to various crops, virtually no measures are taken by peasant farmers to control these diseases. Insects are the major pests in the area. They cause a substantial damage on different crops. However, only a very limited number of farmers use Malathion in order to control insect pests like armyworm and grasshoppers. Due to inadequate and/or delayed supply and poor technical know-how of farmers, the present efficiency of pesticide use by peasant farmers is quite low.

Sub-Basin Specific Environmental Issues: Baro-Akobo-Sobat-White Nile Sub-Basin

In the Baro-Akobo area of the sub-basin, the temperature ranges from around 27 C in the lower lying areas down to 17.5 0C in the highlands. There are short periods where temperatures are in excess of 40 C, the critical value for anthesis of some crops, notably maize, but this does not coincide with the cropping season. Daytime temperature in lowlands is very stable over the year with mean maximum not falling below 30 C even during the rainy season. In contrast, land above 2000m is markedly cooler, with mean maximum temperaurure in the hottest period not exceeding 28 C and generally being in the range of 21-260C. The annual mean minimum ranges from 15 C at Atnago to 7C at 2320 m at Fincha.

The sub-basin is part of a particularly well-watered region of Ethiopia. Most of the upper sub-basin has an annual total rainfall over 1800 mm.

Livestock

The Baro-Akobo area contains about 1.2 million cattle and more than half a million sheep and goats. Cattle are of primary importance, used for draught, milk, capital reserve, and source of cash. Furthermore, they are used for cultural purposes such as status and serve as bride price during marriages.

In the lower sub-basin, the livestock are managed on a migratory system in response to the availability of grazing and water in the plain but the seasonal distribution of the feed is a constraint. In the upper part of Baro-Akobo, feed resources are the main constraints to livestock production.

Degradation of Forests and Woodlands

The Baro-Akobo part of the sub-basin contains about 2.2 million ha of forests. Although isolated into small stands and seriously degraded, they constitute more than half of Ethiopian's remaining forests. Nonetheless, their situation is critical. Loss by exploitation and uncontrolled burning exceed the rate of forest growth. Few primary forests remain: those that remain occur on steep land that is unsuitable even for shifting agriculture.

There are 11 National Priority Forestry Areas: Gerjeda, Sigmo Gaba, Sele Mesengo, Gesha, Yeki, Sheko, Guraferda, Saylem Wangus, Godere, Abobo Gog and Gambela Park.

Based on reconnaissance observations rather than delineating of map units, the forest types delineated include Natural Forest (Afro-Alpine and Sub-Alpine, Coniferous, Aningeria, Olea, Baphia, Evergreen Clump-shade, Mixed Deciduous, Combretum and Acacia, Riparian) and Plantation Forest.

The Afro-Alpine and Sub-Alpine forests lie above 3,200 m where they comprise small trees, herbs, and suffrutecents. Little human activity occurs in the zone other than grazing and barley cultivation. Coniferous forest, lying between 1800 and 2500m occur principally on steep lands, where gravity dispersion of seeds assists their regeneration. Aningeria forestes lie between 1600 and 2000 m where the annual rainfall is about 1600-2400 mm. Olea forests lie between 1500 and 200m, their preference for gentle slopes exposes them to disturbance and exploitation. They comprise a wide range of commercially desirable species. Bahpia forests often merge with riparian forest and are open forest type. The evergreen clump-shade forests occur throughout the highlands plateau. Remnants of the forest, which once clothed Ethiopian's uplands, are now made-up of islands of trees with the spaces between often used for coffee cultivation. There is no forest regeneration. The Mixed Deciduous extends along the southwestern edges of the plateau at about 1200m altitudes. The Combretum and Acacia woodlands occupy the low and upper basin between 500 and 1500m altitude. Riparian forest extends throughout the plateaux drainage pattern, dropping down to the flood plain. Like the woodland of savannah and upland basin, riparian forests are under enormous pressure from local and refugee population.

Forests are key components of the Baro-Akobo environment. Improved forest provides suitable habitat for many types of wildlife. Dense forest intercepts rainfall and helps protect the soil surface against soil erosion. The resulting betterment of hydrological condition will provide benefits to much of the infrastructure such as roads, dams, bridges, and water supply that lead to improvement to human health. Advance in the forest economy will offer alternatives to subsistence agriculture, and off-farm income will improve.

Biodiversity (Fauna and Flora)

The following are the major environmental concerns and measures identified through the biodiversity assessment made in some of the states found in the Baro-Akobo-Sobat-White Nile sub-basin in the Sudan (NBSAP, 2002)

White Nile State

According to the 1958 classification, White Nile State is divided into two divisions. The first is semi-desert and woodland savannah on clay. It has four subdivisions: Acacia tortilis/ Mearua crassifolia desert scrub, semi-desert grassland on clay, and semi-desert grassland on sand and Acacia mellifera-Commiphora desert scrub. The second division is the woodland savannah. It has two subdivisions: Acacia mellifera thorn and Acacia Senegal savannah. From comparison of the historical Harrison and Jackson's classification with the more recent investigations, it can be concluded that annual grasses are still there in their old areas. There are indications of a southern shift in species occurrence. This however awaits further investigation. Available field evidence shows that trees and shrubs have been affected by browsing. Affected species are Maerua crassifolia, which has low density and only found scattered. Browsing, over-cutting and drought are the main causes affecting trees density. Commiphora africana is one of the most affected tree species in the semi-desert.

Clearance of natural land for residence and agricultural production, particularly in the southern limits of the White Nile is the main threatAs a result, the species Dalbergia melanoxylon and Acacia tortilis are endangered. Over grazing especially during the rainy season is the main hazard to plant density. The northern limits of the state are drought-prone as they lie in the semi-desert belt. The second threat is the hazard of fires. Expansion in mechanized rain fed agriculture for food production has been at the expense of the natural ranges. The balance between the numbers of livestock and the grazing has been disrupted. Sand dune fixation in the western part of the state has proved successful.

Upper Nile State

The state is endowed with vast plains of relatively stable clay soils, covered by savannah woodland ecological zone. The low rainfall woodland savannah on clay, Acacia seyal-Balanites alternating with grassland type covers an area of 17,000 km² along the boundary with Blue Nile State, extending in a narrow belt to river Sobat in the south, extending towards Jelhak and the White Nile. It also occurs in an area of about 7,000 km² round Riangnom. The Upper Nile Swamps ecology surveys and the range ecology survey conducted between 1979-1983 are the latest and most detailed investigation of the Sudd of the Upper Nile. A total of 350 species of higher plants were identified. The northern Upper Nile area is now open for both legal and illegal charcoal producing activities. According to Khartoum State in 1999, 38 to 50% of the monthly fuelwood supplies to the capital city originate from northern Upper Nile State. Almost all the fuelwood supplies are in the form of charcoal. The bulk is produced in areas already marked for clearance for mechanized rain fed agriculture.

An adverse effect of the civil war conditions has been the cessation of forestry presence and supervision on forestry plantations and installations. The war conditions were also conducive to destructive elements and profiteers to destroy the forestry plantations by unauthorized felling for logs for sale in the north. Forests National Corporation 1999 figures on government plantations, illustrates the extent of damage caused to the plantations of teak, Tectona grandis, Sunt, Acacia nilotica and other exotic species. The damage caused to teak plantations amounts to 80% of the teak planted area.

Wildlife

Gambela National Park has apparently received legal protection since 1974 and the region was at one time considered as one of the most important wildlife areas. However, its present status hardly warrants designation as a protected area of any kind. Large areas of the original park have been cleared and is being used for cultivation and/or grazing.

A high density of wildlife in the south and south west of the sub-basin were reported to cover 30% of the area sampled from the air. Migration pattern of large mammals were inferred from air photographs; giving a general account of dry season dispersal to the wetter grassland of the west, with rainy season movement to the higher levels of the watershed.

The Baro-Akobo environment was once abundant with wildlife: At least 27 species of large mammals were recorded 25 years ago,(Aatwell (1996)), the basin has undergone severe hunting, civil unrest, and depletion of habitat in recent years that resulted in the reduction of its significant mammal population. Important changes to the habitat have occurred, most notably the occupation of large part of Gambela National Park by a state farm and Abobo Dam, part of whose upper reservoir also extends in to the Abobo Gog protected area.

Fisheries

Studies on the fish and fisheries of the Baro-Akobo part of the sub-basin are limited. The Russian Academy of Sciences carried out a comprehensive study of the fish species of the lower basin in the late 1980s. This study examined the species composition, tropic status and parasitology of the fish populations but provided no information on the fisheries. No estimates of the number of fisheries operation in the region or an evaluation of their catch are available, and the fisheries department does not, as yet, collect such information. Similarly, in the upper sub-basin, ARDCO-GEOSERV study did not cover the fisheries sector in any detail, and with the exception of an ad hoc fish inventory survey around Ale District by the Russian delegation of the Science and Technology Commission, little information is available from other sources. No formal studies have been carried out in the upper sub-basin region and no assessment of the status of the fisheries has been made.

- **Fish Species:** The ad hoc Russian study in the upper catchment around the Ale District found Some 40 fish species out of the 75 identified in the lower Baro-Akobo plain. On the upper plateau, there are Species with a preference for slower flows. As the river descends from the plateau to the lowland plain, it cuts through steep gorges and is fast flowing. In this region, rheophilic (fast water) species such as barbus and Labeo are found.

- **Fishing:** In comparison to the Lower catchment, there is little fishing in the upper catchment of the Baro-Akobo. Fishing occurs on the Baro, Sor, Weber, Yobi, Dibo and Uka rivers, but is purely on a subsistence basis using traditional methods. The Dominant species caught are Oreochromis niloticus, oreochromis zillii and Barbus species. No data exist on the number of fishermen or intensity of fishing in different parts of the catchment or at different times of the year. The reason for the lack of fishing include: the absence of any suitable sized, slow-flowing water or lakes; inaccessibility of major rivers and tributaries for most of the course: and lack of a fishing tradition amongst the local ethnic groups.

- **Fisheries Development:** There is some evidence of attempts to increase fish production. The fisheries department of the Ministry of Agriculture in Ethiopia, for example, stocked Lake Bishan Waka Haye near Tepi with 11,000 tilapia fingerlings and Barta reservoir, west of Dembidolo, constructed by the world Lutheran Federation for irrigation purposes, with 58,000 fingerlings. Unfortunately, there has been no follow up of these activities.

Fish Species (Lower Baro Akobo): Studies carried out on Species by the Russian Academy of Science as part of the overall Russian study (Selkhozpromexport, 1980) found 72 fish species in the lower sub-basin of Baro-Akabo. Nile perch (Lates niloticus) Nile tilapia (Oreochromis niloticus), Catsish (Clarias sp), Bargrus, barbus and Labeo species were important both in ecological and commercial terms.

Fishing in the region is mainly on a subsistence basis, both in the main river channels and many of the floodplain lakes. Virtually, every family that lives near water fishes to supplement its diet. Active fishing is carried using spears, or modifications thereof, cones, various hook and line devices, traps made of reed, etc.

In addition to the subsistence fishermen, there are three fishing co-operatives at Pinudo (at Tata), Pinkew and Itang which were established by Lutheran World Federation.

Fishing is highly seasonal in the lower Baro-Akobo sub-basin. Flooding between June and October prevents most fishermen from operating and thus the main fishing season is restricted to the drier periods between October and April.

No direct estimates of present fishing efforts and production are available because catch and effort data are not collected.

Water Resources and Wetlands

The major rivers in the Baro-Akobo- sub-basin are Baro and its tributaries (Birbir, Geba, Sore), Gilo with its Tributaries (Gecheb, Bitum, Beg), and Akobo with its tributaries Kashu and Alwero. The general direction of the rivers is from east to west. The rivers rise in the high land (2000-3500m) situated in the east of the area and flow to the Gambela plain (500m) in the west

According to the report on the 43 surveyed wetlands of Ethiopia; Cheffie Gebo, Ginina, Abol, Alwero and Tata (Thata) are located in the Baro-Akobo River Basin.

National Parks

The lowland area of Baro-Akobo is the site of Gambela National Park. Three controlled hunting areas, Jikau, Alobo, and Tado, are also located in the sub-basin. Despite efforts made to set aside habitat for the preservation of wildlife, the result has not matched expectation and suitable habitat has become compressed. Important constraints are insufficient staff, insufficient awareness, insufficient finance, and absence of plans to manage priority areas, inadequate infrastructure, and no research capacity.

Sub-Basin Specific Environmental Issues: Main Nile Sub-Basin

The Egyptian coastline extends or 3,000 kilometres along the Mediterranean Sea and Red Sea beaches in addition to the Suez and Aqaba gulfs. Natural conditions on Egyptian Mediterranean coasts differ significantly from those on the Red Sea coasts in terms of salinity, sea currents and temperature. Such difference has led to different biodiversity and ecosystems in each. Nearly 40% of industrial development activities are practiced in Egyptian coastal zones, in addition to a number of urban and tourism development activities. Furthermore, coastal zones monopolize the seaports infrastructure, in addition to agricultural and land reclamation sectors, as well as a developed road network capable of accommodating all development aspects. Egyptian coastal zones production is estimated at 85% of Egypt's production of oil and natural gas; The Gulf of Suez production alone is estimated to be 36 million tons. In addition, the crude oil and natural gas production in the Mediterranean coastal zones is increasing every year.

Through many joint efforts on the regional and international levels under the Global Program of Action for the Prevention of Marine Pollution From land-based Activities (GPA/LBA & MEDPOL), it was possible to identify many polluted areas in need of urgent action. Most of the adverse impacts were identified and their volume estimated in order to enable their elimination. Data pointed out to the existence of hot spots that need special attention where pollution has exceeded permissible limits, such as Abu Qir and El Max. Environmental inspection program results indicated an increase in the number of land-based sources that have adjusted their status and complied with Egyptian Laws and regulations, or that have active environmental compliance programs in place.

Moreover, evidence provided by applied marine environment quality monitoring programs showed a noticeable improvement in the quality of marine environment since the launching of these programs in 1998, particularly at hot spots in the Mediterranean Sea.

The policy measures to tackle environmental degradation comprise both preventive measures and long-term policies. The preventive measures are carried out through the regular assessment of the water quality status and suitability for various uses. Moreover preventive measures include enforcement of laws to protect water resources from pollution. The Ministry of Water Resources and Irrigation formulated a National Program for Water Quality Monitoring in the Nile, canals and drains and Lake Nasser. The Central Laboratory carries out the substantial lab work for Environmental Quality Management affiliated to National Water Research Centre. The monitoring program includes 300 locations for surface water and 230 locations for groundwater. The long term policies to control pollution include covering open conveyance system passing through urban system to closed conduits; coordinating with other concerned ministries to set priorities for wastewater treatment plants due to budget limitation; introducing environmentally safe weed control methods either mechanical, biological or manual and banning the use of chemical herbicides. Subsidies on fertilizers and pesticides were removed and some long lasting agricultural chemicals were also banned. Public awareness programs are introduced to promote the issue of conserving Egypt's water resources in terms of quality and quantity (OSI Environment Synthesis Report pp. 44-45).

Major environmental issues

Water Related Diseases

Throughout history, epidemics related to waterborne or water-related pathogens have plagued Egypt. Some of these events are briefly recounted (Helwa, 1995) here as follows:

The 1973 typhoid epidemics was localized in a small village in Damietta Province, where about 400 students and villagers fell ill.

In the summer of 1983, infective diarrhoea started in a small village in Giza Province and later spread to other areas. The causative organisms were isolated in drinking water network, which was contaminated by an overflow of sewage caused by broken pipe connection.

The 1986 typhoid epidemic affected the old section of Suez City. It was the result of heavy contamination of the old water treatment plant intake by untreated human wastes.

The Ministry of Health monitors routinely for pathogenic bacteria, viruses, and parasites in natural water around Egypt. Results of these surveys indicate that the following pathogens have been found in Egyptian waters:

- **Salmonella:** Have been detected in Alexandria sewage discharged into Mariut Lake, El- Mahmoudia canal and Alexandria beach.

- **Shigella:** The causative agents of bacillary dysentery were isolated from Mariut Lake.

- **E.histlita and E.coli** were detected also in tap water in Abbis II village even though water is treated and chlorinated.

- **Vibrio Cholera:** As a preventive measure, local health authorities in Egypt collect 110 water samples daily from the Nile and main canals, at the intake point of water treatment plants, and from drains and sewage discharges. The samples have been analyzed for Vibrio cholera, with results so far negative.

- **Parasites:** A clear decline in the presence of infective stage of human with Schistosomiasis (Cercaria). The results indicated a decreasing infected snails (intermediate host) population. Infected canals are by now treated with molluscicide.

- **Hepatitis A virus:** No figures are available in Egypt

- **Hepatitis E virus:** Have been detected among children, especially in the rural areas.

- **Viral gastroenteritis:** Gastroenteritis and diarrheal diseases are the most common diseases transmitted by water. These viruses are responsible for 40% among children's under five years of age in Egypt. These diseases are spread by faecal contamination and transmitted to humans via contaminated water supply and food.

- **Poliomyelitis virus:** These viruses have been detected in sewage in Egypt. It is the only water-borne disease, which has a potent vaccine giving testing immunity to vaccinated children. For this reason, the disease is now being eradicated in Egypt.

Soil Degradation and Contamination

The use of traditional inefficient irrigation techniques and the inadequacy of drainage systems have led to the increase in water logging and salinization. Salinity is a potential limiting factor that stifles land productivity in Egypt. Over-exploitation of water for irrigation has led to the depletion of groundwater resources, which has resulted in excessive intrusion of salt water from sea into ground water aquifers. According to published research, vehicle emissions affect the soil of the agricultural land around traffic roads. A strip of at least 40 meter parallel to the Cairo-Alexandria Agricultural Road receives air pollutants, mainly lead, carbon monoxide, nitrogen oxides and sulphur dioxide. These pollutants fall on the plants as well as passing directly into the soil. Pollutants carried by irrigation water are also a major source of soil pollution. An estimated 50 per cent loss of productivity of agricultural land was recorded at Helwan and Shoubrah El-Kheima. Severe damage to plants has been reported in areas close to the industry in Kafr El-Zayat, Edfu, Abu Za'abal and others. Toxic heavy metals accumulate in the tissues of vegetation grown adjacent to sources of air pollution, such as lead smelters, and near traffic roads.

Baseline Status of Lakes and Wet Lands

- **Lake Manzala:** Lake Manzala is the largest northern lake. It is situated in the northeast corner of the Nile Delta, and falling in the jurisdiction of five governorates. It is separated from the Mediterranean Sea by a sandy beach ridge, which has three open connections (bugaz) between the lake and the sea. The surface area of the lake is 280,000 feddans. Lake Manzala has the largest fishery production (78,261 tons in 1998) compared to the other northern lakes. The fish species of the lake have been changed, which previously were characterized as marine fish. After the construction of Aswan High Dam (AHD), the mullet –based brackish water fishery has been replaced by tilapia–based fisheries due to the constant inflow of freshwater with high nutrient concentration. Tilapia represented about 51% of the lake fishery, while mullet represented about 3.6% of the total harvest. (OSI Environment Synthesis Report p. 26)

- **Lake Burullus:** Burullus Lake is situated along the Mediterranean coast and occupies a more or less central position between the two branches of River Nile. The lake is oval in shape with estimated area of about 114,520 feddans. It is a shallow basin with variable depth ranging between 0.6 and 1.6 meters. The lake has about 70 islands, of which 55 are artificially created by filling reed-infested area with soil. Burullus Lake receives its water from different sources:

    - Sea water, through natural inlet at its northeast border;
    - Brackish water dumping from agricultural reclaimed areas and drains; and
    - Brackish-salty water, through the bramble Manila on the west coast.

  After the closure of AHD, margins of the lake were made to develop for land reclamation for agriculture expansion. Eight drains were constructed to leach the soil salinity into the southern shore of the lake. Burullus Lake is considered one of the highly productive lakes in the Mediterranean with about 31% of the delta lake's area. Burullus Lake produced 59,033 tons, representing about 42% of all delta lakes. It has the most productive mullet fishery of the delta lakes due to wide lake- sea connection, which allows high recruitment of mullet fry from the sea each year. (OSI Environment Synthesis Report p. 26)

- **Edku Lake:** It is the smallest northern delta lakes. It is located about 30 kilometres to the Northeast of Alexandria. The lake area reaches about 27,470 feddans. Edku lake is the third fishery productive among delta lakes (10,280 tons in 2001). The source of lake water is coming from two agricultural drains. Bersik drain enters the lake from the southern edge and Edku drain enters from eastern side of the lake. Exchange of water between the northern side of the lake and the sea is insured through a narrow slit 'Boughaz El-Maadia'. The area of the lake is divided into three basins due to emergence of a number of islets. The salinity of Edku lake varies locally and seasonally. It fluctuates from less than 0.09 % in the eastern basin to about 1.4 % at El-Maadia region inside the Boughaz. Edku lake contributes 7% of the overall production of northern lakes (10,300 tons), of which 90% Tilapia and only 5% mullet. (OSI Environment Synthesis Report p. 27).

- **Qarun Lake:** Qarun lake is an inland closed basin of 23,000 hectare, and an average depth of 8 meters. In the ancient times, Qarun Lake was connected with river Nile forming a natural reservoir of freshwater, which supplied Fayoum depression with floodwater of the Nile. Whenever the lake became disconnected from the river Nile, its water level lowered and its surface shrunk due to evaporation, until a new flood raised its level and size again. Consequently, salinity has been steadily increasing. The mean salinity had increased from about 11 ppt in 1906 to about 34 ppt in 1982, and at present, the average salinity reaches 39 ppt. It is estimated that 589,000 tons of salt enters the lake annually. If the level of salinity continues to increase, it may reach 50 ppt by the year 2020 transforming the lake into a dead sea. The only source of water supplying the lake is the agricultural drains (especially wadi and Bats drains). (OSI Environment Synthesis Report p. 27)

WATER QUALITY AND POLLUTION OF THE NILE

Water Quality

Water quality is one of the most important environmental issues in the Main Nile largely in Egypt. Due to intensive agricultural and industrial uses pollution is significantly higher and is important economic problem in the sub-basin.

The protection of water resources is one of the most critical environmental issues in Egypt. Egypt is facing an increasing demand for water due to the rapidly growing population, as well as the growth in urbanization, agriculture and industry. In the meantime, Egypt faces a rapidly increasing deterioration of its surface and groundwater due to increasing discharges of heavily polluted domestic and industrial effluents into its waterways. Excessive use of pesticides and fertilizers in agriculture also causes water pollution problems.

An assessment of water quality in Egypt indicated that the major water quality problems are pathogenic bacteria/parasites, heavy metals and pesticides. Major sources of these pollutants are the uncontrolled discharge of human, industrial and agricultural wastes.

Industrial and Agricultural Pollution

At present industrial use of water is estimated at 5.9 bcm per year out of which 550 mcm per year is discharged untreated into the River Nile. About 125 major industrial plants are located in the Nile valley, which represent about 18% of the existing industries and discharging 15% of the heavy metal loads. About 250 industrial plants are located in Greater Cairo, which represents 35% and contributing about 40% of the total metal discharges. The Delta excluding Alexandria has some 150 industries, which contribute about 25% of the heavy metals discharging to drains. Alexandria is a major heavy industrial centre with some 175 industries, about 25% of the total in Egypt

Sources of Pollution

- **Upper Egypt:** Sources of industrial pollution along the Nile in Upper Egypt area are mainly agro-industrial and small private industries. Sugar cane industries significantly influence Nile water quality at Upper Egypt-South zone. Hydrogenated oil and onion drying factories influence Nile water quality at Upper Egypt-North zone.

- **Greater Cairo:** The area has a population of approximately 18 million and encompasses many industrial and commercial activities. Heavy industry is located around, south and north of Cairo. Many small industries and some heavy industry are randomly located throughout the city. Although wastewater discharges of the small industries are generally low, concentrations of certain industries in specific areas, such as the tanning industry may cause local contamination problems. An overview of pollution sources include 23 chemical industries, 27 textile and spinning industries, 7 steel and galvanizing industries, 32 food processing industries (including a brewery), 29 engineering industries, 9 mining and refraction industries, and petrol and car service stations, bakeries (>350), marble and tile factories (>120) and tanneries in South Cairo.

- **Lake Nasser:** Generally speaking, water released from Lake Nasser mostly exhibits the same seasonal variation and the same overall characteristics from one year to another. Downstream changes in river water quality are primarily due to a combination of land and water use as well as water management interventions such as: different hydrodynamic regimes regulated by the Nile barrages, agricultural return flows, and domestic and industrial waste discharges, including oil and wastes from passenger and riverboats.

- **River Nile from Aswan to Delta Barrage:** Chemical Contamination: From the available data, the following can be concluded that Dissolved Oxygen Concentration (DO) situation is not alarming. Specific "hot spots"could not be detected. In all monitored sites, DO concentrations were higher than 7.0 mg O2/l, indicating the high assimilation capacity of the Nile. Chemical Oxygen Demand (COD) values showed slight, but steady increase from south to north. 21 samples out of the 35 samples were not complying with the standard value given by law 48/1982 for ambient water quality (10 mg O2/l). Biochemical oxygen Demand (BOD5) which is a measure for biodegradable organic compounds showed a random distribution but did not exceed the standard value (6 mg O2/l) given by the law. The relationship between COD/BOD values indicates the presence of non-biodegradable organic compounds, from industrial sources. An increase in TDS from 171 mg/l at Aswan to 240 mg/l at the Delta Barrage has been recorded. But this is within the permissible limit given by the law.

- **Biological Contamination:** Law 48/1982 did not specify a standard for faecal coliform (FC) counts for the ambient water quality of the Nile River. Therefore, the value given by the WHO (1989) as a guideline for use of water for unrestricted irrigation (103/MPN 100ml) has been taken as a guide for the evaluation of the water quality in this report. The results of the microbiological examination indicated a great variation in the spatial distribution of the faecal coliforms counts. Great excesses have been found around the catchments areas of Kom Ombo, El-Berba, Main Ekleet and Fatera drains. FC counts in the water samples taken from the specific bank side, where the drain water is pumped, are even higher. This proves the presence of untreated human wastes in these drains.

- **Damietta and Rosetta Branches:** The Rosetta receives water of a number of agricultural drains, which are heavily polluted by industrial and domestic sewage. The drains receive large parts of the wastewater of Cairo. The wastes in the drains contain high levels of suspended and dissolved solids, oil, grease, nutrients, pesticides and organic matter. It is suspected that toxic substances are present as well. The Damietta Branch also receives polluted water from a number of agricultural drains; The Fertilizer Company is considering the major point source of industrial pollution at Damietta branch.

- **Alexandria Area:** Alexandria is a major industrial centre with some 175 industries, about 25 per cent of the total in Egypt. These industries include paper, metal, chemical, textile, plastic, pharmaceutical, oil and soap and food processing. The plants are reported to contribute some 20 percent of the total wastewater of Alexandria. The industries discharge their effluents mainly to Lake Mariut and partially to the sewerage network. According to a survey made by Drainage Research Institute, different types of industrial wastes are disposed to Lake Mariut. At least 17 factories discharging directly to the lake through pipelines, 4 factories collect their wastewater in trenches. Moreover, nineteen factories are lying in the vicinity of the treatment plants, 22 factories discharging to nearby drains and then to the lake.

Water Logging/Salinity/Sodicity

Salinity: It is estimated that in Upper Egypt, approximately 4 bcm of drainage water returns to the Nile every year. This drainage water has a much higher salinity than the originally ingested irrigation water and contributes to an increase of salinity of the River Nile along its course from the High Aswan Dam to the Delta. Fortunately, the high mixing ratio of Nile and drainage water keeps the increase of salinity within acceptable limits. Salinity increases from 160 mg per litre at the High Aswan Dam to 250 mg per litre in Cairo. In the Delta, because of the domestic and industrial pollution from Cairo and because of intensive agriculture, salinity in the drainage and irrigation systems further increase; salinity of drainage water discharged into the Mediterranean Sea or the northern Lakes averaged 2260 mg per litre. More than half of this drainage water has a salinity <2,000 mg per litre and could be potentially reused for irrigation and drinking water supply after appropriate treatment and mixing. Due to more intensive use, salinity of the discharged drainage water may increase in the next years and re-use of drainage water may become more complicated than before. With the construction of the High Aswan Dam in 1964, silt deposits on the Nile flood plains have decreased from 24 million tons per year to 2.1 million tons per year. This decrease has been responsible for a significant increase in the use of chemical fertilizers, resulting in increased values of nutrients in canals and drains.

The salt affected soils in Egypt are located in the north, east and west of Nile Delta, soils adjacent to lakes Edko, Maryut, El-Burrullus and El Manzala; and also in some areas such as Wadi El-Natrun, Oases and El-Fayoum. This is mainly due to the wide use of flood irrigation and unaccounted-for water usage, water irrigation from the Nile is exaggerated leading to soil water logging and poor drainage of excessive water that exceeds the growing plants needs. Thus, soil salinity components reach a level causing damage to plant production and deterioration to some of the chemical and biological soil elements. Some lands become so rich in soda due to the increase in sodium element causing more degradation in physical elements. During the seventies, sedimentary soil area affected by salinity and soda was estimated to be 30 to 35% of the total Nile valley and Delta area (State of Environment Report, 2005).

The salinity measurements made by (Drainage Research Institute (DRI) in the Delta show that closer to the Mediterranean Sea, salinity in the drainage water increases, to reach level close to 10,000 mg per litre close to the coast. Although part of the salinity increase may be caused by leaching of salts from the soil, it is believed that most of this increase is caused by upward seepage of brackish groundwater. This theory is supported by observations from DRI and RIGW with regard to chemical composition (major ions) of adjacent drainage and ground water.

Threats to the Biodiversity

Egypt's unique geographical position at the junction between two large continents (Africa and Asia), and its inclusion as part of the Mediterranean Basin, has permanently influenced both the people and the biota of the country socially, economically and biologically.

As part of the Sahara of North Africa, Egypt has the climate of the arid Mediterranean region, with notable differences between the coastal and inland areas. Under such harsh geographical and bio climatic conditions, it is to be expected that the biotic wealth of Egypt is not only poor relative to the total area of the country, but also sparse and widely scattered.

In the process of identifying the different types of fauna and flora in Egypt, certain groups (e.g. flowering plants) have been carefully surveyed and well documented, while others (e.g. mosses and liverworts) have not received adequate attention. Each of these habitats has its unique fauna and flora and numerous land and marine areas are listed as protected sites. An estimated 18,000 species of flora and fauna are in Egypt. With regard to flora, there are 44 species of viruses, 238 bacteria, 1,260 fungi, 1,148 algae, 369 non-flowering vascular plants and 2,072 flowering plants species. The fauna include 10,000 species of insects, 1,422 other vertebrates, 755 fishes, 105 reptiles and amphibians, 470 birds and 126 species of mammals. However, until to date, there are no clear statistics that quantify the rate of biodiversity loss in Egypt. (OSI Environment Synthesis Report p. 35)

Egypt's biodiversity has faced threats from various sources. These include intensive agriculture systems, which entail the widespread use of agricultural chemicals in the form of fertilizers and pesticides. Another source of threat is the effects of industrialization. Industrialization programs have accelerated enormously in the second half of the 20th century, and have contributed to the rapid deterioration of the environment. Moreover, excessive hunting of animals and destruction of plant life have endangered the existence of several species of resident and migratory birds, as well as a number of hoofed animals (e.g. gazelles and antelopes).

Accordingly, Egypt is exerting tremendous effort to combat the threats to biodiversity through the conservation of wildlife, natural resources and natural habitat. This is clearly manifested in the declaration of 21 protected areas by prime ministerial decrees in accordance with Law 102/1983, covering about 8% of the total national surface, with plans to have this extended further to 17% by 2017.

Wastewater Treatment Systems

The treatment systems in Egypt can be divided into two basic types: aerobic and anaerobic treatment. The four most common aerobic treatment technologies are activated sludge, aerated lagoons, oxidation ponds, trickling filters and rotating biological contactors (RBC). Activated sludge and oxidation dishes represent 58% of the technologies and 72% of the total wastewater treatment capacity (El-Gohary, 2002). In Greater Cairo, the capacity of the El Gabal El Asfar secondary treatment plant (WWTP) was 3 Mm^3 per day and services 12 million people. A secondary WWTP with 0.33 Mcubic meter/day treatment capacity exists at El-Zenein and 0.4Mm^3 per day treatment plants exist at Berka (0.6 Mm^3 per day to primary standard) and Shoubra El-Kheima (about 0.6 Mm^3 per day).

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Annex 4

The Eastern Nile Basin: **Agriculture and Irrigation**

Annex 4: The Eastern Nile Basin: Agriculture and Irrigation

Agriculture is the most important economic activity and plays a major role in the lives and livelihoods of most households in the EN countries, as well as contributing significantly to overall economic growth and Gross Domestic Product (GDP). A wide variety of crops are grown in the region both under rainfed and irrigation for domestic consumption and export. Rainfed agriculture, supported to some extent by small scale irrigation and water harvesting systems, is the dominant form of agriculture in the upstream countries (Ethiopia and South Sudan), whereas irrigated agriculture is dominant in the two downstream countries (Sudan and Egypt). Though there is huge potential (apart from Egypt) for rainfed agriculture, production level is low being largely subsistence and extremely vulnerable to climatic conditions and in some parts, to the disruptive impact of civil conflict.

Irrigation development is a priority in all the EN countries and is considered as an effective vehicle to mitigate the impact of climatic conditions and enhancing rural development and food security. There is approximately 5.3 million ha currently under irrigation in the region with additional 4 million ha potentially suitable for further expansion. Although, production levels in Egypt are relatively higher, the overall performance of the existing irrigation schemes in the region generally is unsatisfactory. Since water scarcity and high investment cost would be a limiting factors for expansion of irrigated areas, **intensification of existing rainfed and irrigated agriculture is a key for boosting production and enhancing food security in the region.**

AGRICULTURE IN EGYPT

Crop Production

Agriculture in Egypt is the most important productive sector in the economy. It provides 20% of Gross Domestic Product, 34% of the total exports, 32% of the total labor force and much of the Egyptian food Supply. Egypt is located in semi arid zone with very low, irregular and unpredictable rainfall. Annual rainfall ranges between a maximum of about 200 mm in the northern coastal region to a minimum of nearly zero in the south, with an annual average of 51 mm. Due to this, Agriculture in Egypt is almost entirely dependent on irrigation from the Nile, which is the main source of water supply. Out of 55.5 the BCM allocated to Egypt by the 1959 agreement, 84% is used for agriculture.

Egypt covers an area of about one million km², of which only 35,000 km² is cultivated and permanently settled. The Nile Valley and Nile Delta are the most important regions, being the country's only cultivable areas supporting about 95% of the population. The regions were created by the sediments and deposits of the Nile for thousands of years until the construction of the High Aswan Dam in 1968. The Nile valley extends approximately 900 km from Aswan to the outskirts of Cairo. The Nile Valley is also known as Upper Egypt, while the Nile Delta region is known as Lower Egypt. The Delta of about 25,000 km² consists of flat, low-lying areas, with about 200 km length from south to North, and a coastline of about 300 km long. It is among the most densely-populated agricultural areas in the world.

The total cultivated area in Egypt is 3.4 million ha, representing only 3 percent of the total land area. The entire crop area is irrigated, except for some rain-fed areas on the Mediterranean coast and north Sinai. The old irrigated lands, lying in the Nile Valley and Delta with fertile alluvial soils, cover an area of 2.25 million ha. Over the past four decades, newly reclaimed desert lands amounting to 1.1 million hectares has been added to the agricultural area. The soils of these areas are sandy and calcareous, with poor organic matter and macro-and micro-nutrients. The program of desert land reclamation started in the 1980's. They are located on the western and eastern sides of the delta, the Sinai region (El Salam canal project) and west of the Nile valley in Upper Egypt (Toshka project). The land holdings are fragmented, with the average size of farm units ranging between 0.6-1.5 ha.

Egypt is not food self-sufficient. It is producing only about half of its food supplies and food imports reached about $ 10 billion in 2012 (Mohamed M Nour, 2013), and demand is expected to increase with the growing population. It imports substantial amount of wheat and varying proportions of other agricultural commodities and processed food. Leading imports in rank order of value were: 1) cereals (wheat and corn); 2) lumber; 3) beef; 4) soybeans; 5) vegetable oils; 6) feed materials (soybean meal & corn gluten feed); 7) edible beans; 8) dairy products; 9) sugar; and 10) cotton (Agricultural Economy and Policy Report, 2009). Food self-sufficiency will further reduce in the future due to population increase and an expected shift towards more export oriented crops (National Water resources Plan 2017).

Croppimg Patterns

Due to the favourable climate, plentiful water, and exceptionally fertile soils, Intensive and multiple cropping agricultural practices are common in Egypt. Cropping intensity on the average reaches 180%, meaning that about 6.0 million ha are harvested annually over 3.3 million ha of land. The high cropping intensity was made possible after the completion of the high Aswan dam in 1968 and through improved water management and cultivation of early maturing varieties. The agricultural production can be divided in five categories: (1) cereals, (2) Fodder, (3) pulses, (4) industrial crops and (5) horticultural crops. Cropping patterns in the Delta and Upper Egypt are identical with the exception of sugar cane grown in Upper Egypt only, and rice cultivated in the Delta only. Rice cultivation in the Delta is seen as one of the means to control salinity. Table A3.5 shows area covered by major crops in the past five years.

Yields

Crop yields in Egypt are considered to be high. Following the Agrarian Reforms (Green Revolution) in the early 1960s, crop yields and total production in Egypt has increased significantly over the years. For instance wheat yield has increased from 2 ton/ha in the early 80s to 6.4 ton/ha in the present day, maize from 4 ton/ha to 7.6 ton/ha, rice from 3.5 ton/ha to 9.4 ton/ha, cotton from 1 ton/ha to 2.8 ton/ha. The Green Revolution has been accomplished through two stages: land redistribution and strong control over farmers (1960 – 1980) then dissemination of technology packages (1980 – 1993). By 1993 the agricultural sector was liberalized and the Government control over farm areas, price and procurement are lifted. Input subsidies are progressively removed and the private sector involvement in processing and Trade improved. The only remaining major government involvement is in the food subsidy (in some wheat products, bread subsidy in particular).

In general, the present high average yields achieved in Egypt are attributed to:

- Favorable climatic conditions for crop growth especially in the Delta;
- Adequate and reliable water supply in most areas of the irrigation system managed by a strong irrigation bureaucracy at no cost for farmers
- Investments in irrigation and drainage infrastructure: all the irrigated area of Egypt is drained, rehabilitation and improvement of the existing infrastructures are being carried out at almost no cost for farmers

Table A4.1: Harvested area of major food crops (Ha)

Crop	2009	2010	2011	2012	2013	Average
Wheat	1,335,295	1,287,627	1,284,946	1,336,234	1,418,708	1,332,562
Maize	983,081	968,519	888,329	1,041,345	900,000	956,255
Rice	575,467	459,525	593,185	620,285	700,000	589,692
Sorghum	141,253	140,157	156,986	142,744	141,200	144,468
Sugar cane	133,019	134,538	136,709	138,300	139,600	136,433
Soybeans	7,179	15,233	9,548	7,000	8,000	9,392
Seed Cotton	119,462	155,039	218,451	120,000	140,000	150,590
Vegetables	97,817	131,454	131,648	118,500	-	119,855

Source: FAO-STAT-2014

- Effective dissemination of green revolution technology packages including improved crop varieties, fertilizers and pesticides
- Efficient public agricultural research centers and extension services at no charge for farmers.

Irrigation Sub sector

The total irrigated area in Egypt is 3.35 million ha plus estimated 40,000 ha of oases. Annual cropped area is approximately 6.0 million ha and cropping intensity is 180%. The Nile is the source of irrigation water although in some oases fossil underground water is used.

AGRICULTURE IN ETHIOPIA

Crop Production

Agriculture is the backbone of the national economy in Ethiopia, accounting for 46.3% of the GDP, 84% of exports and employing 85% of the labour force. Both industry and services are dependent on the performance of agriculture, which provides raw materials and generates foreign currency for the importation of essential inputs. In spite of its importance the agriculture sector is dominated by subsistence rain-fed agriculture, with nearly 12 million small holder houses engaged in this system and contributing approximately 95 per cent of the agricultural GDP (Ministry of Agriculture, 2014).

Almost all the subsistence farm activities are concentrated in the highly populated and degraded highlands (elevations between 1500 and 3000 masl). Family land holding size is generally small, between 0.5 and 1.5 ha and the production system is outdated. Animal traction (oxen) and family labour are used for land preparation and other farming activities to produce a wide range of crops. Livestock production is an integral part of the system, but is increasingly being restricted to stall-feeding of animals due to scarcity of land. Shortage of land due to high population density, deteriorating soil fertility due to over grazing and deforestation and rainfall volatility is the biggest challenges facing this production system. There is not much agricultural activities in the lowlands, though there is huge potential for the development of both rain fed and irrigated agriculture.

Though commercial farms are emerging, their contribution to the national production so far is still small especially within the basin. Outside of the basin, commercial farms include the public irrigated farms producing the bulk of industrial crops (sugar, cotton, tobacco) and horticulture crops in the Awash valley; state owned rain-fed farms mostly in the highlands that produce wheat and the rapidly growing private cut-flower business located in the vicinity of Addis Ababa and the rift Valley.

Within the basin, sesame producing commercial farms are largely concentrated in the Tekeze Atbara sub basin. There are also a number of large scale farm projects at various stages of advancement recently initiated by foreign investors from India, Pakistan and Saudi Arabia for production of food crops (rice) and industrial crops (sugar cane) in the Baro Akobo Sobat sub basin (Gambella Region).

Cropping Patterns

There are two rain fed production seasons in Ethiopia, Meher and Belg. Meher is the production season during the major rainy months (July-October) while Belg is the production season during the short rains (January-April). In some areas (including Abbay. Blue Nile and Tekeze.Atbara sub basins) double cropping is practised by growing seasonal crops (mostly food grains and vegetables) during both Meher and Belg seasons.

The total cultivated area (Meher, Belg and commercial farms) in the country had reached 15.5 million ha in 2013, of which between 3 to 4% is under irrigation. Table A3.1 show the cultivated areas during the past 5 years. The cultivated area is showing a steady increment each year. Between 2010 and 2013 alone the total cultivated area has increased by 1 million ha. The main reason behind is population growth and to some extent expansion of commercial farms

Table A4.2 : Total Cultivated areas in Ethiopia (ha x 1000)

Crop	2009	2010	2011	2012	2013
Small holder –Meher					
Cerials	8,770	9,233	9,691	9,589	9,601
Pulses	1,585	1,489	1,358	1,619	1,863
Oil Seeds	855	781	775	881	818
Vegetables	162	138	127	160	193
Root Crops	146	212	214	200	206
Fruits	48	53	55	61	62
Chat	138	139	205	180	174
Coffee	391	395	499	552	529
Hops	24	24	22	23	23
Sugar Cane	16	19	23	22	22
Enset	279	396	302	326	351
Sub Total	12,414	12,879	13,269	13,613	13,842
Small holder (Belg)	**NA**	**1,203**	**1,244**	**1,173**	**1,192**
Commercial Farms (Meher&Belg)	**NA**	**342**	**415**	**452**	**460**
Total		14,424	14,928	15,238	15,494

Major crops grown in the country and in parts falling within the Eastern Nile basin are:

- **Cereals:** These include barley, teff, sorghum, wheat, oats, millet and maize. As the major staple grains they occupy (on the average) 71 % of the total Meher cultivated area by subsistence farmers. Barley, wheat, teff and oats grow in cooler areas, while sorghum, maize and millet grow in relatively warmer areas of the country.
- **Pulses:** Pulses include beans, peas, chickpeas and lintels, which occupy 12% of the Meher cultivated area by subsistence farmers. They are the major sources of cheap protein for the majority of the population and grow in cooler areas,
- **Oil seeds:** include neug (niger seed), linseed, groundnuts, sunflower and sesame which grow in warmer areas. They occupy about 6% of the cultivated area and are the major sources input for the local oil processing plants as well as for the export market.
- **Vegetables and Root crops:** These occupy about 2.7% of the Meher cultivated area and grow in both cooler and warmer areas; holders living near to urban centres largely practice vegetable farming.
- **Fruits:** Include citruses, bananas, mangos, papaya, etc, which grow in warmer areas. They occupy only 0.4% of the cultivated area.
- **Cash crops:** Include coffee, chat, hops, cotton and sugarcane. They grow in warmer areas and occupy about 5.3% of the cultivated area. Coffee alone cover 4% of the cultivated area and is the major commodity for the country,
- **Enset:** Also known as false banana locally occupies about 2.5% of the Meher cultivated area. It grows in relatively warmer areas and is the major staple food in the south and south western parts of the country. . Within the EN, Enset grows only in the Baro Akobo Sobat sub basin.

Table A3.2 provides a summary of where the different crops are grown.

Table A4:3: Cropping patterns in sub-basins

Crop	Baro-Akobo-Sobat White Nile	Abbay-Blue Nile	Tekeze-Setit-Atbara
Cereals	Wheat, teff and barley are dominant crops in the medium and highland areas, maize and sorghum grow in the lowlands by transhumant farmers	Wheat, teff and barley are dominant crops in the medium and highland areas, maize and sorghum grow in the low lands under irrigation and rainfed.	Wheat, teff and barley are dominant crops in the medium and highland areas, maize and sorghum grow in the low lands under irrigation and rainfed
Pulses	groundnuts are grown in lowland areas at household level	Beans, peas, chick peas, lintels grow in the high lands, while few groundnuts are grown in lowland areas	Not common crops
Oils seeds	Not common crops	Are common crops in medium to highland areas	Sesame is the dominant crop grown by commercial farms in the lowlands.
Vegetables	Are grown to limited extent at household level	Are dominant crops in small scale and traditional irrigation schemes	Are dominant crops in small scale and traditional irrigation schemes
Fruits	Mangos are dominant household fruits in mid to lowland areas	Grow in households and are generally confined to mid and lowland areas	Limited amount in small scale and traditional irrigation schemes
Cash crops	Sugarcane, coffee, chat grow at household level in mid and lowland areas under irrigation and rainfed.	Sugarcane, coffee, chat grow at commercial and household level in mid and lowland areas under irrigation and rainfed.	Limited Sugarcane, coffee, chat grown at household level in mid and lowland areas (irrigation and rainfed)
Enset	Is a major/common food crop growing in mid and highland areas	Not common crop	Not common crop

Yields

Despite significant improvements achieved over the past two decades, crop yields in the country are still low, as compared to world standards. Average yields of major cereals have increased by over 60% in the past years (from 1.16 ton/ha between 1995 and 2000, to 1.87 ton /ha between 2009 and 2013). The overall agricultural productivity has increased by an average of 8% in the last seven years (Ministry of agriculture, 2014), due to the following:

- Appreciating the importance of the agricultural sector to the national economy and food security, the government has demonstrated strong commitment to transform the sector by an increased budget allocation.
- To enhance the productivity of small farmers and to improve food security both in the rural and urban areas, the government designed and implemented an "Agricultural Development Led Industrialization" (ADLI) strategy. The strategy aims to use agriculture as the base for the country's overall development,
- The government also introduced specific policies and provided technical and institutional support to farmers, in its drive to increase food production through intensive cultivation. These policies included fertilizer supply and distribution, improved seed supply and distribution, development of small-scale irrigation, conservation of natural resources and environment, agricultural research and extension work & marketing and price policy,
- Improved international market opportunities for agricultural commodities, particularly for oil crops and pulses.

Even though significant achievements have been recorded in the agricultural sector in the past years, poverty and food insecurity are persistent in Ethiopia. The country is not self-sufficient in food and its overall economy until recently has been too weak to purchase food on the international market to meet its needs. Many Ethiopians are too poor to buy food even when it is available; and Ethiopia's rain-fed agriculture depends on highly variable and increasingly unpredictable climatic conditions.

Because of the government's interventions in the agricultural sector and relatively favourable climatic conditions, dependency on food aid has reduced in the past few years. According to the Humanitarian Requirements Document (HRD) released at the end of January 2014 by the Government of Ethiopia, 2.7 million people are food insecure, and they need humanitarian assistance between January and December 2014. This is relatively small as compared to the previous years.

Irrigation sub-sector

Irrigated agriculture is considered as one of the major drive for increasing productivity and enhancing food security in Ethiopia. The country has huge water and land potential suitable for irrigation development in the 12 basins, three of which are located in the Eastern Nile. The total surface water irrigation potential of the country is estimated at 3.7 million ha (Ministry of Water, Irrigation and Energy). In addition, up to 1.1 million ha of land could be irrigated using the country's ground water potential (EWIMI, 2010). Despite this, the country relies predominantly on rain fed subsistence agriculture, which often is affected by rainfall variability and recurrent drought and a number of other constraints. Of the total 15.5 million ha of cultivated land, a little over 500,000 ha (3.2%) is currently estimated to be under irrigation nationwide.

Depending on their size, irrigation schemes in Ethiopia are classified as:

- Small Scale Irrigation (SSI) schemes; often community-based, traditional schemes, (<200 hectares) and covering the majority (>380,000 ha) of the total irrigated area.
- Medium scale Irrigation schemes; they are either community based or public schemes, with sizes ranging from 200 to 3,000 ha.
- Large Scale Irrigation schemes; include public and private commercial farms with sizes more than 3,000 ha. They are mostly located in the Awash River Valley and for the production of industrial crops (cotton and sugarcane) and horticultural crops.

The study, design and implementation of small scale irrigation schemes are under the responsibility of the Federal Ministry of Agriculture and Water or Agricultural Bureaus of Regional States. The Federal Ministry of Water, Irrigation and Energy is responsible for the medium and large scale irrigation schemes.

The estimated area so far developed under irrigation in the EN part of Ethiopia is about 120,000 ha (ENIDS CRA Study, 2010). Of this amount, the existing large scale irrigation schemes covers only an area of 17,000 ha (10, 000 ha Fincha Sugar scheme and 7,000 ha Koga small holders irrigation scheme), whereas the remaining balance (a little over 100,000 ha) are small scale irrigation schemes, 80% of which are traditional. Details of the existing (120,00ha) and planned irrigation projects in Ethiopia are presented in Section 5,3.8.

Traditional irrigation has been practised for many years in Ethiopia. The schemes are constructed and managed by the communities by diverting water from nearby streams or small rivers. There are no water control structures and diversions are made using locally available material (stones, tree trunks, etc). They often are destroyed by flood and have to be re-built each year after the rains. Irrigation methods are either basins or furrows on unlevelled fields. Modern small scale irrigation schemes are usually constructed by NGOs or the government assistance and provided with better control and diversion structures. The study, design and operation and maintenance of small scale irrigation schemes are under the responsibilities of the Water and Agricultural Bureaus of Regional States.

Cropping pattern of small scale irrigation and rainfed agriculture are quite similar, dominant crop are food crops (cereals, pulses) and vegetables, in schemes located near towns. Crop yields (though reported to be two to three times better than the rain fed farms) are low. The major reasons being:

- Poor design and construction,
- Poor operation and maintenance,
- Use of outdated irrigation and farming technologies,
- Inadequate research and extension services,

- Lack of credit facilities, poor market structure and information
- Lack of agricultural inputs (fertilizers, improved seed, chemicals, etc),

In order to reduce vulnerability to climate change and improve productivity of the agricultural sector, the government of Ethiopia is highly committed to expand irrigated agriculture. The total area of planned expansions in the three sub-basins (Abbay-Blue Nile, Baro -Akobo- Sobat and Tekeze) of the EN amounts to 1.59 million ha. Of this amount, about 300,000 ha are small scale irrigation schemes. The estimates are based on the suitability of land for irrigation using surface water only. If lands suitable for other modern methods of irrigation (sprinkler and drip) are considered, the potential irrigable areas will increase substantially. Details of existing and planned irrigation schemes are provided in 5.3.8. Except a few schemes around Lake Tana, almost all the schemes are dam dependant because of the high seasonality of the tributary rivers.

AGRICULTURE IN SOUTH SUDAN

Crop Production

As with the other EN countries, agriculture is considered as the major drive for growth, enhancement of food security and alleviation of poverty. The country is endowed with huge land and water resources and favourable climatic conditions for agricultural development. Over 95% of the total area of South Sudan (658,842 km2) is considered suitable for agriculture, 50% of which is prime agricultural land suitable for producing a wide range of agricultural products, including annual crops such as grains, vegetables, tree crops such as coffee, tea, and fruits, livestock, fishery, and various forest products (CAMP SAR, 2013).

Following a long period of civil war and instability, levels of production are low and the contribution of agriculture to the national economy so far is insignificant, estimated at 36% of non-oil GDP in 2010 (South Sudan an Infrastructure Action Plan Document, 2012). The value of total agricultural production in South Sudan was estimated at only US$808 million in 2009 (World Bank, 2012) with 75% of this value accruing from the crop sector with the rest attributed to the livestock and fisheries sectors.

About 90% of the population lives in rural areas and is dependent on agricultural activities (crops production, livestock and fisheries) for their livelihood. The estimated land under cultivation in the country is about 2.7 million ha, which is only about 4 % of the total land area.

Cropping Patterns

Over 98% of agricultural production is rain- fed, predominantly characterized by low input and low output traditional and subsistence farming. Cropping activities, for the most part are, based on small, hand-cultivated units often farmed by women-headed households. Manual land preparation limits the area households can cultivate. Efforts are being made by the government and NGOs to promote the use of animal traction, so that larger areas would be cultivated at household level.

The most common crops grown in the six agro ecological zones of the country include sorghum, millet, maize, beans, pumpkins, cassava, sweet potatoes, groundnuts, sesame and rice. Coffee and tobacco growing is also practiced in some states. Except rice and coffee, similar crops are grown in the three states (Upper Nile, Jonglei and Eastern Equatoria) located in the EN basin. Despite the availability of fertile land and favorable agro climatic conditions, the performance of the agricultural sector is not satisfactory.

The crops grown in the three states located in the EN Basin, Upper Nile, Jonglei and Eastern Equatoria, are almost the same as the other parts of the country (Table A3.3).

Table A4.4: Cropping pattern in the Eastern Nile part of South Sudan

Crop	Upper Nile State	Jonglie State	Easter Equatoria State
Cereals	Maize, sorghum	Maize, sorghum, bean	Maize, sorghum, bean, wheat, millet
Cash crops	groundnut, sesame, sunflower, cow pea	groundnut, sesame, tobacco, cow pea	groundnut, sesame, cow pea, banana
Vegetables	Okra, tomatoes, pumpkins, etc	Okra, egg plant, tomatoes, pumpkins,	Okra, tomatoes, pumpkins, etc
Cereals area (ha)	80,100	107,600	130,500
Average cereal yields (T/ha)	0.59	0.66	1.08

Source: CAMP, 2013

Yields

Average yields fell from 0.75 t/ha in 2005 to 0.65 t/ha, in 2010 and the country's total net cereal production declined almost by 19 % to about 562,600 tonnes over the same period. (South Sudan Agricultural sector Investment Plan, 2013), much lower than the other EN countries. The result has been food insecurity in South Sudan. Cereals, primarily sorghum and maize, millet and rice are the dominant staple crops, with sorghum cultivated by more than half of all households. South Sudan imports as much as 50% of its requirements from neighbouring countries, particularly Uganda and Kenya.

Major factors/constraints contributing to the existing poor performance of the agricultural sector, among others, include:

- Use of extremely outdated agricultural technologies; rain-fed traditional and subsistence farming, simple farm implements; small average farm sizes (0.4-1.7 hectares),large post harvest losses; lack of irrigated and commercial farms.
- Weak/ non-existent research and extension services and credit facilities to farmers,
- Lack of improved seed varieties and agricultural packages,
- Poor and inadequate infrastructure; transportation, storage and processing facility is underdeveloped and electricity services are not available in rural areas,
- Weak markets and non-existent market information systems.
- Shortage of farm labour; Close to 80% of farm labour is provided by women who combine farming with their other domestic activities. Available labour is expensive;
- Little involvement of the private sector in development and service delivery,
- Unclear and fragmented land tenure system,
- Insecurity; conflicts disrupt crop cultivation and displace farmers, causing serious food insecurity in many areas.
- Drought and flooding, particularly in the lowland areas.

The country is planning to increase the performance of the agricultural sector through both horizontal expansion and intensification of the existing cultivated areas and a Comprehensive Agricultural Development Master Plan (CAMP) is under preparation with the assistance of JICA. The Master Plan is expected to identify the agricultural potential of the country, recommend institutional set up and set priorities for development together with the resources required for implementation.

Irrigation Sub-sector

Irrigation is considered as one the major vehicle for boosting agricultural production and enhancing food security in South Sudan. With its abundant land and water resources (River Nile and its tributaries, wet lands and reach aquifers), the country is believed to have ample potential for irrigation development. However, no proper study and inventory have been conducted so far to determine the country's exact water resources and irrigation potential. Previous studies conducted in the EN region and NBI (ENIDS-CRA Study and EWUAP-Large Scale Irrigation study, NELSAP-Regional Agricultural Trade

Project, etc) have not covered South Sudan in their assessment of potential irrigable areas in the Nile Basin countries. The Irrigation and Drainage Master Plan (IDMP), which among others is expected to identify the country's irrigation potential is still under preparation with the assistance of JICA and will not be ready until June 2015. In addition, the Baro Akobo-Sobat Integrated Water Resources Management and Development Study, recently launched by ENTRO, which is also expected to identify potential irrigable areas in the sub basin, has not yet been advanced. Because of these, it is found very difficult to determine the size of the country's irrigation potential and estimate the water requirement of the agricultural sector in South Sudan.

Based on the NEL Region-Multi Sector Investment Opportunity Analysis study conducted in 2012, the irrigation potential of all of South Sudan was estimated at 28,237,299 ha with around more than 10 million ha in the EN part of the country. While this estimate is clearly unrealistic based as it was only on a consideration of the land resources (the available water resources and other technical, social, environmental and financial issues have been not considered), it is evident that the potential is vast.

As per the information obtained from the South Sudan workshop participants in the Situational Analysis workshop (Khartoum, October 2014), the estimated irrigation potential in the EN part of the country is 2.65 million hectare. This is based on the IDMP Draft Progress Report 2. Despite several attempts to get hold of this report in order to understand the details behind this estimate of potential, it has not been possible to obtain. However, for the purpose of the MSOIA study, it is not the overall irrigation potential that is required but rather the irrigable area that has been identified for development at the project/scheme level(at least at the project identification phase). In the absence of such information it has been assumed that up to 165,000 (as estimated by FAO, 2013) of the overall potential could be developed in the Baro-Akabo-Sobat Sub-basin in the foreseeable future. This figure will have to be revised in line with irrigation development plans as they emerge and are made available.

The existing irrigated area in the country is limited to two schemes(Aweil and NUNIS) totalling 42,500ha. NUNIS (Northern Upper Nile Irrigation Schemes) located in the EN basin has 35,000 ha consisting some 22 small-scale irrigation along the White Nile (most currently abandoned). Rice is the main irrigated crop and current yields are low (1.3 ton/ha) (Irrigation and Drainage Master Plan preparation Task Team assessment of May 2013).

All the existing schemes require heavy rehabilitation works to bring them to the required level of operation and production. The Ministry of Electricity, Dams, Irrigation & Water Resources has conducted feasibility study and detailed design on two of the schemes to start the rehabilitation works. The Government is committed to developing the irrigation potential of the country in order to reduce vulnerability to rainfall variability.

AGRICULTURE IN SUDAN

Crop Production

Sudan is endowed with huge land and water resources and favourable climate for the development of agriculture under rainfed and irrigation conditions. Agriculture contributes a significant portion to the GDP and offers employment to 70-80% of the rural Labour force. Despite the increasing predominance of oil exports, agriculture remains an important sector in the Sudanese economy, contributing an annual average of 45 % to total GDP during years 2000 to 2010 (Khalid H.A.Siddig, et al, 2011). The value of the crop and livestock sub-sectors together contributes 80 to 90 percent of non-oil export earnings. Moreover, agriculture contributes to other activities such as transportation, agro-industries, and commerce, in the industrial, trade, and service sectors which account for a large share of the GDP. With the decline of the oil export in recent years (after the separation of the South Sudan), the country is giving more emphasis to the intensification of the agricultural sector thus, its contribution to the national economy and food security is expected to increase significantly in the coming years. The sector is generally divided into four sub sectors:

- Traditional rain fed,
- Semi Mechanized rain fed (commercial farms),

- Irrigation and
- Livestock

The traditional rainfed sector provides staple food for the majority of the subsistence farmers, other domestic consumers and contributes to the export sector. The semi-subsistence-based rainfed farming system exists mainly in Kordofan, Darfur, Sennar, and the Blue and White Nile areas. It covers 50% of the total cultivated land in the country and supports the bulk of the rural poor, estimated at 70%. The total cropped area in this system is estimated at 9 million hectares, with small farmers typically having 4.2 to 6.3 hectares cultivated for subsistence and income. The total area fluctuates annually depending on the availability of rainfall. In addition to the staple food crops (sorghum and millet), the system is also largely involved in the production of oil seeds (sesame and groundnuts). Some farmers also integrate livestock in their production plans. The smaller farms regularly produce about 90 percent of millet, 10 percent of sorghum, 48 percent of the groundnut and 28 percent of the sesame grown in the country. Almost all the gum Arabic is also produced from this sub sector.

Nevertheless, this system is characterized by low crop productivity due to use of traditional farming practices, inadequate input, research and agricultural services, erratic rainfall and recurrent draught, pests and disease infestations. Its average contribution to the total agricultural GDP is only about 16% (Siddig, 2009).

Farmers in the traditional subsector use greater levels of labour input and appear to pay much more attention to good farming practices than the private farmers in the mechanized subsector with a wider use of crop rotation, more frequent and timely sowing higher sowing rates, greater plant densities, more efficient use of land, etc. They usually receive greater returns in terms of yields per ha than the private sector. Traditional farmers have demonstrated that they are the best potential for agricultural growth in Sudan. By promoting the traditional farmers, agricultural development in Sudan will combine growth with poverty reduction because most of these farm households are poor.

Semi-Mechanized Rainfed agriculture system started in the mid 1940s on a limited scale in the vicinity of Gedaref. With time the area increased to about 6 million hectares in rainfall areas ranging between 400-800 mm annually in Gedaref, Blue Nile, White Nile, Sennar and Southern Kordofan (Nuba Mountains) areas. Under this system, large parcels of land, typically more than 400 ha but sometimes ranging between 20,000 and 100,000 ha, are leased out to individuals. The farms are run by private/commercial farmers and companies for producing sorghum, sesame, sunflower and little of short staple cotton. The subsector contributes about 3 % of the agricultural GDP and usually provides 65 percent of the sorghum and 53 percent of sesame and almost all of sunflower produced in the country (ENTRO-Economic models for the analysis of Agricultural policies of Sudan). Land preparation, seeding and most threshing on these farms are mechanized, while weeding and harvesting are done by seasonal labour. Livestock is not integrated in this farming system.

Low-cost, minimum or zero tillage combined with low-input agriculture approaches have been practised over a period of 50 years, leading to low yields of crops from the vast areas leased at very low rents from local authorities. No proper crop rotation is maintained. Investors move seamlessly from crop to crop, usually from sorghum to sesame and vice versa, depending on prices of crops, loans available and government incentives. Soil fertility has reportedly been declining because of the continued planting of sorghum without crop rotation. As the semi mechanized farms are mostly located in the alkaline clay areas, only few crops had been found suitable for cultivation in the heavy cracking clay soils, Sorghum being the principal one. The soils also pose difficulties for mechanized operations under both very dry and wet conditions. This sub-sector suffers from a number of limitations such as (Idris Nur & Ali, 2007):

- Low Yields (use indigenous Varieties, heavy soils with poor fertility, absence of crop rotation),
- High cost of production,
- Shortage of formal credit,
- Absence of machinery services for small farmers,

- Horizontal expansion and deforestation resulting in land degradation,
- Competition for land and conflicts with traditional farmers and pastoralists.

Cropping Patterns

Sorghum, millet and maize are the main food crops. Other important produce for the domestic market includes sugarcane, dates, wheat, sunflower, pulses and forage. The principle export crops are cotton, gum arabic, sesame, groundnuts, fruits and vegetables (Sudan is the world's largest producer of Gum Arabic). Livestock represents a very important part of the national economy, as well. Its production increased during recent years as a result of better veterinary treatment, better credit policy, and higher prices both in local and international market.

In general, the total cultivated area has shown a trend of increase from 12 million ha for the 1990-95 period to 18 million ha in the period 2005 – 2010 (ENIDS-CRA, 2010). The increase occurred in the rain-fed sector due to the increase of areas cropped with sorghum, millet and sesame resulting from favourable export opportunities for farmers involved in the semi-mechanized farming system. There was no significant irrigation development since the end of the 1970's. Harvested area in the rain-fed farming systems show high fluctuations because of recurrent droughts resulting in crop failures every four to five years. In the irrigated farming system, harvested area also fluctuates mainly because of difficulties in the maintenance of canals (removal of silt) and variations in water availability for winter crops. Table A3.4 shows the estimated percentage of crops grown by sub sector.

Yields

In spite of the availability of technically proven research outputs (high yielding varieties), the yields of the cereal crops (sorghum, millet and wheat) are generally low. The yield of cotton under the three production systems is also generally low. With the exception of sesame, mainly grown in the semi mechanized sector, production levels of the other crops have remained low and stagnant in the past years. Agriculture production growth thus is attributed by expansion of cultivated areas only.

The main reasons for low productivity, among others, include:

- Poor agricultural practices and the use of outdated technology,
- Recurrent draught in rainfed areas,
- Absence of adequate extension and credit facilities,
- Poor Operation and Maintenance of irrigation infrastructure and shortage of water

Agriculture is the most important potential contributor to economic growth, food security and alleviation of poverty thus, should receive considerable attention to attain sustainable growth and

Table: A4.5: Percentage of Crops Grown by Sub-Sector

Crop	Irrigation Sub sector (%)	Semi-Mechanized Rain-fed (%)	Traditional Rain-fed (%)
Sorghum	25	65	10
Millet	5	5	90
Wheat	100	0	0
Cotton	99	0	1
Groundnuts	52	0	48
Sugar Cane	100	0	0
Sesame	na	53	28
Sun flower	1	99	0
Gum Arabic	0	0	100
Fruits	70+	Na	Na
Vegetables	70+	Na	Na

Source: ENTRO-Economic models for the analysis of Agricultural policies of Sudan development. In view of the expected population increase and the limited nature of the available land and water resources for horizontal expansions, more emphasis should be given to vertical expansion (increasing productivity of the existing farms). This could be achieved through intensification and diversification of the existing agriculture, via rehabilitation and modernization, introduction of appropriate technology, provisions of input and credit facilities, improvement of research and extension services, etc.

Irrigation Sub-sector

Although, the irrigated area covers about 10% of the total cultivated area, the irrigation sub sector contributes more than half of the total volume of the agricultural production in the country. Its importance has significantly increased in the past decades as a result of drought and rainfall variability and uncertainty in the rain fed sub sector. It contributes an average of 28 % of the total value of the agricultural production, 100% of wheat and sugar, 95% of long staple cotton, 52% ground nuts and 25% of sorghum produced in the country (Radia, 2013 and EWUAP-LSI Study, 2009). Other main irrigated crops include vegetables, fodder, maize, sunflower, roots and tubers, fruits and rice.

Traditional irrigation has been practiced for centuries in Sudan using the annual flood waters of the Nile for recession agriculture. Modern irrigation agriculture started in 1920s with the construction of Sennar Dam and the establishment of the Gezira scheme during the colonial era. After independence in 1955, the command area of Gezira was doubled to 924, 000 ha with the completion of the Mangil extension and became the largest irrigation scheme in the world under single management. The 1970's were a period of rapid irrigation expansion in Sudan due to the construction of the Rahad Scheme (126,000 ha), the New Halfa Scheme (146,138 ha), El Suki (37,800 ha), Kenana sugar estate (37,700 ha), North-West Sennar sugar scheme (13,900 ha), Assalaya sugar scheme (14,700 ha) and a number of smaller schemes along the Blue Nile and its tributaries, White and Main Niles. Almost all these schemes have been established with similar design and management style of Gezira scheme. The completion of the Jebel Awlia Dam (1937) on the White Nile approximately 20 Km upstream of Khartoum has led to the rapid development of pumping schemes. In Sudan, irrigated area expanded from 1 million ha in 1956 to about 1.9 million ha (including spate irrigation in Gash and Tokar deltas) by the end of the 1970's. There is no major expansion after the 1970.

Parts of all four sub-basins are to be found in Sudan. All types of farming systems are practised in all the sub basins. Irrigation is largely concentrated in the Abay-Blue Nile sub basin, while semi- mechanized farming is practiced mainly in Abay-Blue Nile and Tekeze-Atbara sub basins. Traditional rainfed farming exist in all the sub basins in areas that have above 400 mm rainfall.

BASIN-WIDE DEMAND FOR IRRIGATION

None of the four countries is food secure and the levels of demand are increasing. The situation in each of the countries can be summarized as follows:

- **Ethiopia:** Even though high achievements have been recorded in the agricultural sector in the past years, poverty and food insecurity still persist in Ethiopia. Though the current situation has shown substantial improvement, four to six million people are chronically food insecure and depend on food aid for survival in the past years. In 2011, the country imported 1.7 million Tons of wheat (FAO STAT, 2014).

- **South Sudan:** Existing production in the country is not sufficient to satisfy the demand and the country imports as much as 50% of its requirements from neighbouring countries, particularly Uganda and Kenya. Total food imports are estimated to be in the range of USD 200-300 million a year (South Sudan an Infrastructure Action Plan Document, 2012). The food security situation has deteriorated in recent years due to a large number of returnees, refugees from Sudan and internally displaced peoples, natural population growth, a reduced harvest (in 2011) and food price inflation caused by greater demand and tight foreign reserves following the oil shutdown

(SAR-CAMP, 2013). The situation is more aggravated at present due to the recent crises in the country.

- **Sudan:** Despite the availability of large arable land both under rain fed and irrigation, Sudan is not food self-sufficient and has to import substantial amount of food crop annually to fill the gap between demand and supply. Relief aids to draught and conflict affected areas also contribute to filling the gaps. Table A3.6 below indicate the estimated cereal demand and supply balance for the year 2012.

Table A3.6: Sudan Cereal Supply/Demand Balance, January - December 2012 ('000 tones)

Crop	Production	Demand	Deficit
Sorghum	2,469	3.433	-964
Millet	385	638	-253
Maize	51	51	0
Wheat	524	2,116	-1,592
Rice	25	74	-49

Source: QUASI Special Report, 2012

- **Egypt:** Despite the availability of large irrigable land, with relatively high productivity, Egypt is not food self-sufficient. It is producing about half of its food supplies and food imports reached about $10 billion in 2012 (Mohamed M Nour, 2013), and demand is expected to increase with the growing population. It imports a substantial amount of wheat and varying proportions of other agricultural commodities and processed food. In 2011, the country imported 9.8 million tonnes of wheat, 7 million tonnes of maize, 1.1 million tonnes of soya bean and 1.1 million tonnes of sugar (FAO STAT, 1014).

BASIN OVERVIEW

Agriculture makes a large contribution to the GDP of all four countries and employ 32 to 90% of the labour force. Agriculture is by far the most predominant economic activity in the Eastern Nile Sub-basin. It contributes 20 to 46 % of the portion of the export earnings also comes from the agricultural sector. A wide variety of crops are grown for export and local consumption. Crop production system ranges from largely rain fed subsistence agriculture to large irrigated schemes, the latter of which are mainly found in Egypt and Sudan, and to limited extent in Ethiopia. There are huge variations in production levels, from very low in South Sudan to relatively high in Egypt. All countries are not able to produce sufficient amount of food crops to meet the demands of the growing population and have to rely on importing significant portion of their requirements. Highly variable rainfall and recurrent draughts, use of poor agricultural/ irrigation technologies and inputs, inadequate research and extension services, and absence of rural infrastructure, market and credit facilities are among the key reasons for the low production levels in the countries.

All countries in the EN consider irrigated agriculture as the major driving force for enhancing food security and increasing the contribution of the agricultural sector to their economies. There is about 5.3 million hectares of land currently under irrigation in the EN, almost all of which is located in the two downstream countries, Sudan and Egypt. Although Ethiopia and South Sudan have huge potential, irrigation development so far is insignificant. All countries have ambitious plan for expansion of irrigation schemes. The planned expansion in the three countries Ethiopia, Egypt and Sudan alone amounts to 3.88 million hectares (Table A3.7 below).

As can be seen from the above table, the existing water use in the countries (including the consumption by the other competitive users municipality, industry, etc has almost reached the full capacity

Table A3.7 : Summary of existing and planned irrigation schemes in the Eastern Nile

Country	Existing irrigated land (Mha)	Estimated existing water use (BCM/anum)	Planned expansion area (MHa)	Estimated additional water requirement (BCM/anum)
Egypt	3.350	58*+ 10**	1.12	20
Sudan	1.800	10 + 5***	1.17	13
Ethiopia	0.120	0.86	1.59	18
South Sudan	0.035	0.46	NA	NA
Total	5.315	84.32	3.88	51

* Amount includes the 4.8 BCM recycled water and 6 BCM renewable ground water use in Egypt
*- Evaporation loss at Aswan Dam
**- Evaporation loss from existing Dams in Sudan

of the River Nile. The planned expansion in South Sudan is currently not known as the country is under preparation of Irrigation and Drainage Master Plan (IDMP). Estimated existing water use and additional water requirement for future expansions in the three countries are 74 and 51 BCM per annum. The future water requirement would increase substantially when the requirement of South Sudan is included. Existing and proposed irrigation per sub-basin is summarized in the figures below.

Figure : Tana-Beles and Upper Dinder-Rahad Sub basin Existing and Planned irrigation Projects

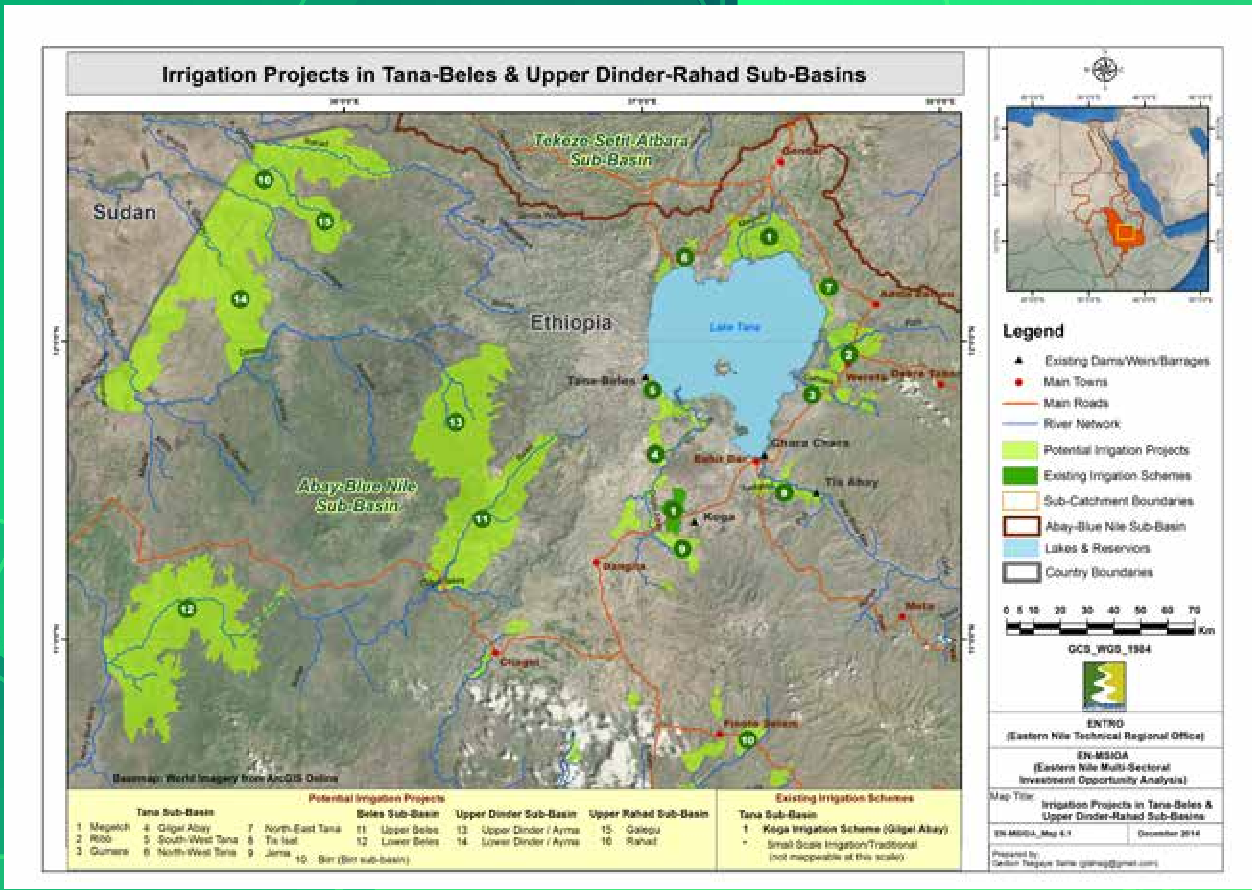


Figure : Fincha,Guder & Didessa Sub basin Existing and Planned irrigation Projects

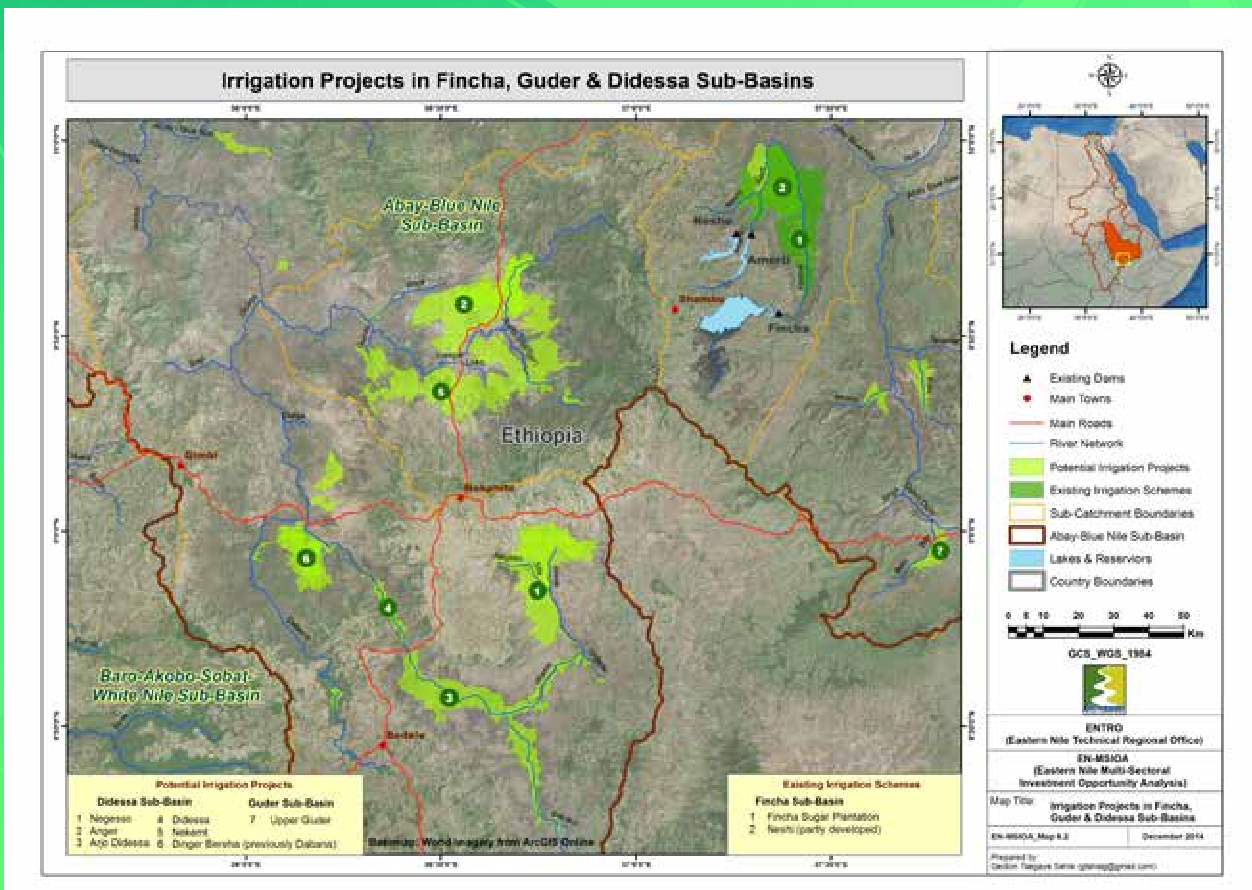


Figure : Baro- Akob- Sobat Sub basin(Ethiopia part) Existing and Planned irrigation Projects

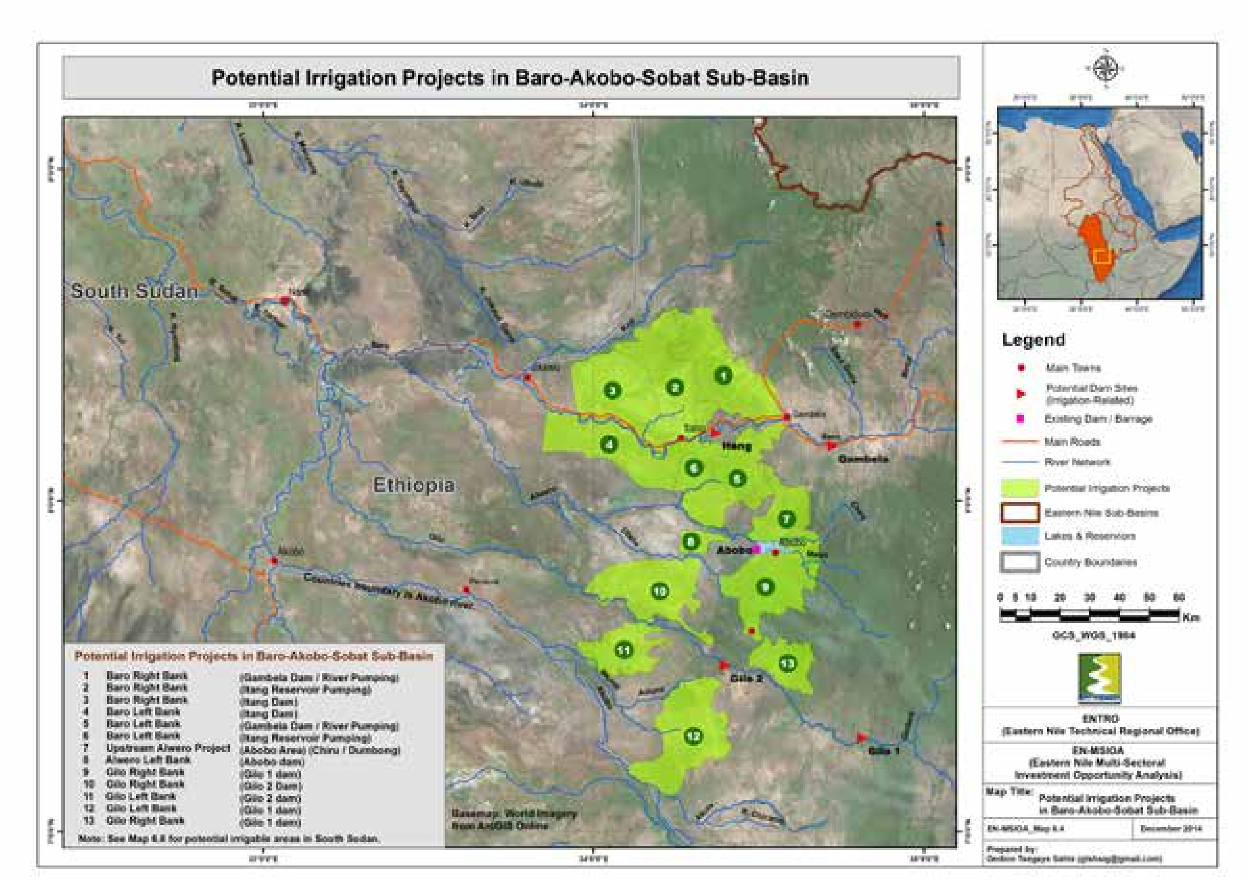


Figure : Baro- Akob- Sobat Sub basin(South Sudan part) Existing and Planned irrigation Projects

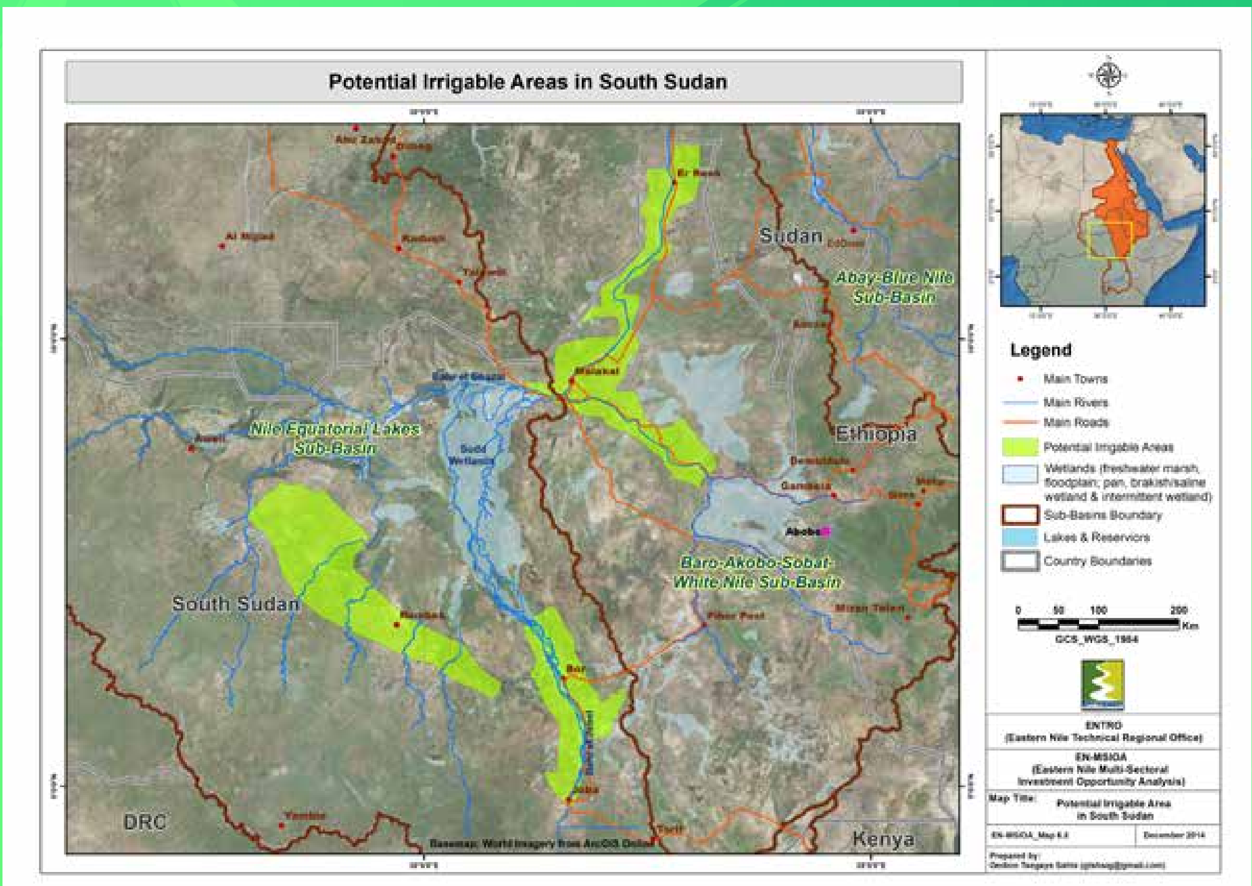


Figure : Lower Blue Nile & White Nile Sub basin Existing and Planned irrigation Projects

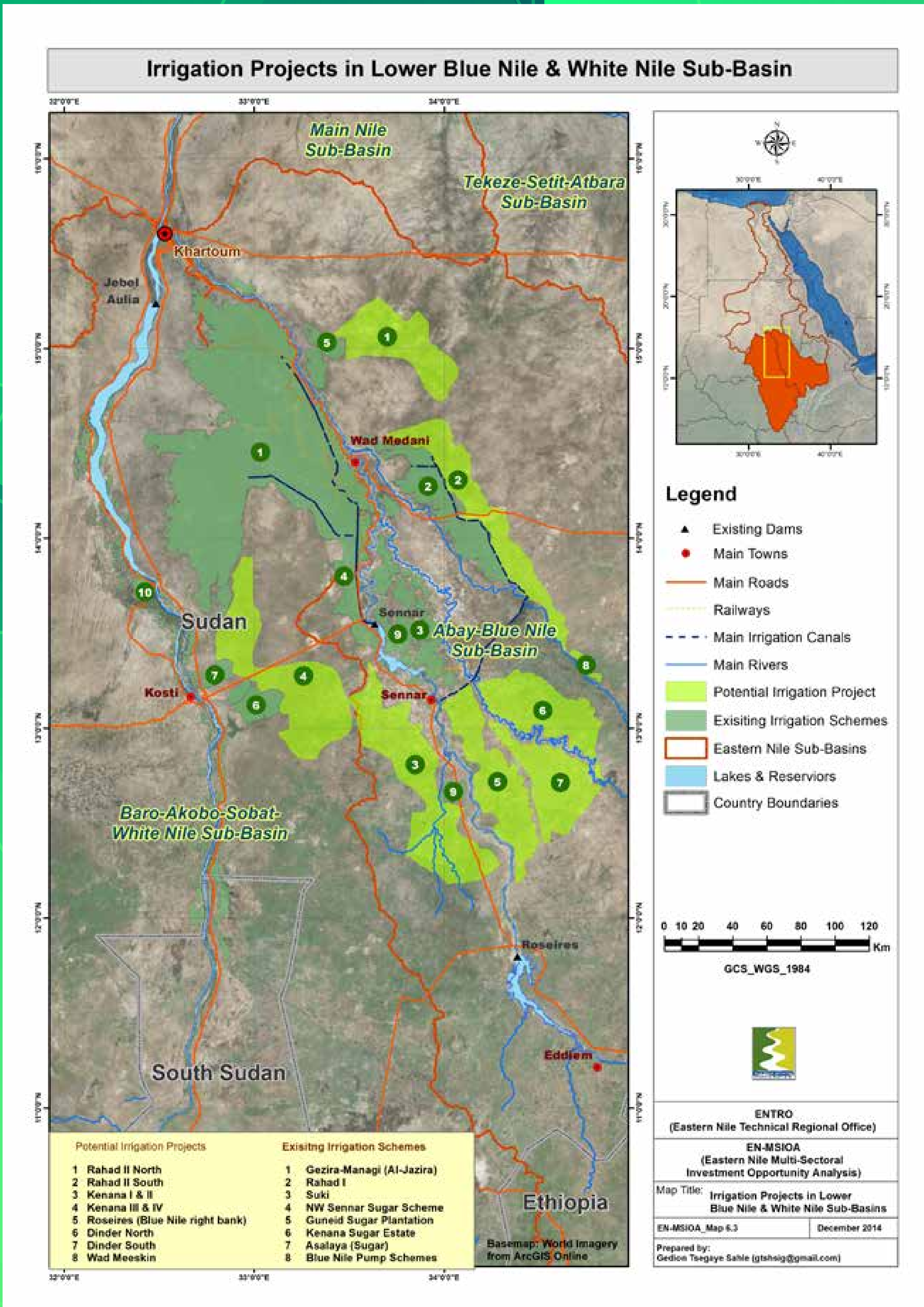


Figure : Tekeze-Setit-Atbara Sub basin Existing and Planned irrigation Projects

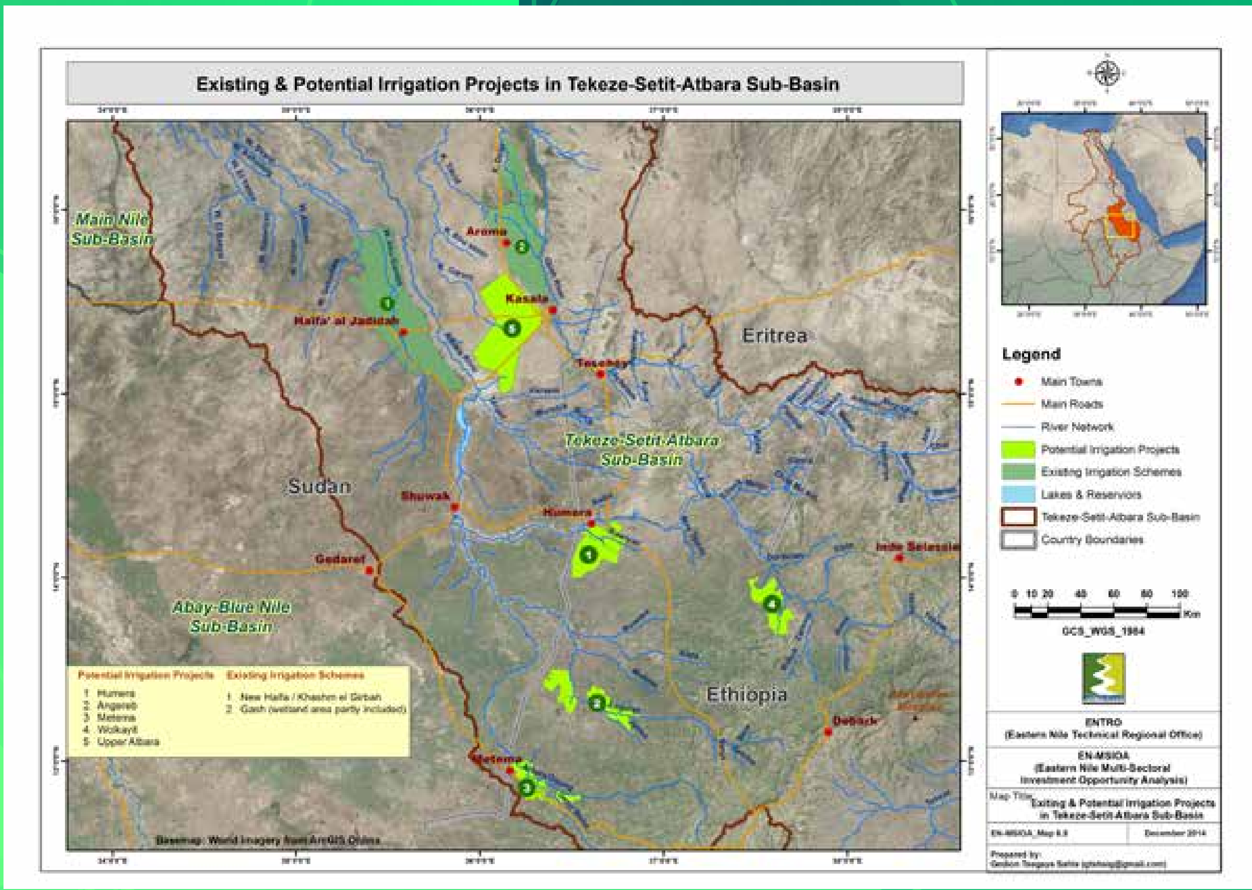


Figure : Main Nile Sub basin Existing and Planned irrigation Projects

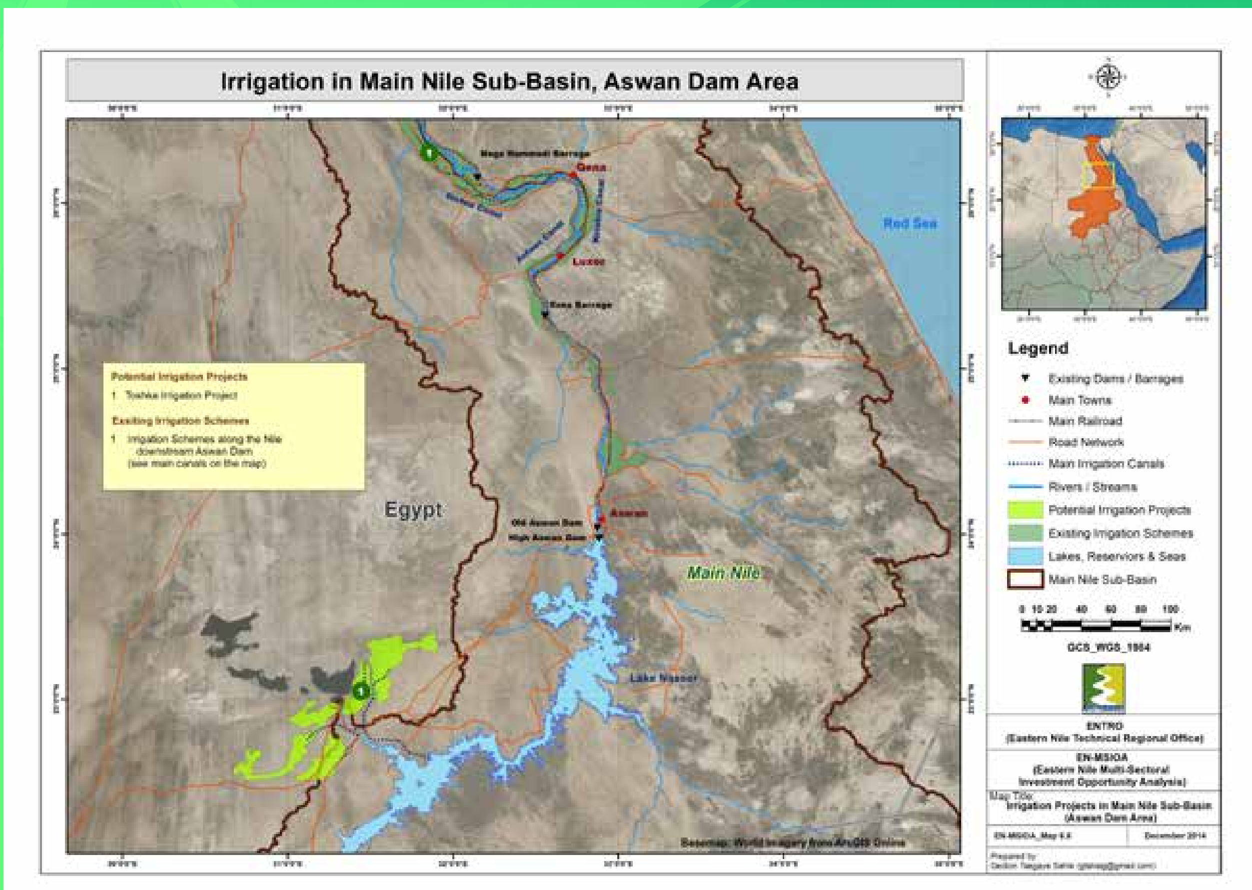
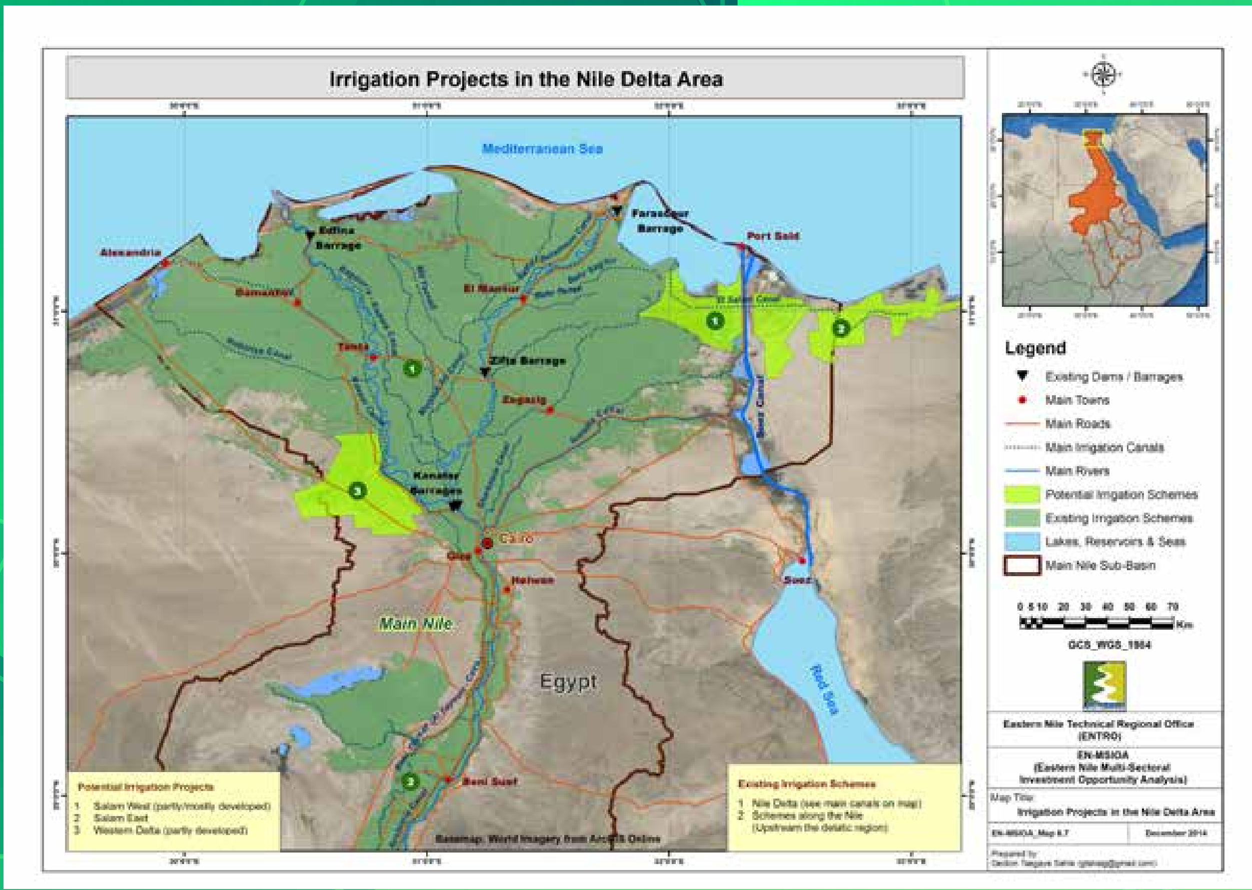


Figure : Main Nile Delta Sub basin Existing and Planned irrigation Projects



It will thus, not be possible to implement all the planned expansions as it is now, unless additional water is made available for the irrigation sector, through use of all available opportunities, which among others, include:

- Implementation of upstream water conservation projects like constructing storage dams in Ethiopia,
- Optimization of the existing Dams operations,
- Increasing water use efficiency and productivity of the existing schemes (rehabilitation and modernization, change of cropping patterns, etc) and
- Implementation of integrated joint/trans boundary projects, etc.

Moreover, except for the fast-track Irrigation Projects (Tana-Beles-Ethiopia, Upper Atbara-Sudan and West Delta-Egypt), on which the three countries in 2004 jointly identified and agreed to undertake detail feasibility studies on 100,000 ha in each country and out of this develop 20 to 30,000 ha, all the rest of the expansion projects are planned unilaterally by the countries. While this is understandable from the point of view of food security and rural economic development, the impact of increased upstream water abstraction on downstream water resources and vice-versa is not yet properly known. Since uncoordinated planning and development of irrigation expansions could be a potential source of conflict, safe irrigation expansions that have no significant detrimental effects on downstream or upstream water resources availability should be identified in a coordinated manner based on proper study and analysis. These require the continuous effort, dedications, and high level of cooperation and trust among all the four EN countries.

Annex 5

Photo istock/NBI

The Eastern Nile Basin: **Fisheries and Livestock**

Annex 5: The Eastern Nile Basin: Fisheries and Livestock

FISHERIES

Egypt

Overview

The fishing sector in Egypt can be divided into the marine, inland and aquaculture sub-sectors; While the marine sub-sector is very important for the country it is not presented here, and only inland fisheries and aquaculture are reviewed.

inland fisheries

Fishing in the inland sub-sector is carried out in the in land waters which consist, more than 10 relatively large lakes, the great reservoir behind the Aswan High Dam (Lake Nasser), the Nile River and irrigation canals and some small water bodies in the western part of the country. In 2009, fish production from this sub sector was 260, 000 tons representing about 24% of the total fish production in Egypt. Fishing in the ten lakes yields about two thirds of the inland catch, while fishing in the Nile River System represent about one third.

Inland fisheries produce different kinds of species. The four main species, which represent more than two thirds of the total production from inland fisheries, include: tilapia (40 percent), catfish (15 percent), grass carp (10 percent) and mullets (6 percent) (FAO, 2010). Two of the ten lakes (Qarun and Wadi Al Raiyan) have no outlet and contain brackish water and produce mostly marine species. There is a large number of small boats of different size (more than 21 300), being used in inland fisheries. Of these, more than 12, 000 are operating on the Nile System. As these boats do not travel far, there is also a large number of landing sites. Along the River Nile alone, there are more than 700 registered landing sites and countless unregistered sites.

Aquaculture

Under this sub sector, fish is produced in ponds / fish farms that have a size of between 2 to 8 ha. It is also produced integrated with rice farms. Aquaculture is currently the largest source of fish supply in Egypt, with over 99 percent produced from privately owned farms. In 2009, the total fish produced from this sub sector was 705,000 tons, almost 65% of the total fish produced in the country. The Ministry of Agriculture and Land Reclamation is targeting a harvest of 1 million tons from aquaculture alone, by year 2017 (National Water Resources Plan 2017).

The development and expansion of modern aquaculture began in Egypt two decades ago and has shown significant growth in the past few years. Annual production from aquaculture increased by more than 10 times, between 1990 and 2008, at an average annual growth rate of 14.4 percent (FAO, 2010). Egypt is the 1st in Africa and 11th in the world in aquaculture production (Abdel Rahman, 2010). Aquaculture considered as the only viable option for reducing the gap between supply and demand of fish in Egypt. The rapid development in aquaculture has also created a large number of jobs for farm technicians and skilled labor. More than 750, 000 individuals including men, women and children are directly employed. The expansion of aquaculture has succeeded in reducing and stabilizing the cost of fish in Egypt allowing accessibility to the poorer rural population to healthy and affordable animal protein.

Most of the farms are located in the northern and eastern parts of the Nile Delta where they utilize both brackish and freshwater. The majority (85%) of fish farms are semi-intensive type, about 10 percent are intensive (cage culture in fresh water) and the rest 5 percent are under rice-fish culture. Because of competition for land and water with other agricultural activities, intensive aquaculture, in earthen ponds and tanks, is also developing rapidly at present days. Both marine and fresh water species are produced tilapia being the dominant. It accounts for more than half of all fish produced through aquaculture. other species include mullets, carps and cat fish. Egypt is the world second in regard to tilapia production, next to China and first in mullet production.

Constraints

Existing constraints for the development of the fisheries sector include:

- Use of backward fishing technologies; Most fishers are artisanal, and operate gillnets, trammel nets and long lines from small boats,
- Lack of skilled personnel and in adequate knowledge and management of the fisheries potential,
- Weak institutional and legal framework for the sector,
- Lack of research and extension facilities,
- Pollution, infestation of wild plants, illegal fishing, etc.,
- Little involvement of the private sector.

Ethiopia

Overview

Ethiopia is a land locked country with no marine coastline, thus fisheries are entirely dependent on fresh inland water bodies (lakes, reservoirs and rivers). It has no significant aquaculture development also. Lake Tana (the largest lake and fish source), Rift Valley Lakes (Ziway, Langano, Hawassa, Shalla, Chamo and Abiyata and reservoirs constructed for hydro power production (Koka, Melka Wakena, Gilgel Gibe, Tekeze) are the major sources of fish. These waters have an estimated annual fish potential of 51,500 ton, which can meet 44 percent of the projected demand in 2015, based solely on population size (FAO, 2003). If factors other than population (relatively cheaper prices of fish, increased income, improved supply and distribution network) are considered, the projected demand could increase by 15 to 20%. In view of this, the present water bodies or fish supply sources will not be able to meet the demand. This calls for an increasing focus on enhancement of artificial water bodies and development of aquaculture.

Fishing on all these water bodies for local consumption is taking place. Fishing for commercial production is mainly concentrated on lakes Chamo, Ziway and Tana (only Tana is within the basin). Fish sizes in these lakes are declining due to over exploitation. The main fish species are Nile tilapia, Nile perch, Barbus and Catfish. Nile perch represent about 60 % of the catch. Fish consumption is seasonal. Demand rises substantially during the fasting season and days of the Ethiopian Orthodox religion. Demand is higher than supply during the two months of main fasting season and vice versa during the non-fasting periods. In general Ethiopians do not consume large quantities of fish, although preference for fish is increasing especially by high income groups. Overall, per capita fish consumption is very low (as little as 200 g/year), but in areas with sufficient and regular supply, consumption can reach up to 10 KG/year (FAO, 2003).

Fishing techniques are extremely primitive, with very few motorized boats (limited to a very small number on Lake Tana). The predominant boat is the reed (papyrus) tanqwa. It is even difficult to obtain certain materials for nets (lead rope and floats). Gill nets are the most common, but there is also some use of line-fishing (the latter for Nile perch). Traps, scoop nets and baskets are also used, particularly in the rivers (Ann Gordon, Sewmehon, Melaku, 2010).

Constraints

With the increasing demand, prospects for fishery development in Ethiopia are promising as long as the major constraints are addressed properly. These include:

- Establishing/expanding small scale commercial aquaculture;
- Improving research, technology and extension services;
- Expanding and improving support infrastructure such as access roads, landing and onshore processing facilities;
- Expanding distribution networks; and
- Strengthening the government fishery administration in the areas of effective resource monitoring, coordination, planning and control of the industry

South Sudan

Overview

Like Ethiopia, South Sudan is a land-locked country, thus has no coastal fishery. All fisheries are based on inland fresh water bodies consisting of the major rivers (Nile, Sobat) and the vast wet lands (Sudd, Mechar). Though, the contribution of fishery to the GDP is low, substantial size of the population are engaged in fishing activities. According to a 2010 baseline survey report on agriculture and animal resources in South Sudan, about 14 % of households in South Sudan, particularly those in the Sudd area and along the River Nile and its tributaries, are engaged in fishery as a source of livelihood.

Fish is a primary source of cheaper protein and accounts for about 4 percent of food consumption in South Sudan (Agricultural Sector Investment Plan, 2013). The potential catches for the country are unknown, and estimates vary widely. However, many studies indicate the fisheries production potential to be in the range of 100,000 to 300,000 metric tons per year. No proper field assessments and inventory have been undertaken so far to support these figures. Moreover, due to the subsistence nature of the fishing activities, it is very difficult to estimate catches at household level. According to the SAR of the Comprehensive Agriculture Master Plan preliminary estimates, the consumption of fish in South Sudan is far higher than generally recognized at about 17 kg/person/year, which is comparable with neighbouring countries. To supply this consumption level the catch must be in the order of 140,000 tones and definitely much more due to post -harvest losses (losses resulting from lack of refrigeration, poor weather condition and insect infestation of dried fish are expected to be substantial). Table A4.1 below shows the estimated consumption of different fish products in the country.

Access to fishing is open, with no control on the number of fishers or entry. Fishing method is predominantly subsistence and traditional; using hooks or locally made nets. The caches are sold in local markets as fresh, dried or salted products. Smocked fish are also produced to some extent in areas where there is sufficient fire wood. Though fresh fish products are more preferable, much of the catch is dried due shortage of ice, transportation and cold storage facilities. Large amounts of fish (mostly smocked) are being imported to South Sudan from Uganda. Frozen and canned fish products are also imported from a number of other countries for sale in supermarkets. Reliable data on the exact figures of import are not available.

In addition to river and lake fishing, there is significant potential for aquaculture development, especially in part of the Green Belt (stretch across Southern Greater Equatoria), where there are year round water supplies, suitable terrain (many clay soil areas and gravity fed water supplies) and an almost ideal climate for aquaculture. However, currently there is little aquaculture development in the country, due to a number of constraints which include; land tenure uncertainty, lack of hatcheries, no feed mills and shortage of skills. There are about 38 ponds currently operating in the country, most of which are concentrated in CE and WE States (CAMP, 213). Great efforts have been made to introduce village level aquaculture largely through NGOs which provide technical support, land and some limited funds. Potential fish production from the aquaculture sector could reach as high as 250,000 tons per year, if well developed and managed (FAO Country Report, 2012). Among others, technology and skills transfer from neighbouring countries such as Uganda and Kenya and from that of Egypt from the EN countries would probably be the best way to advance the sector in the short term.

Table A5.1: Fish Consumption in South Sudan

Product	Tonnes	Kg/year/cap
Salted	4,618	0.56
Dried fish	79,732	9.65
Fresh fish	59.031	7.15
Total	143,381	17.36

Source: SAR-CCAMP, 2013

Constraints
Although South Sudan has huge fishery potential, its development and contribution to the national economy has been deterred by a number of constraints, which among others, include:

- Absence of policy, regulatory and strategic frameworks and incentives,
- Use of poor subsistence nature technologies,
- Lack of cold storage facilities due to weak or total absence of power supply,
- Little involvement of the private sector and absence of effective processing technologies,
- Inadequate transport infrastructure and market chains,
- Lack of skilled man power and inadequate research and extension facilities.

The Directorate of Fisheries and Aquaculture Development (DoFAD) in the former MARF now MAFTARFCRD is responsible for the development of fisheries in South Sudan. By the Constitution, management of the fishery in the states is delegated to the State Authorities.

Sudan

Overview
Fishing is another important sector of the national economy in Sudan. The average yearly production averages around 33,000 tons, from which sea fish represent about 1,500 tons. Perch is the most important fresh-water fish, which is caught mostly in the Nile River.

The principal source of fish in Sudan is the Nile River system. In central and northern Sudan, several lakes and reservoirs have been formed by the existing dams on the Nile and its tributaries: the 180-kilometer section of Aswan Dam Reservoir (Lake Nubia) on the main Nile in Sudan and the reservoirs behind the Roseires, Sennar and Marowe Dams on the Blue Nile, the Jebel Aulia Dam on the White Nile, and the Khashm al Girba Dam on the Atbara tributary of the main Nile. The Gebel Aulia Reservoir has a fish potential of 15, 000 tons/year and production of 13, 000 tons/year (86.7%). Roseires Reservoir has a potential of 1, 700 tons/year and fish landings of 1, 500 tons/year (88.2%). Sennar Reservoir has an estimated fish capacity of 1, 100 tons/year and an actual fish yield of 1, 000 tons/year (91%). Lake Nubia's potential is 5,100 tons/year, but is able to produce only 1, 000 tons of fish annually (19.6%). Production from other Nile River localities has been estimated at 4, 000 tons/year (FAO Country Profile, 2009).

Three main sub sectors identified in the fishery sector are subsistence, artisanal, and commercial fisheries. Subsistence fishing accounts for the large part and is found in practically all of the inland waters of Sudan, but especially in the isolated areas where the Nile and its tributaries seasonally overspill their banks and create innumerable lagoons and backwaters; about 10 - 11 000 tons of fish are believed to be caught in these waters by traditional method (spear, line and cast nets used from the banks or from canoes and papyrus rafts). The artisanal sector exists alongside subsistence activities, principally on the Jebel Aulia reservoir and the lower reaches of the White Nile before the confluence with the Blue Nile; typically, the artisanal fisherman owns a one oar-propelled boat of traditional design. Commercial activities are, as yet, little developed but market orientated fisheries have been established on dam impoundments and reservoirs relatively close to urban centers; a few motorized craft are now in use. All production and commercial activities are practiced by the private, semi-private and cooperative sectors.

The principal species taken in these fisheries are the large and highly prized Nile perch, Labeo, Tilapia and Alestes species. The majority of the catch is consumed fresh, the balance being crudely sun-dried, generally without salting. As a result of inadequate transport, distribution and marketing facilities, lack of ice and poor handling methods, fish quality standards are often extremely low; about a fifth of the entire catch is believed to be lost as a consequence. Generally, fish prices are high relative to meat which is more widely available. Apart from the subsistence areas, the bulk of fish consumption is heavily concentrated in Khartoum.

The country's second source of fish, the Red Sea coastal area, was relatively unexploited until the late 1970s. Annual production amounts to about 1, 500 tons of fish, shellfish (including pearl oysters), and other marine life. Fishing for shrimp on a small commercial scale also takes place. 6-7 metre long dhows (mostly unmotorized) and few slender canoes are employed for catching fish. The main landing point is Port Sudan. Fishing operations are largely artisan and of a subsistence nature and are concentrated in near-shore areas. Commercial fisheries are confined to indigenous firms.

The Fisheries sector presently makes only a marginal contribution to the Sudanese economy; accounting for only 0.4% of the GDP (FAO Country Profile, 2009). Fishing is regarded as an occupation of rather lowly status and the relatively few persons are engaged in the venture. The aquaculture industry is not developed as yet.

Constraints

In general, the fisheries sector in Sudan is not yet fully exploited, the major constraints being:

- Lack of trained personnel and modern fishing experience,
- Lack of fishing equipment and vessels,
- High post-harvest losses resulting from improper handling at source and during distribution,
- Lack of marketing chains and Inadequate planning,
- Insufficient infrastructure facilities and institutional capacities.

LIVESTOCK

Introduction

The Region is endowed with huge potential for livestock development. It has the largest livestock population in Africa. However, the development and contributions of the livestock sectors to the national economies of the countries so far is not as expected. The total water requirements for the sector is significant but is spread out. Natural surface water bodies and groundwater are the main watering sources. While the development of water resources for livestock is unlikely to feature as a regional-scale water resources development project, it is important that other types of development (especially irrigation) take into account the needs of livestock farmers. Better livestock farming practices are also a key component of watershed management interventions.

BASIN-WIDE PERSPECTIVE ON FISHERIES

The fisheries sub sector is an important source of cheap protein for poor communities and a major economic activity for those living around the major lakes and reservoirs, along the River Nile and coastal areas. In addition to these water bodies, there is also good potential for aquaculture development especially by the private sector in all countries.. Inadequate modern fishing equipment, shortage of transport, cold storage facilities and market chain, lack of technical staff and inadequate legislations are among the major constraints for fisheries development in the EN. The present rate of fishing in many of the natural water bodies in basin is excessive. Given that fish stocks are decreasing because of over-fishing, capture fisheries alone cannot be considered as a sustainable future for the fisheries. Therefore, at present, a potential for growth of aquaculture exists. It would help alleviating the pressure on the region's natural fish stocks, and may allow increase the current level of fish production - thus guaranteeing fish exports to international markets and supply to national markets.

Regarding the future, the situation is more worrying and the potential for aquaculture much more evident. In effect, the regional balance between fish production and consumption appears clearly negative, meaning that regional consumption and fish exports would adversely compete. The decline in the situation decline between now and 2030 can be explained by two main factors: firstly the demographic increase (more people is more fish demand); and secondly the willingness of some countries to improve the national diet, especially access to protein, through increasing individual fish consumption (more fish for each people). Given the land shortage, fisheries and/or fish farming can be developed to improve food security and livelihoods. Also, there is good experience for aquaculture development in Egypt that could be up scaled to the other EN countries.

Egypt

Livestock in Egypt is an important component of the agricultural sector, representing about 24.5% of the agricultural gross domestic product with value of more than USD 6 billion (FAO, 2011). Livestock population has shown increment in the past years. The cattle population amounts 4.95 million head, while the buffalo population reached 4.2 million head in 2013. Regarding small ruminants, the sheep population reached 5.45 million head, while the goat population exceeded 4.3 million head in 2013. The camel population is about 142,000 head, while horses and asses exceeded 4 million head in 2013 (FAO STAT 2013).

There are three types of livestock production systems in Egypt. These include.

- **Traditional:** is largely subsistence oriented system for the farm family and surrounding communities. It is characterized by low production inputs and outputs and holding of few animals. It is practiced for sheep, goats, cattle, and buffalo in the various agro-ecological zones.

- **Semi- intensive:** The semi-intensive sub-system depends on improved local breeds and husbandry techniques for producing raw buffalo and cow milk. Lamb and calf fattening is also practiced. Small farmers who do not own agricultural lands or control agricultural holdings are the main producers,

- **Intensive systems:** The intensive production sub-system is characterized by high inputs and outputs as well as very large livestock holdings. This sub-system operates on the production of exotic cattle and constitutes about 10% of the total animal production system. It is the source of milk for the local milk processing industries. About 60% of white meat production comes from this sub system also.

About 98 % of the livestock sub sector is run by the private sector, a large portion of which are small holder /traditional farmers. The government owns only 2% of the livestock population. The cattle population is largely concentrated in middle Egypt and middle Delta regions. While about a third of the buffalo population is found in the Middle Delta region. Sheep and goat are concentrated in upper and middle Egypt and Western Delta regions. Indigenous cattle represent about 60% of all the cattle population, while mixed-breed cattle represent about 37% and imported cattle about 3%.

The rangeland in Egypt is poor because of little rainfall unevenly distributed over limited areas. According to FAO (2010) rangelands provide only 5% of animal feed in Egypt. The main source of livestock feed is therefore, clover (berseem) cultivated on the irrigated areas. Alfalfa is also used to some extent. Up to 1.2 million ha (20% of the cultivated land) in Egypt is covered by fodder crops annually.

The cut-and-carry feeding system is associated with small scale irrigated farms (less than 1–2.5 ha) where fodder crops (berseem, alfalfa, sorghum, Sudan grass, etc.) are harvested to feed farm animals. Surplus green fodder is sold in nearby towns and villages to other livestock owners. Weeds and crop residues are also used. In large-scale dairy farms ir-

Table A5.2: Estimated livestock Population in Egypt

Livestock	2009	2010	2011	2012	2013
Cattle	4,524,950	4,728,721	4,779,743	4,946,410	4,950,000
Buffaloes	3,838,721	3,818,236	3,983,167	4,164,928	4,200,000
Sheep	5,591,580	5,529,529	5,365,065	5,429,524	5,450,000
Goats	4,139,257	4,174,986	4,258,175	4,306,258	4,350,000
Asses	3,350,000	3,350,000	3,355,000	3,355,000	3,356,000
Camels	137,112	110,571	136,930	141,537	142,000
Horses	66,215	65,965	71,087	74,042	74,050
Total	21,647,835	21,778,008	21,949,167	22,417,699	22,522,050

Source: FAO STAT, 2014

rigated fodder crops are produced, mainly berseem in winter and sorghum and maize (corn) silage in summer. Mechanical harvesting (chopping) and hand cutting are both practiced and green fodder is fed among total mixed rations to the dairy herd, while any surplus may be made into hay which is baled and stored.

Though the livestock sub sector in Egypt is important for the economy, it is still undeveloped and the country is not self-sufficient in beef production as yet. In 2012, Egypt imported 47,600 heads of live cattle, 85, 365 tons of frozen beef, 1,800 tons of chilled beef and 49, 270 tons of frozen buffalo meat (USDA, 2012). It is estimated that import of live cattle will increase to more than 100, 000 heads in the coming years.

The large potential of the sub- sector in Egypt is largely lost due to a number of constraints, which include:

- Shortage of animal feed is the major limiting factor, causing high mortality of young animals and low daily weight gain and poor reproduction performances. This is more sever in rain fed areas, where there is inadequate use of beresem,
- Shortage of water in most range areas located far from the River Nile and irrigated areas. Animals often have to travel long distances to water points,
- Inefficient marketing channels and a lack of reliable market information, particularly for the small scale production system,
- In adequate veterinary, extension services and limited access to improved breeds, especially to small scale farmers,
- Resource degradation, due to overgrazing and poor range management,
- Intrusion of other uses such as dry land farming on to range lands,
- Low animal product prices, not sufficient to attract investment due to competition with imported products,
- Occurrence of frequent draught in rain fed areas.

Ethiopia

Livestock production plays an important role in Ethiopia's economy. It contributes to 12-16% of the GDP, one-third of agricultural GDP and 16% of total export value (MOARD, 2013). It also contributes to the livelihood of 70% of the total population. Livestock are a source of food, draft power, transport, bio-fertilizer and fuel, cash income and social prestige especially in pastoral areas – and hence the livestock contribution to the national economy is much larger when animal transport, draught power, fertilizer, etc are taken into consideration.

In the highlands, livestock is an integral part of the crop production system. Almost all house hold in some way keeps livestock at subsistence level for draft power, transport, meat, milk and as source of income. Population density and expansion of cultivated areas has limited grazing areas and heavily affected livestock production in the highlands. In the lowlands, livestock supports the livelihood of approximately 10% of the total population living in the Afar, Somali and Borena regions. Livestock is the major source of livelihood of these populations that are highly mobile in search of water and grazing. Camels are the most important animals serving as both food and means of transport. However, the lowlands are affected by recurring draught which results in heavy loss of livestock population.

Ethiopia has the largest livestock population in Africa. About 70% of the cattle are in the highlands, and the remaining 30 percent are kept by nomadic pastoralists in the lowland areas. Most of the estimated 50 million sheep and goats are raised by small farmers who used them as a major source of meat and cash income. About three-quarters of the total sheep flock is in the highlands, whereas lowland pastoralists maintain about three-quarters of the goat herd. Camels are kept in the lowlands below 1500 masl.

Table A5.3: Livestock population in Ethiopia (millions)

Livestock	2012	2013
Cattle	53.99	54
Sheep	25.48	26.5
Goat	24	25
Horses	1.9	2
Mules	0.35	0.35
Donkeys	5.6	5.7
Camels	0.92	0.93

Source: FAO-STAT (2014)

Though the country has great livestock potential both for local use and export, its production and contribution to the national economy is not as expected due to a number of constraints. These, among others, include:

- Technical constraints- genetic limitation for production, inadequate and poor quality of feed resources, prohibitive price of crossbred heifers. The dominant local breed of cattle are the Zebu type, which have low meat and milk yields,
- Institutional constraints - Poor linkage between research, extension and technology users, inadequate extension and training service, unreliable market and unavailability of credit.
- Socio-economic constraints - Unavailability of adequate grazing land due to shrinkage and degradation of rangelands, recurrent drought and conflict especially in the lowlands. Practically all animals are range-fed. During the rainy seasons, water and grass are generally plentiful, but with the onset of the dry season, forage is generally insufficient to keep animals nourished and able to resist disease; reluctance of pastoralists to commercialize cattle because of social importance and lack of alternative assets,
- limited and periodic access to appropriate animal health services, heavy reliance on the public sector for animal health services, poor facilities for health services,
- Absence of proper marketing structure; lack of domestic and international market information system, inadequate processing and cold storage facilities, under-developed livestock transportation systems, repetitive taxation, etc. Only 2% of milk produced in the country is marketed,
- Little involvement of the private sector in processing and marketing of livestock and livestock products; only 150,000 litres of milk is processed daily

South Sudan

Large parts of the population in South Sudan are supported by Livestock for their livelihood. Especially in the floodplains and the semi-arid pastoral areas, livestock is the major source of livelihood for the pastoral and semi pastoral communities. In addition to its important cultural value, livestock is one of the important activities of the agricultural sector contributing approximately 15% of the GDP (Situation Analysis Report-CAMP, 2013). According to FAO's 2009 estimates, South Sudan has substantial livestock population (see table below) making the country the 7th in Africa and the 3rd in the EN countries. Given the relatively small human population, the country has also the largest livestock per capita holding in Africa. More than 85% of the households hold one or more livestock, to support their livelihood. Herds are concentrated primarily in western parts of Upper Nile state, and in East Equatoria, Jonglei and Bahr El- Ghazal states.

Livestock are mainly raised by pastoralists and semi- pastoralists, accounting for 47 and 43% of the livestock population respectively. Communities living in urban and surrounding areas keep the remaining 10% of the livestock population (SAR-CAMP, 2013). Under the pastoralist and semi-pastoralist system, production is entirely dependent

Table: A5.4 : Livestock population in South Sudan (millions)

Livestock	2012
Cattle	11.75
Sheep	12.10
Goat	12.45
Horses	1.90
Mules	0.35
Donkeys	5.60
Camels	0.92

Source: SAR – CAMP (2013)

on access to grazing land and watering points and hence, shortage of grazing land due to expansion of sedentary faming, draught and flooding is often the source of internal conflict in the country.

Nevertheless, South Sudan has significant size of livestock population, its potential has not yet been fully exploited and its contribution to income generation, food security, industrial growth and export is not as expected. Some studies indicate that the estimated value of current livestock production is equivalent to 20% of the sub-sector's potential. Market value is only limited to the sale of red meat, mostly within the immediate local rural market and adjacent urban centres. The country, which was once exporter of cattle to neighbouring countries Uganda and Kenya, is now importing meat from Uganda. Major challenges limiting the production and exploitation the livestock sector, among others, are:

- Lack of comprehensive policy, legal and regulatory frameworks
- Poor productivity due to predominantly traditional subsistence nature of production system
- Lack of veterinary, research and extension Services
- Conflicts and insecurity disrupting livestock activities
- Lack of water and pasture
- Lack of shelter/space
- Inadequate road infrastructure and means of transportation; absence of processing facilities
- Lack of both skilled and unskilled man power
- Lack to access to markets , inadequate Information and communications technologies

Sudan

Next to crop production, livestock is the second most important sub-sector within the agricultural sector in Sudan. Livestock export has become an increasingly important part of the economy, competing with cash crop sales as the fastest growing non-oil export sector. This is largely due to initiatives such as the recent rehabilitation of livestock export facilities (including veterinary quarantine centres), provisions of watering points and revisions to livestock marketing and taxation policy. Sudan's close proximity to the large and expanding market of the Arab world is also an additional advantage for the growing contribution of the sub sector to the economy. After the lifting of the import ban on Horn of Africa livestock in 2009, the demand for Sudan's livestock (camels, sheep, goats and cattle) has increased in Egypt, the Arab States of the Gulf and Saudi Arabia. The sub sector comprises about 47% of the agricultural GDP for the period 2000-2008; this contribution is increasing over the years implying the increasing importance of this sub-sector (ENTRO-Economic models for the analysis of Agricultural policies of Sudan).

In Sudan, some 5% of livestock are raised by settled farmers, and 95% are raised by pastoralists who are either transhumance or nomads. The latter crossing borders into neighbouring countries in search of water and pasture for their livestock. Due to this and absence of regular census, it is difficult to estimate the exact numbers of livestock in Sudan. However, many studies indicate that, Sudan has the second largest herd in Africa. (see table below). Sudanese cattle are of two principal varieties: Baqqara and Nilotic. The Baqqara and two sub-varieties constituted about 80 percent of the country's total number of cattle.

Sudan is self-sufficient in meat and other livestock products. In 2005, Sudan produced 350,000 tonnes of cattle meat and 5.5 million tonnes of cow milk making the country self-sufficient for these products. Sudan exports live animals, meat, skin and hides mainly to the Arab countries. However, several constraints deprive the country from realizing the full potential of this sub-sector (ENIDS-CRA study). Major constraints include:

- Overgrazing in some areas, particularly around settlements,
- The great distances that animals often have to travel in search of water and pasture,
- Expansion of agriculture, particularly mechanised farming, into traditional grazing land, often causing conflicts between transhumant and settled farmers;
- Draught and seasonal nutritional deficiencies;
- Prevalence of disease leading to early culling of cattle;
- Poor husbandry and veterinary services;
- Poor integration of livestock in the rotation of arable crops including absence of fodder in the rotation;
- Difficulty of marketing and processing milk due to the remoteness of grazing areas far from the centres of consumption;
- Lack of processing facilities, services and infrastructure such as research, extension, roads, and livestock markets.

Table A5.5: Livestock population in South Sudan (millions)

Livestock	2012
Cattle	29.30
Sheep	39.00
Goat	30.50
Camels	4.60
Mules	0.35
Donkeys	5.60
Camels	0.92

Source: QUASI special Report (2012)

Basin-level Perspective on the Livestock Sector

Livestock is a crucial subsistence and economic activity in all the EN countries, the region being home for the largest livestock population in Africa. It is a major means of livelihood especially for pastoralists and agro-pastoralists living in the semi-arid areas of Ethiopia, Sudan and South Sudan. Livestock potential in the region has not yet been fully exploited due to a number of constraints, which among others include; shortage of drinking water supply and pasture, inadequate research, extension and veterinary services, lack of market, absence of clear policies and adequate legislation.

Photo istock/NBI

Annex 6

The Eastern Nile Basin: **Electricity and Public Service Infrastructure**

Annex 6: Electricity and Public Service Infrastructure

6.1 ELECTRICITY GENERATION AND HYDROPOWER

6.1.1 REGIONAL CONTEXT

Demand at both the regional level is growing rapidly as summarized in Table A6.1. As far as the current situation is concerned, only in Egypt is the installed generating capacity greater than the peak demand, and here only by a small margin. Regional demand can only be met by increasing capacity and by the sharing of capacity via an expanded interconnection.

6.1.3 Country Context: Egypt

Overview: More than 30,000MW is currently generated in Egypt, with hydropower having a share of 9.5%.

The electricity sector in Egypt is led by the Ministry of Electricity and Renewable Energy, Under it the Egyptian Electricity Holding Company which includes 6 electricity production companies, one transmission company and 9 distribution companies, and six Authorities: Renewable Energy Authority, Hydro Power Projects Execution Authority, Nuclear Power Plant Authority, Nuclear Material Authority, and Atomic Energy Authority. The Egyptian Electricity Utility and Consumer Protection Regulatory Agency established in 2000 to regulate and supervise the electric power activities and issue required licenses. The Supreme Energy Council (the highest policymaking authority) oversees and guides the Egyptian energy sector and approves and monitors its implementation plans.

Some key facts are as follows:

- Situation in Year 2013
    - Installed Capacity: 30,800 MW
    - Max Load: 27,000 MW
    - No. of Consumers: 30 Million
    - Electricity Share per Capita: 1,950 Kwh
- Diversifying Energy Resources in Generation
    - Steam: 47.5%
    - Combined Cycle: 39.7%
    - Hydropower: 9%
    - Gas Turbine: 6.6%
    - Wind and Solar: 1.2%
- Renewable Energy: On February 2008, the Supreme Energy Council approved the Egyptian Renewable Energy National Strategy to Satisfy 20% of the generated electricity by 2020 using renewable energies. This strategy includes providing 12% of the generated electricity (7200 MW) from wind energy by 2020. On July 2012 the Cabinet approved the Egyptian Solar Plan which includes adding 3500 MW (2800 MW CSP, 700 MW PV) of Solar Energy by 2027.

Table A6.1: Current and forecasted generation and peak demand requirements in all four countries

	Generation (GWh)					Peak demand (MW)					Annual growth (%)			
	Egypt	Ethiopia	Sudan	South Sudan	TOTAL	Egypt	Ethiopia	Sudan	South Sudan	TOTAL	Egypt	Ethiopia	Sudan	South Sudan
2012	164,628	7,869	12,737		**185,234**	25,000	1,398	1,853	33	**28,284**				
2015	196,334	14,688	14,662	474	**226,158**	31,880	2,956	2,947	80	**37,863**	5.5	4	19	53
2020	260,589	35,062	24,496	1,868	**322,015**	41,874	7,474	5,087	300	**54,735**	6.2	30	14.5	55
2025	342,626	53,209	33,448	3,173	**432,456**	54,402	12,636	6,613	500	**74,151**	6	13.8	6	13.3
2030	446,301	73,944	40,990	4,274	**565,509**	69,909	17,868	7,979	712	**96,468**	5.7	8.2	4	8.5
2035	575,478	89,047	47,381	5,479	**717,385**	88,947	23,556	9,476	1,033	**123,012**	5.4	6.3	4.8	10
2039	666,846	120,740	53,878	6,348	**847,812**	109,230	25,761	11,000	1,200	**147,191**	5.7	6	4	5

- Large Wind
  - Installed capacity:550 MW
  - Under implementation:540 MW
  - In Pipeline: 880 MW

- Solar
  - In Operation: Kuraimat 140 MW Solar thermal power plant including solar field of 20 MW
  - Two remote settlements (100 houses + some facilities) in Matrouh Governorate were electrified by PV systems since 2010.

The Total Installed Capacity of PV Systems in Egypt is more than 10 MW for lightening, Water Pumping, Wireless Communications, Cooling and Commercial Advertisements on highways.

- Hydropower:
  - Installed capacity from hydro is 2843 MW
  - Hydro power represents 9% from the generated electrical energy
  - Assuit Hydro Power Project (32 MW) is under implementation planned to be operated by 2017

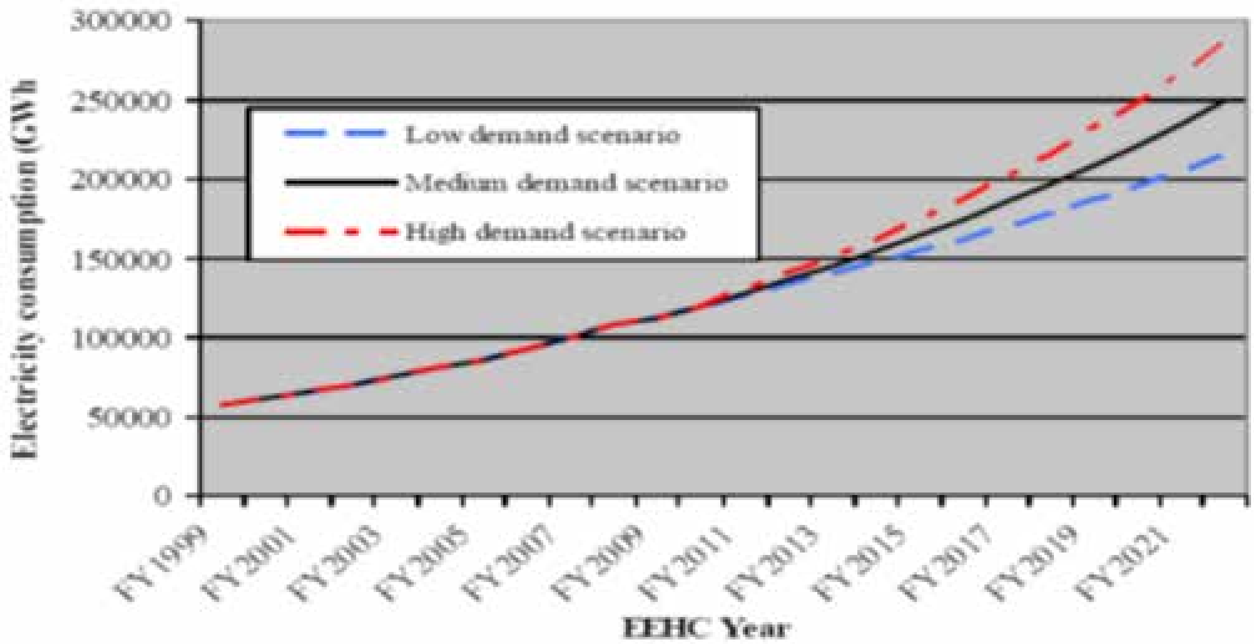
Generation Capacity: The current generation capacity is 32,379MW. 2,862MW is generated by hydropower, all situated on the Main Nile. Detail are presented later in this chapter. The remainder is produced by a combination of steam turbine, gas turbine, combined cycle, photo voltaic, concentrated polar system.

Current and projected demand: Electricity Sector Expansion and Investment Plan Up to year 2020: Three scenarios for electricity demand forecasts (medium, High and low), the medium demand scenario indicates an expected growth rate in demand of about 6.25%. The EEHC's forecast of power demand under; low, medium and high growth scenarios is summarized in Figure A6.4.

Based on the medium scenario, EEHC needs to add about 3,000MW of electricity generation capacity annually between fiscal years (FY) 2012 and 2020 to meet its forecast of power demand, to be implemented with the participation of the private sector.

Planned Projects: Egypt has plans for the implementation of an additional 109,230 MW by 2039. This includes thermal steam power plants (54,400MW), thermal combined cycle gas turbine power plants (37,200MW), Nuclear Powe Plants (1,000MW) and wind and solar power plants (7,630MW). No new hydropower plants are planned.

Figure A6.1: EEHC's forecasted power demand scenarios



Current Transmission and interconnection:
Regional interconnection is as follows:

- Arab Maghreb Interconnection: Egypt-Libya since 1998. Arrangements are under preparation for Libya -Tunisia interconnection in order to achieve the interconnection between Arab Maghreb (Egypt/Libya/Tunisia/Algeria/Moroco).
- Arab Mashreq Interconnection: Egypt-Jordan in operation since 1998, Jordan- Syria since 2000 and Syria-Lebanon since 2009.

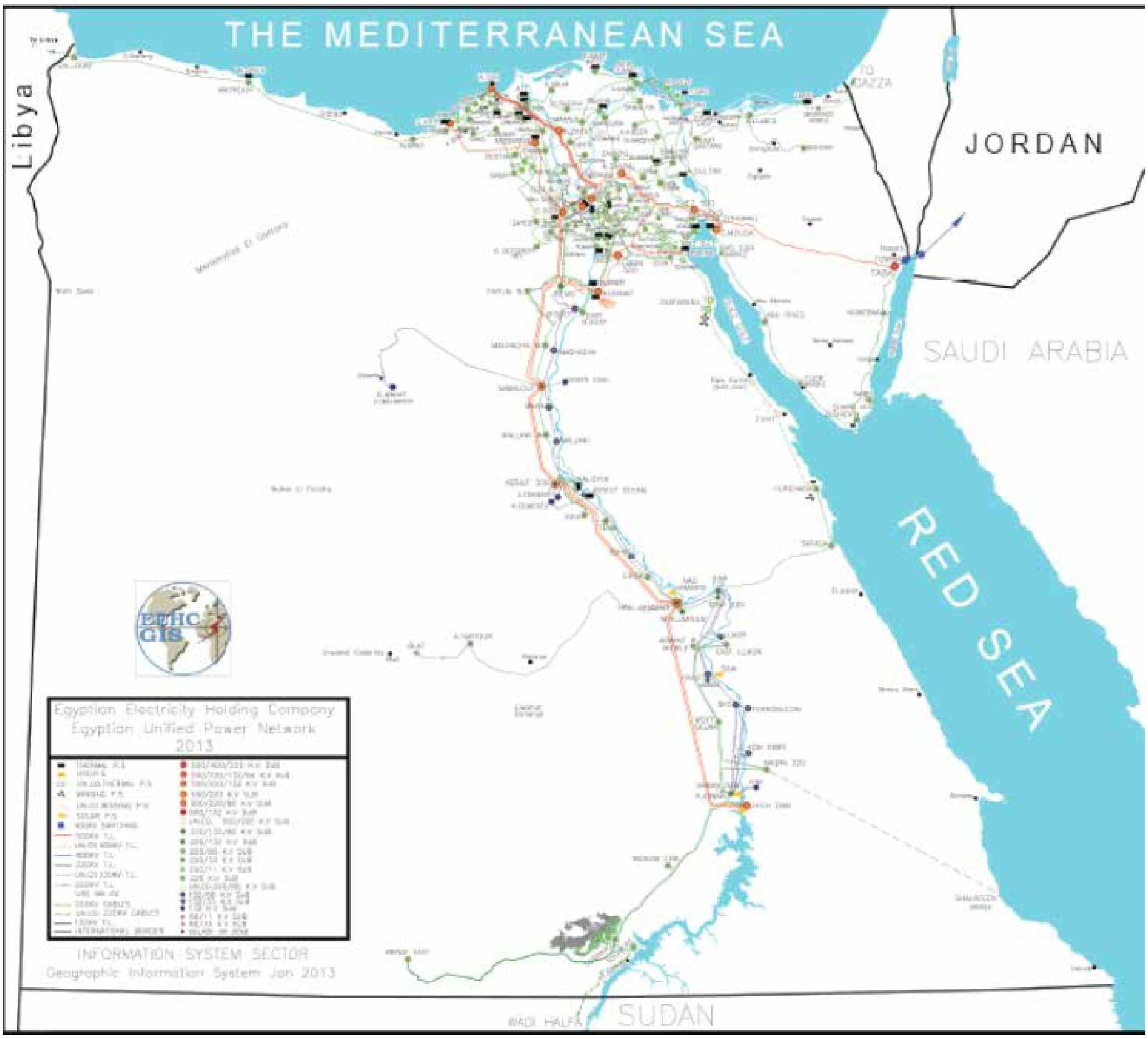
  These have led to interconnections between transmission systems of Lebanon, Syria, Jordan, Egypt and Libya.

The Egyptian electricity transmission grid is shown in Figure A6.5.

Planned Regional Interconnection Projects: The following projects are under consideration (see also Figure 5-5)

- Feasibility Study completed of exchange of power up to 3000 MW between Egypt and Saudi Arabia. Steps for implementation to be completed by 2015.
- The Axis of African Electrical Interconnection: Techno-economic feasibility study for the interconnection between Egypt and Inga Dam in Democratic Republic of Congo (DRC) passing through Central Africa and Sudan to transmit 40 GW of hydro power generated from Inga to North Africa and Europe was conducted.
- Techno-economic feasibility study for electrical energy trade between the Eastern Nile Basin Initiative (Egypt, Ethiopia, and Sudan) was completed in December 2008. The study

Figure: A6.2: Egyptian Electricity Transmission Grid



concluded the feasibility of exporting 3200 MW from Ethiopia to Sudan (1200MW) and to Egypt (2000MW).

- Feasibility study for the interconnection between Egypt and Sudan by constructing 180KM, 220 KV overhead transmission line between the two countries is under preparation.
- The Axis of Electrical Interconnection with Europe: Discussions are under way between Egypt and Greece for the interconnection between the transmission networks of the two countries. The interconnection with Greece will be established by constructing 2000 KM, + 500 KV DC link including a submarine cable.
- Future Vision for Regional Electrical Interconnection: The study for upgrading the interconnection with Arab Maghreb Countries through Libya to 400/500 kV has been finalized in April, 2004. The study final report was presented to the concerned countries (ELTAM) , and it was agreed to implement the recommended projects for starting the National Networks (500/400KV) of Egypt and Arab Maghreb Countries. It is expected that Egypt will finalize the construction of the 500 KV Sidi Krir / El Saloom line and El Saloom 500 KV substation by year 2015.

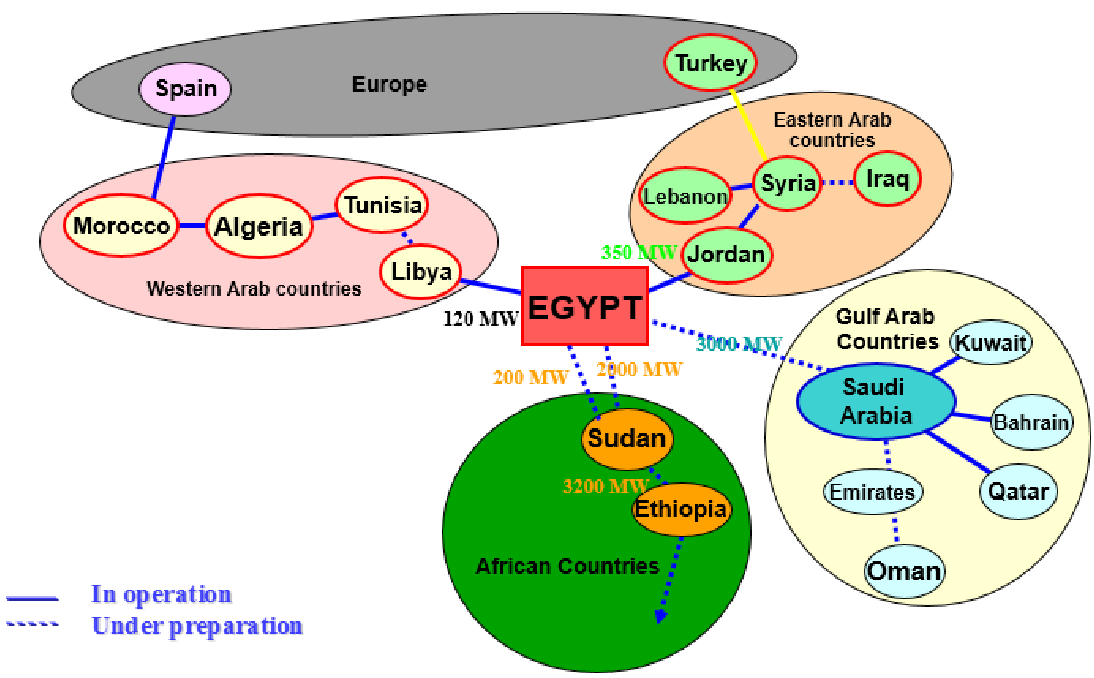
6.1.2 Country Context: Ethiopia

Overall: Ethiopia is well endowed with huge hydropower resources as well as a significant geothermal potential for the generation of electricity. The economically exploitable potential is estimated at 45,000 MW. At the same time, per capita energy consumption is one of the lowest in the world. 17% of population has access to electricity and the existing capacity for electricity production is about 2000 MW.

The Electricity sector was restructured in 2012, the former Ethiopian Electricity Power Corporation (EEPCO) split to two Power entities: the Ethiopian Electric Power (EEP) and the Ethiopian Electric Utility (EEU). EEP is in charge of Power planning, construction, operation and maintenance of the system and EEU is in charge of the distribution network construction and dealing with consumers.

Generation capacity: The current interconnected system has a total installed capacity of 2,083 MW (end of 2012) including 87 MW of diesel plants at Dire Dawa, Awash, and Kaliti, and a Wind Power plant at Adama (51MW). The remainder is hydropower. Significantly, peak demand will surpass the current installed capacity by 2015, even under the low case scenario.

Figure A6.3: Future vision for Egyptian interconnection



Future demand: The current high level of economic growth is expected to continue, resulting in an ever-increasing demand for electricity in the country. The energy requirement in 2012 was around 8,000 GWh and anticipated to triple by 2017 even under the low case scenario, and rise to close to 100,000 GWh by 2025 (high case scenario). The forecasts for generated energy and peak demand are summarized in Table A6.2.

Planned projects: Three hydropower projects are currently under construction the Grand Ethiopian Renaissance Dam (GERD) 6000 MW, Gigle Gibe III 1870 MW and Genale Dawa 254 MW, totaling 8,154 MW, which will bring the total generation capacity to 10,237 MW of which hydropower will represent 98%. The new Expansion Plan anticipated to add (by 2023)a further 12,414.9 MW to the already existing and under construction total of 10,237 MW, which will bring the total to 22,651.9 MW, necessary to face the rapidly increasing demand, Hydropower will represent 98% of the total installed capacity.

6.1.2 Country Context: South Sudan

Overview: Current electricity capacity available to South Sudan is about 30MW. Only 1% of the population has access to electricity. Only three states of the 10 States have electricity. South Sudan has large Hydropower potential located on Bahr El Jabal River (shared with Uganda) in the NEL basin. There is also potential for small hydropower development all over the country. At this stage the country lacks the infrastructure and electrification is limited to major cities provided by diesel generating units using expensive fuel..

Generation capacity: The generation capacity is limited to 21MW, all provided by diesel units.

Planned Projects: According to the Infrastructure Plan for South Sudan, a sum of 336 MW diesel power (sets of up to 5 MW) and 40 MW hydropower is to be in-stalled 2015-2020, and an additional 115 MW diesel power and 300 MW hydropower is to be established 2021-2025. Feasibility Studies were completed for huge hydropower sites to be constructed during the Long Term Plan beyond (more than 2025). These include the Grand Foula project with a capacity of around 800MW, Shakuli (250MW), Lakki (250MW) and Bedden (500MW) all in the NEL basin. Between them they should generate nearly 10,000 GWh. There are no projects planned in the Eastern Nile part of the country but a project for 40 MW at Foula is under discussion to supply power to South Sudan through TL of voltage 132 KV and, although these hydropower sites are not within EN Basin, it is foreseen that they will affect the EN region if implemented (according to EAPP master plan and Figure A6.1)

Interconnection and Transmission Systems: South Sudan currently imports about 12 MW from Sudan through 33 kV Transmission system connecting Rossieres Hydropower Plant to Renk City in Upper Nile State in South Sudan. At present there is no national

Table A6.2: Forecast for Generated Energy and Peak Demand: Ethiopia

Year	Total Energy Requirement (GWh)			Total Peak Demand (MW)		
	Base Case Scenario	High Case Scenario	Low Case Scenario	Base Case Scenario	High Case Scenario	Low Case Scenario
2012	7,869	8,294	7,573	1,326	1,413	1,281
2013	9,680	10,763	9,034	1,681	1,884	1,575
2014	12,371	14,171	11,272	2,157	2,483	1,975
2015	17,447	21,490	14,393	2,956	3,560	2,499
2020	45,960	56,932	34,760	7,474	9,080	5,798
2025	77,343	97,294	48,848	12,636	15,671	8,504
2030	105,827	141,098	66,263	17,868	23,331	11,817
2035	135,386	196,419	79,296	23,556	32,972	14,809

Figure A6.4: Forecasted Exchange of power with South Sudan

electricity transmission grid providing interconnection within the South Sudan States. There are city distribution networks for Juba, Wau and others.

Planned Regional Interconnection Projects: Ongoing studies include the following:

- Study to import electricity from Ethiopia through 220 kV TL Gambella/Malakal/Juba.
- Study under NELSAP to connect South Sudan to Uganda through 400 kV TL

6.1.3 Country Context: Sudan

Overview: Sudan has a mix of energy generation types including hydropower and thermal power plants running either steam or gas turbine units. Wind technology electricity generation has been recently implemented in the country. Sudan envisions a significant expansion of coal-fired power plants at the Red Sea. The electricity system within Sudan consists of the main National Grid, a number of isolated off-grid systems and some existing private generation companies. The Sudanese Electricity Transmission Company Ltd. (SETCO) is responsible for transmission system, the Sudanese Hydropower Generation Company Ltd. (SHGC) is responsible for hydropower Generation while Sudanese Electricity Transmission Company Ltd. (SEDCO) is responsible for the distribution system all under the Ministry of Water Resources and Electricity. The Ministry of Water Resources and Electricity updated the Expansion and Investment Planning for the Electricity system until year 2031, issued in December 2013.

Current and projected demand: The demand in 2012 was just under 10,000 GWh and anticipated to more than double by 2020 even under the low case scenario. The requirement could be close to 50,000 GWh by 2031 (high case scenario). The forecasts for generated energy and peak demand are summarized in Table A6.3.

Table A6.3: Forecast for Generated Energy and Peak Demand

Year	Total Energy Requirement (GWh)			Total Peak Demand (MW)		
	Base Case Scenario	High Case Scenario	Low Case Scenario	Base Case Scenario	High Case Scenario	Low Case Scenario
2012	9,742	10,130	9,369	2,013	2,083	1,945
2013	11,241	11,995	10,509	2,295	2,433	2,162
2014	12,819	13,812	11,716	2,595	2,777	2,393
2015	14,662	16,043	13,023	2,947	3,201	2,645
2020	24,496	28,036	21,416	5,087	5,742	4,516
2021	26,066	29,719	22,662	5,351	6,024	4,724
2026	33,448	37,571	29,121	6,613	7,360	5,829
2031	40,990	46,141	35,928	7,979	8,913	7,062

Generation Capacity: Total existing generation capacity amounts to 2,898MW and includes 1617MW of hydropower generation capacity dominated by hydropower scheme at Merowe (1250MW). All hydropower is situated in the Eastern Nile Basin. There is currently 850MW of thermal power with the rest made up from wind and solar power generation.

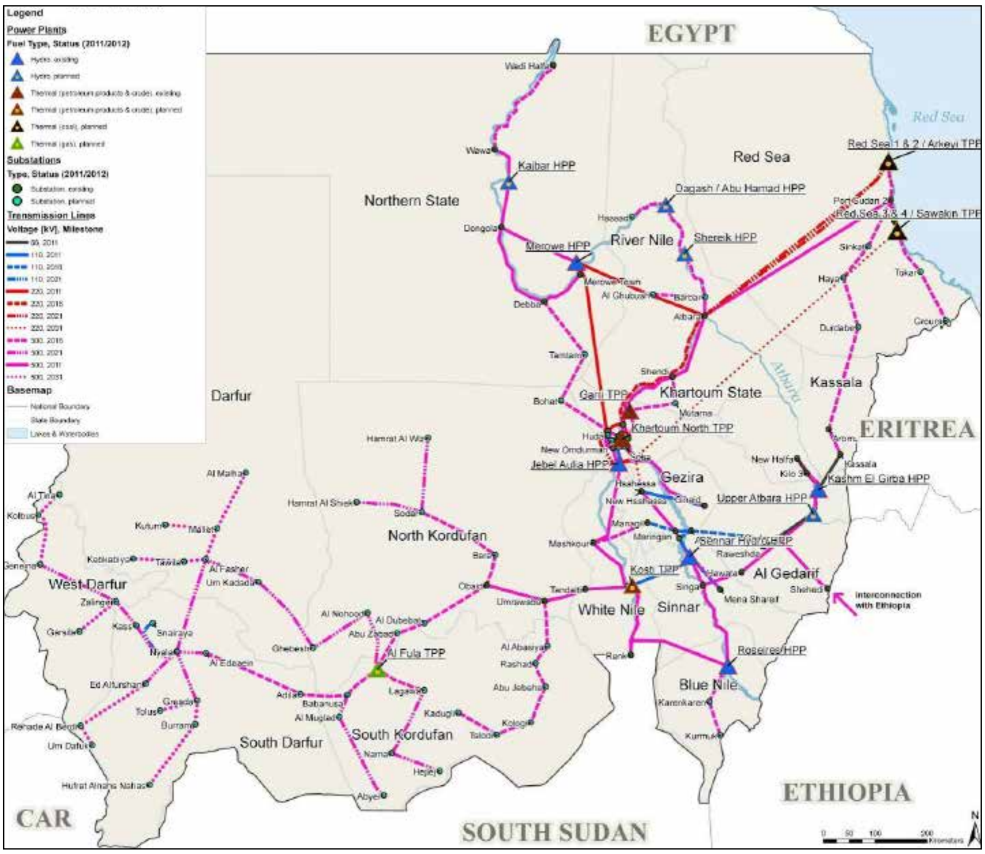
Planned Projects: Information of planned projects comes from the updated the Expansion and Investment Planning for the Electricity system until year 2031, issued in December 2013 by the Ministry of Water Resources and Electricity. More than 5,200MW are planned through thermal power plants and more than 350MW from wind and solar power. Major expansion of hydropower is also planned, around 2,300MW, a large proportion of which lies in the Eastern Nile basin. Details are provided later in this chapter. The planned cumulative generating capacity for Sudan through to 2031 is shown in Figure A6.2. Given that peak demand will require a capacity of between 7,062 and 8,913MW, it is clear that it will be necessary to import power through the regional interconnection system.

Current Interconnection and Transmission Systems: The electricity system within Sudan consists of the main National Grid, a number of isolated off-grid systems and some existing private generation companies. The main grid system is divided into the Khartoum, Central, Eastern and Northern areas. The towns of Atbara and Shendi in River Nile state, which were previously supplied by local off-grid generation, were connected to the National Grid as part of the Merowe transmission reinforcement scheme. The existing transmission network is shown in Figure A6.2.

Future Interconnection and Transmission Projects: The Transmission system expansion till year 2031 has also been studied and approved by SETCO. Studies prepared for interconnection with neighbouring countries include:

- The interconnection between Ethiopia / Sudan / Egypt to transfer a sum of 3,200 MW from Ethiopia to Sudan through a AC 500 kV OHTL and then out of the transferred energy a sum of 2000 MW be transferred to from Sudan to Egypt through DC 600 kV OHTL.

Figure A6.5: Sudan existing and planned Transmission network till 2031



- Feasibility study for the interconnection between Sudan and Egypt on:
  - Option I: 220 kV OHTL connecting Toshka substation in Egypt to Old Halfa substation in Sudan of approximately 162 Km length.
  - Option II: 500 kV OHTH connecting Nag Hammadi substation in Egypt to Algoreair substation in Sudan of approximate length 767 Km.

6.1.4 REGIONAL INTERCONNECTION IN THE EASTERN NILE BASIN

Studies: Recently concern has been given to the interconnection and Power Trade between EN countries through NBI and EAPP through many studies. These include:

- NBI-Opportunities for Power Trade in the Nile Basin; A scoping Study- by Norconsult and Statnett financed by World Bank- January 2004
- Regional Power System Master Plan and Grid Code Study By SNC Lavalin and PB-Nov. 2011
- EAPP- Update Regional Master Plan- Under preparation by Energynet.dk and EA Energy Analysis - Draft Final report: August 2014
- ENTRO- EN Power Trade Study- Phase II-EDF-December 2008. An export from Ethiopia capacity of 1200 MW to Sudan, and 2000 MW to Egypt, is profitable for the region (See Figure A6.7)
  - *Transmission Interconnection (AC/DC Mix with tapping station in Sudan)*
    - Ethiopia exports 3200 MW to Sudan, including 2000 MW for Egypt.
    - 500/400 kV substation located at Mandaya HHP, with four 500/400 kV transformers 510 MVAr each.
    - Four 500 kV AC circuits between Mandaya HPP and Kosti 500 kV substations (570 km)
    - AC/DC 2 x 1075 MW converter station located at Kosti substation in Sudan, and a SVC.
    - 600 kV DC bipolar line between Rabak and Nag Hammadi. (1650 Km)
    - A third circuit between Nag Hammadi and Asuit (Egypt reinforcement).
  - *Economic assessment*
    Investment costs are estimated about 1 860 MSD2006 , O&M costs are about 18 MSD2006 per year and revamping costs about 230 MSD2006 Social mitigation costs are about 16 MSD2006 .
    - Net present value (NPV) of the project is positive for both demand scenarios: 1 810 MSD2006 for medium Ethiopian demand and 2 210 MSD2006 for low Ethiopian demand, 10% discount rate, medium fuel price projection. (About 160 MUD to 320 MUSD must be added to NPVs from CO2 savings, if this project is eligible to Clean Development Mechanism.)
    - The payback period is reached after 8 full years of operation for low Ethiopian demand and 7 full years for medium Ethiopian demand.
    - The Benefit to Cost Ratio (BCR) of the both scenarios are above 3 for a 10% discount rate, and remains superior to 2 for 8% and 12% discount rates.
    - Both scenarios have high Economic Internal Rate of Return (EIRR), respectively 18% and 17%.
    - The sensitivity analysis executed for a low Ethiopian demand including updated fuel prices projection, shows that the variant with anticipation is even more profitable, with a BCR of 4.9
    - High fuel prices assumption enhances the interest of the Eastern Nile Regional Power Interconnection project, with a BCR as high as 8.1.

Conclusions: Based on four preliminary screening criteria – (1) Hydropower project; (2) Within EN Sub Basin; (3) regionally significant effect (capacity above 350 MW for the generation projects and include more than one EN country for the interconnection projects); and (4) recommended by the Ethiopian Power system expansion Plan and Sudan Expansion Plan and NCORE report for Knowledge-Base Development - the projects of regional significance listed below can be considered for hydropower generation and the regional interconnection.

Figure A6.6: Eastern Nile Interconnection

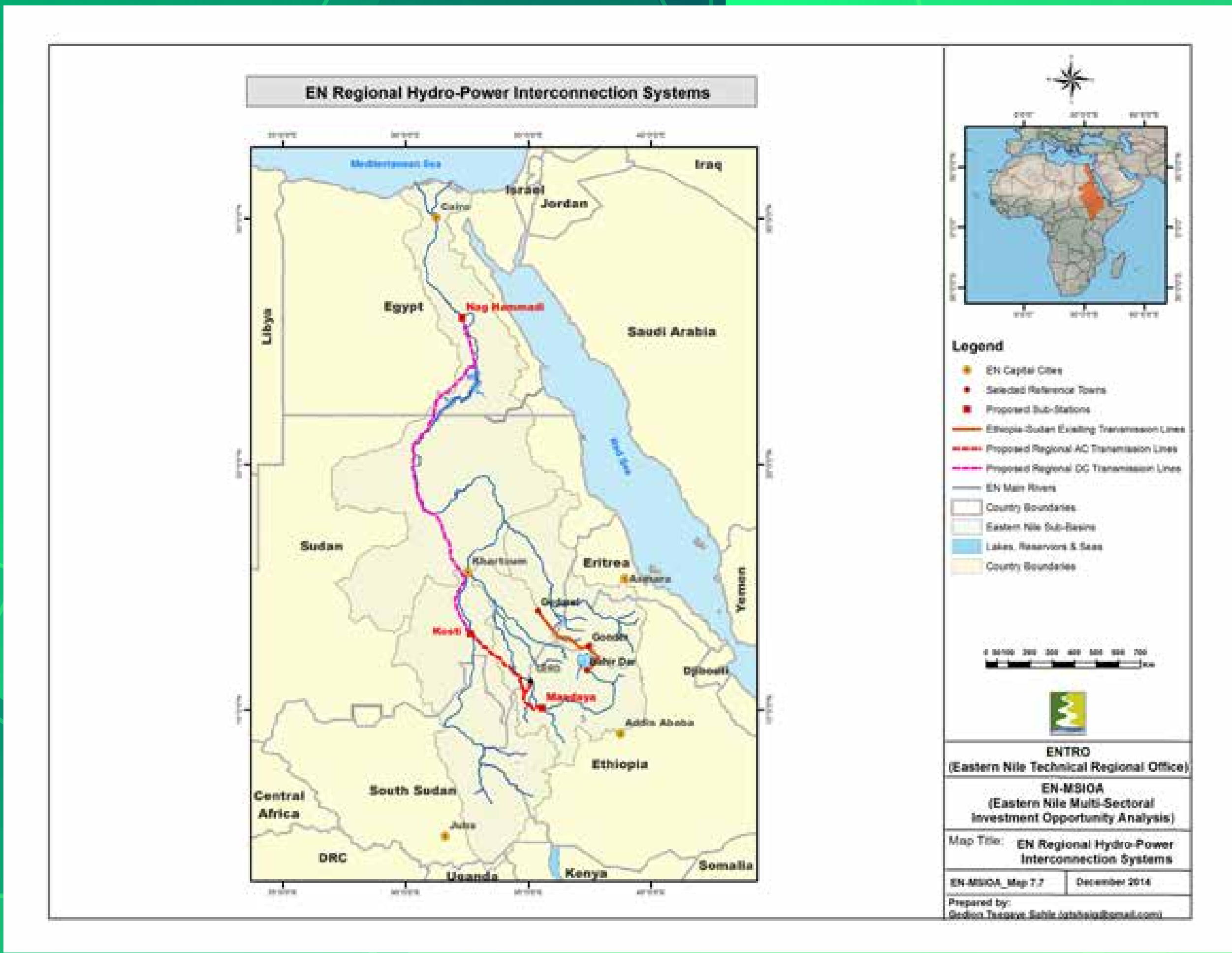
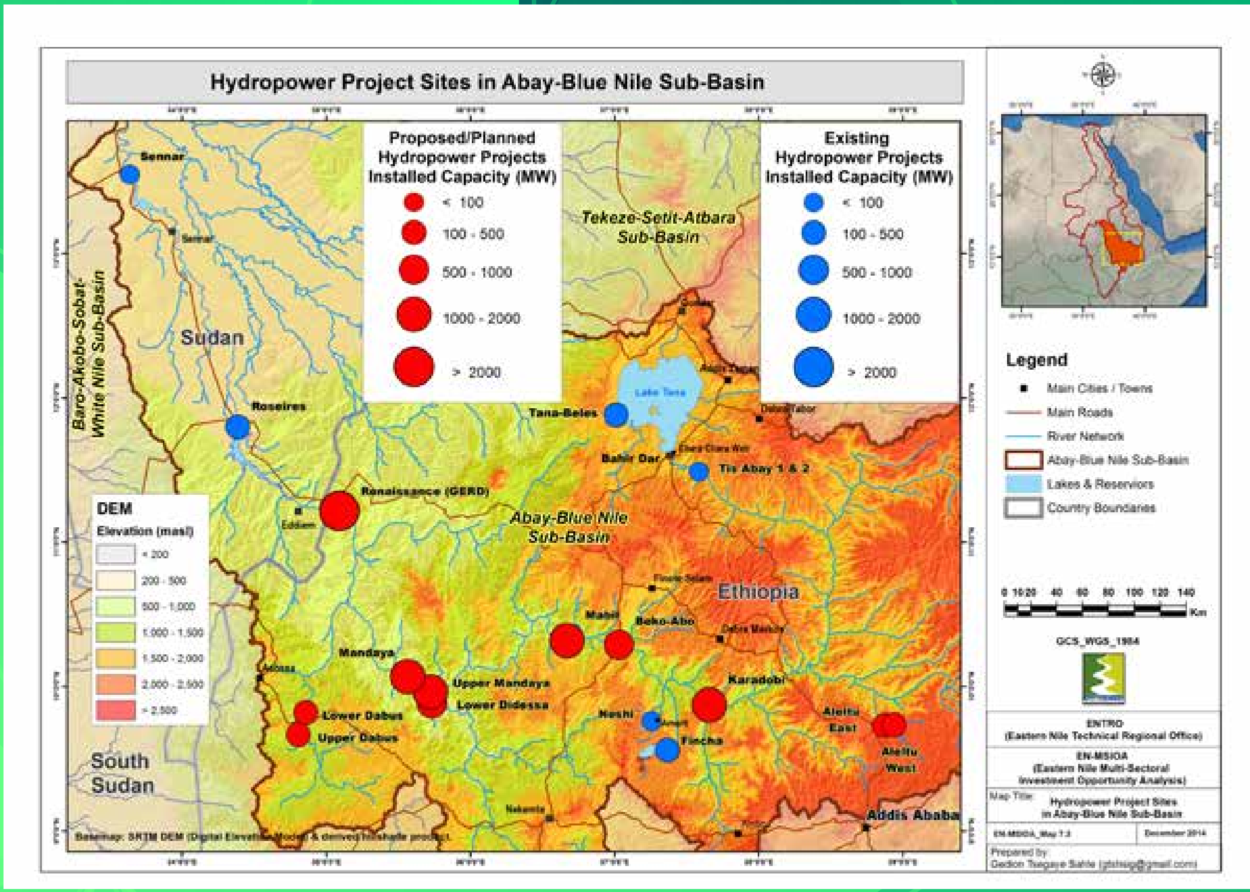


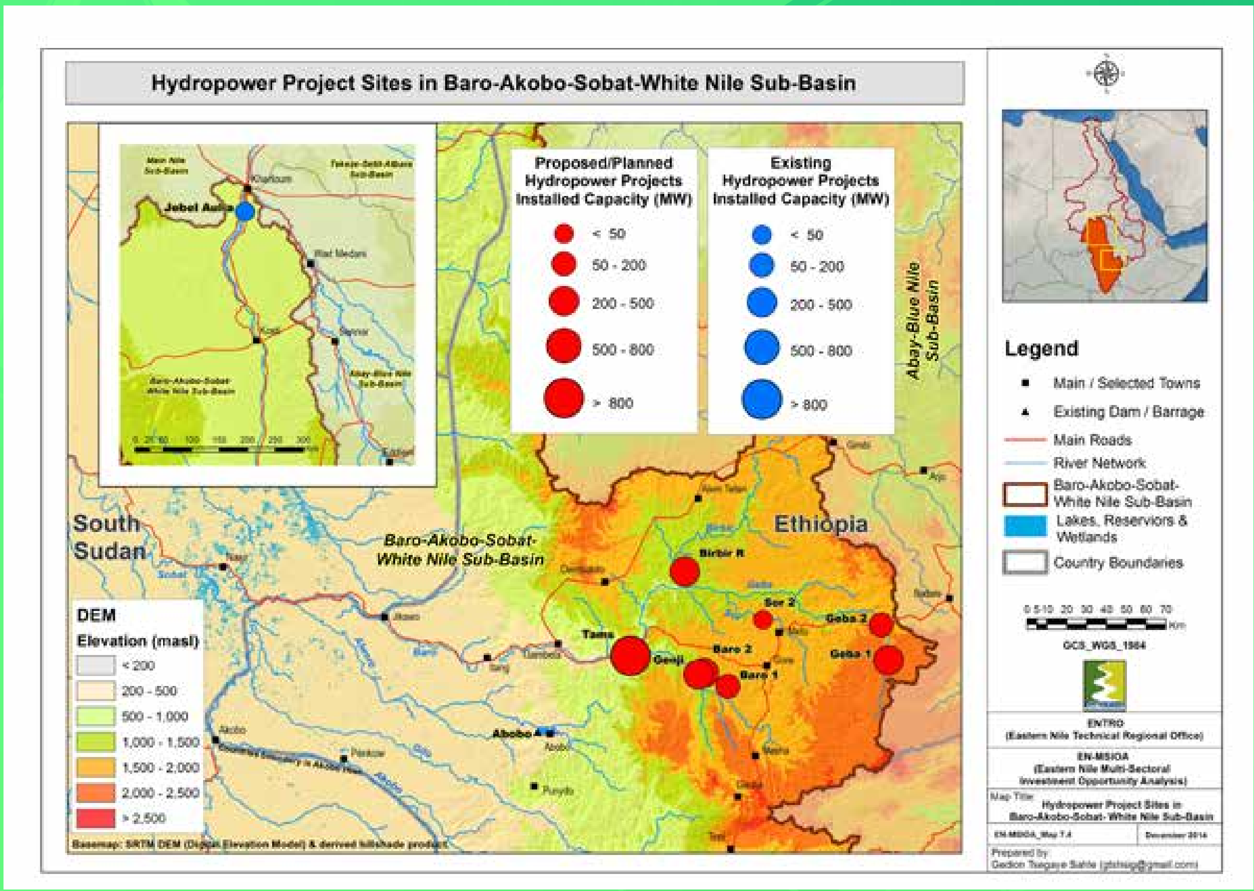
Table A6.4: Future generation Projects in EN Region

Hydropower Project Name	Country	Sub Basin	Status (Ex, Uc, FS, PFS)	Planning Horizon	Dev. level	Capacity (MW)
High Aswan Dam	Egypt	Main Nile	Ex		√	2100
Aswan 1 + 2			Ex		√	592
Esna			Ex		√	86
Nag Hammadi			Ex		√	64
Damietta			Ex		√	20
Assiut			Uc	15-25		32

Hydropower Project Name	Country	Sub Basin	Status (Ex, Uc, FS, PFS)	Planning Horizon	Dev. level	Capacity (MW)
Beles	Ethiopia	Abay/Blue Nile	Ex		√	460
Tis Abay I & II			Ex		√	84
Finchaa			Ex		√	134
Amarti Neshe			Ex		√	98
Grand Renaissance			UC	15-25		6000
Tekeze I		Tekeze/Atbara	Ex		√	300
Karadobi		Abay/Blue Nile	PFS- Sep 2006	15-25		1600
Beko Abo			PFS- Sep 2010	15-25		935
Upper Mandaya			PFS- Dec 2007	15-25		1700
Lower Didessa			GERD Study - 2001	15-25		550
Yeda 1			FS -2000	15-25		118
Yeda 2			FS - 2000	15-25		162
Aleltu East			FS- Feb 1995	15-25		189
Aleltu West			PFS- Jan 1994	15-25		264.6
Upper Dabus			GERD Study - 2002	15-25		326
Baro I		Baro-Akobo / Sobat	FS- Sep 2006	15-25		166
Baro II			FS- Sep 2006	15-25		479
Genji				15-25		216
Birbir			GERD Aug 2001	15-25		467
Geba 1+ 2			FS- Feb 2005	15-25		371.5
Sor 2				15-25		5
Tams			PFS- Jan 2009	15-25		1000
Tekeze 2		Tekeze/Atbara	GERD study 2006	15-25		450
Grand Foula	South Sudan	White Nile	PFS- June 2009	25-40		800
Shokuli			PFS- June 2009	25-40		250
Lakki			PFS- June 2009	25-40		250
Bedden			PFS- June 2009	25-40		522
Roseires	Sudan	Abay/Blue Nile	Ex		√	280
Sennar			Ex		√	26
Khashm El Girba		Tekeze/Atbara	Ex		√	18
Jebel Aulia		White Nile	Ex		√	30
Merowe		Main Nile	Ex		√	1250
Sitet /Rumela		Tekeze/Atbara	Uc			320
Shereik		Main Nile	FS	15-25		420
Dagash			FS	15-25		312
Kajbar			FS	15-25		360

Ex= Existing Uc= Under Construction FS= Feasibility Study PFS= Pre Feasibility Study


Hydropower Project Sites in Abay-Blue Nile Sub-Basin
Proposed/Planned Hydropower Projects Installed Capacity (MW)
< 100
100 - 500
500 - 1000
1000 - 2000
> 2000
Existing Hydropower Projects Installed Capacity (MW)
< 100
100 - 500
500 - 1000
1000 - 2000
> 2000
Tekeze-Setit-Atbara Sub-Basin
Baro-Akobo-Sobat-White Nile Sub-Basin
Sudan
South Sudan
Ethiopia
Abay-Blue Nile Sub-Basin
Sennar
Roseires
Renaissance (GERD)
Tana-Beles
Lake Tana
Bahir Dar
Tis Abay 1 & 2
Mabil
Beko-Abo
Mandaya
Upper Mandaya
Lower Didessa
Lower Dabus
Upper Dabus
Neshi
Fincha
Karadobi
Aleltu East
Aleltu West
Addis Ababa
DEM
Elevation (masl)
< 200
200 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
> 2,500
Basemap: SRTM DEM (Digital Elevation Model) & derived hillshade product.
Legend
Main Cities / Towns
Main Roads
River Network
Abay-Blue Nile Sub-Basin
Lakes & Reservoirs
Country Boundaries
0 10 20 40 60 80 100 120 140 Km
GCS_WGS_1984
ENTRO (Eastern Nile Technical Regional Office)
EN-MSIOA (Eastern Nile Multi-Sectoral Investment Opportunity Analysis)
Map Title: Hydropower Project Sites in Abay-Blue Nile Sub-Basin
EN-MSIOA_Map 7.3
December 2014
Prepared by: Gedion Tsegaye Sahle (gtshsig@gmail.com)


Hydropower Project Sites in Baro-Akobo-Sobat-White Nile Sub-Basin
Proposed/Planned Hydropower Projects Installed Capacity (MW)
< 50
50 - 200
200 - 500
500 - 800
> 800
Existing Hydropower Projects Installed Capacity (MW)
< 50
50 - 200
200 - 500
500 - 800
> 800
Main Nile Sub-Basin
Tekeze-Setit-Atbara Sub-Basin
Jebel Aulia
Baro-Akobo-Sobat-White Nile Sub-Basin
Abay-Blue Nile Sub-Basin
South Sudan
Ethiopia
Birbir R
Sor 2
Geba 2
Geba 1
Tams
Genji
Baro 2
Baro 1
Abobo
DEM
Elevation (masl)
< 200
200 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
> 2,500
Basemap: SRTM DEM (Digital Elevation Model) & derived hillshade product.
Legend
Main / Selected Towns
Existing Dam / Barrage
Main Roads
River Network
Baro-Akobo-Sobat-White Nile Sub-Basin
Lakes, Reservoirs & Wetlands
Country Boundaries
0 5 10 20 30 40 50 60 70 Km
GCS_WGS_1984
ENTRO (Eastern Nile Technical Regional Office)
EN-MSIOA (Eastern Nile Multi-Sectoral Investment Opportunity Analysis)
Map Title: Hydropower Project Sites in Baro-Akobo-Sobat-White Nile Sub-Basin
EN-MSIOA_Map 7.4
December 2014
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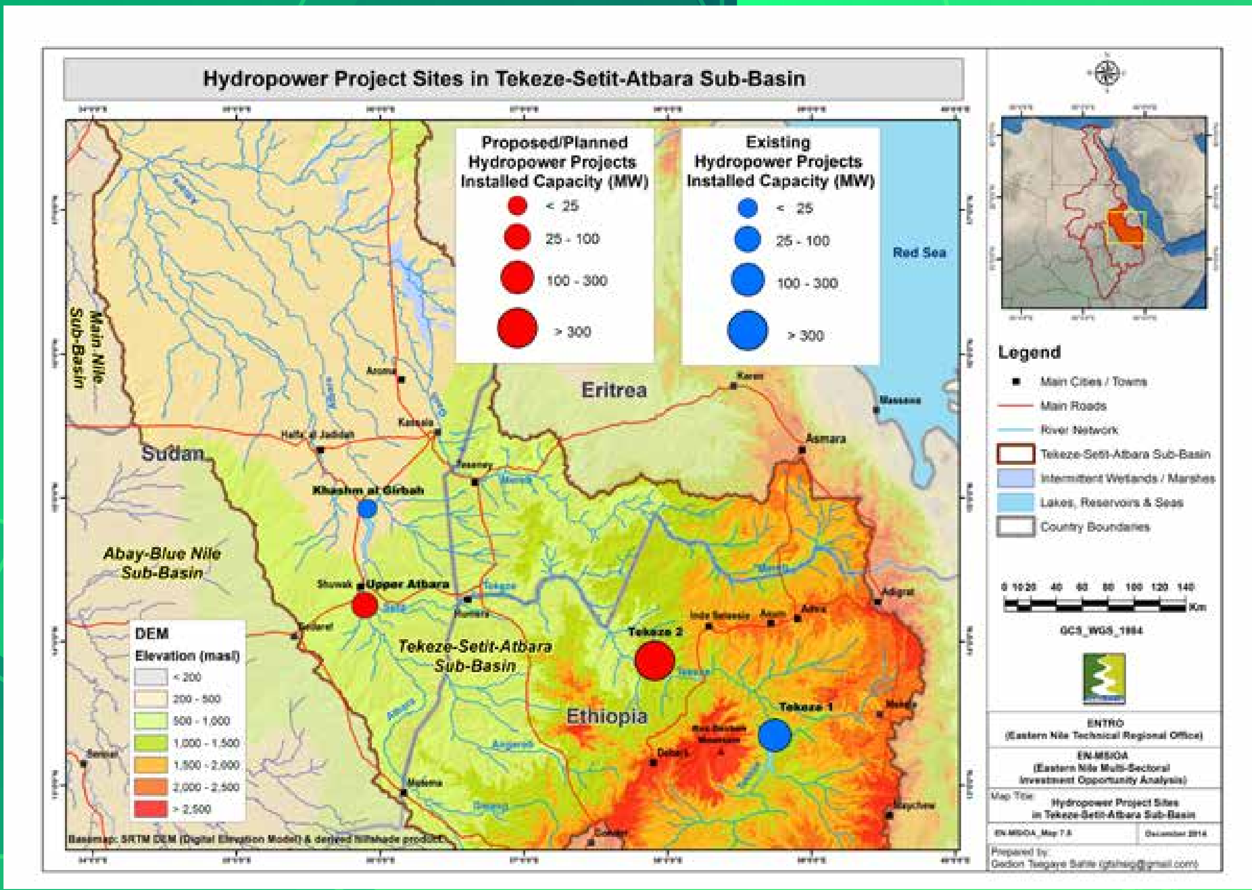
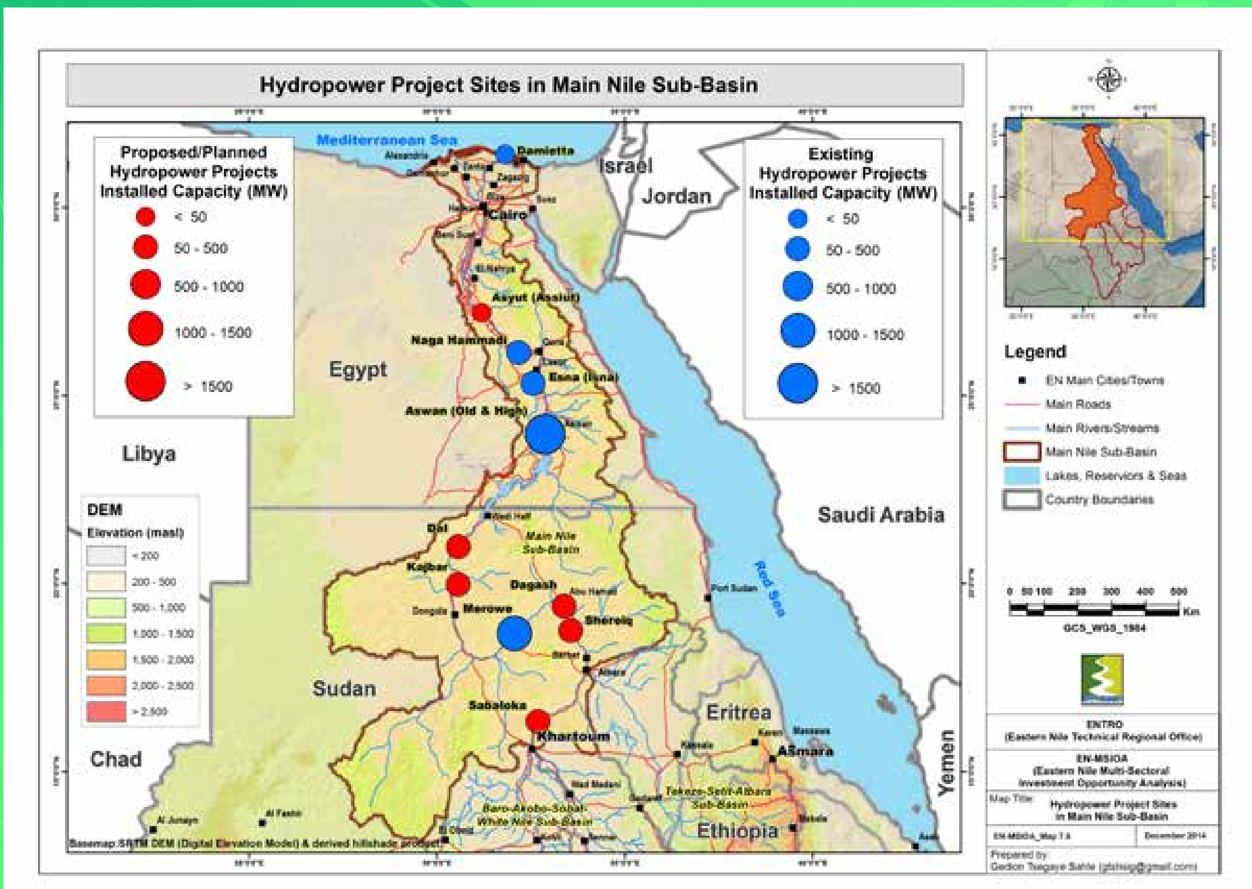

Hydropower Project Sites in Tekeze-Setit-Atbara Sub-Basin
Proposed/Planned Hydropower Projects Installed Capacity (MW)
< 25
25 - 100
100 - 300
> 300
Existing Hydropower Projects Installed Capacity (MW)
< 25
25 - 100
100 - 300
> 300
Red Sea
Eritrea
Sudan
Main Nile Sub-Basin
Abay-Blue Nile Sub-Basin
Tekeze-Setit-Atbara Sub-Basin
Ethiopia
Khashm al Girbah
Upper Atbara
Tekeze 2
Tekeze 1
Asmara
DEM
Elevation (masl)
< 200
200 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
> 2,500
Basemap: SRTM DEM (Digital Elevation Model) & derived hillshade product
Legend
Main Cities / Towns
Main Roads
River Network
Tekeze-Setit-Atbara Sub-Basin
Intermittent Wetlands / Marshes
Lakes, Reservoirs & Seas
Country Boundaries
Km
GCS_WGS_1984
ENTRO
(Eastern Nile Technical Regional Office)
EN-MSIOA
(Eastern Nile Multi-Sectoral Investment Opportunity Analysis)
Map Title
Hydropower Project Sites in Tekeze-Setit-Atbara Sub-Basin
December 2014
Prepared by:
Gedion Tsegaye Sahle (gtshsig@gmail.com)


Hydropower Project Sites in Main Nile Sub-Basin
Mediterranean Sea
Proposed/Planned Hydropower Projects Installed Capacity (MW)
< 50
50 - 500
500 - 1000
1000 - 1500
> 1500
Existing Hydropower Projects Installed Capacity (MW)
< 50
50 - 500
500 - 1000
1000 - 1500
> 1500
Israel
Jordan
Damietta
Cairo
Asyut (Assiut)
Naga Hammadi
Esna (Isna)
Aswan (Old & High)
Egypt
Libya
Saudi Arabia
Red Sea
Dal
Kajbar
Dagash
Merowe
Shereiq
Sabaloka
Khartoum
Main Nile Sub-Basin
Sudan
Chad
Eritrea
Asmara
Yemen
Ethiopia
Tekeze-Setit-Atbara Sub-Basin
Baro-Akobo-Sobat-White Nile Sub-Basin
DEM
Elevation (masl)
< 200
200 - 500
500 - 1,000
1,000 - 1,500
1,500 - 2,000
2,000 - 2,500
> 2,500
Basemap: SRTM DEM (Digital Elevation Model) & derived hillshade product
Legend
EN Main Cities/Towns
Main Roads
Main Rivers/Streams
Main Nile Sub-Basin
Lakes, Reservoirs & Seas
Country Boundaries
Km
GCS_WGS_1984
ENTRO
(Eastern Nile Technical Regional Office)
EN-MSIOA
(Eastern Nile Multi-Sectoral Investment Opportunity Analysis)
Map Title
Hydropower Project Sites in Main Nile Sub-Basin
December 2014
Prepared by:
Gedion Tsegaye Sahle (gtshsig@gmail.com)

6.3 Infrastructure and Public Services

6.3.1 Abbay-Blue Nile Sub-basin

Abbay (Ethiopia)

- **Water supply:** Provision of and access to safe and adequate water supplies and sanitation are low and or absent in most parts of the Abbay Gorge and adjacent areas. The 2007 Census data for Ethiopia indicates that 42 % of the households in Benishangul-Gumuz Region of the Abbay River Basin in Ethiopia had access to safe drinking water. The sources of water supply include protected wells, springs, and shared public and private pipes. The figures for the Oromia and Amhara regions were 42% and 50% respectively. The majority of the population in the Abbay sub-basin do not have access to safe drinking water and are therefore exposed to water-borne diseases such as diarrhoea, cholera, dysentery, etc.

- **Sanitation:** Basic sanitation facilities for solid and liquid waste disposal are also virtually non-existent. Sanitation facilities in the woredas located adjacent the western sections of the Abbay River are among the poorest in Ethiopia. Most people do not have sanitation facilities of any kind. Approximately 80% of the population in the Benishangul Gumuz region does not have toilet facilities.

- **Health:** The main health issues and challenges are:
    - Limited health services, poor access to clean drinking water and sanitation facilities and widespread poverty. Access to the limited health facilities is also compromised by the large distances and physical barriers associated with the natural topography and rivers in the area.
    - Malaria is the single most important public health problem affecting communities located in the vicinity of the Abbay Gorge. Malaria remains the single largest cause of death for children under five in the Abbay-Blue Nile basin and other parts of the EN Basin. Malaria has a significant impact on potential earnings and household food security. Malaria also imposes direct financial costs on individuals in the form of expenditure on insecticide-treated mosquito nets, clinic fees, anti-malaria drugs, and funeral costs. Malaria has also a serious impact on children who tend to be more vulnerable. Repeated malaria infections amongst children can impact on schooling and result in children failing grades and dropping out of school altogether. Malaria therefore results in a considerable loss of income and places a heavy burden on families, health systems and society as a whole. In so doing malaria can be a major constraint to national economic development. Health economists argue that economic growth rates in countries with high malaria rates are lower than those without malaria.
    - The other dominant water-borne and water-related diseases include Schistosomiasis, Onchocerciasis and Trypanosomiasis (human sleeping sickness), acute watery and bloody diarrhoeas, intestinal parasites and scabies, are also common and are linked to the poor water supplies and absence of basic sanitation facilities.
    - HIV/AIDS is a new disease emerging in the study areas. Reports indicate that the disease is prevalent and on the rise (Norplan et al. Beko-Abo EIA, 2010). The adult HIV prevalence in Ethiopia in 2009 was estimated to be between 1.4% and 2.8% by the Ethiopian Health and Nutrition Research Institute. The HIV prevalence in the Abbay Valley area affected by the proposed dams is likely to be lower than the national HIV prevalence average due the isolated nature of large sections of the study area (Norplan et al. Beko-Abo EIA, 2010).

- **Roads and river crossings:** As a consequence of the dissection of the highlands by the Abbay River and its tributaries the road infrastructure in all three regions is poorly developed. All-weather roads tend to be confined to the ridges and plateaus between the deeply incised rivers. As a result the Abbay has only three road crossings. The main areas of inaccessibility are located in the western parts of North and South Wello in the Abbay Gorge; the middle and the Lower Abbay Gorges; and the western Lowlands of the Dinder and Beles Valley.

The road infrastructure in Benishangul Gumuz region is one of the poorest in the country. As a result travelling within the region is difficult and expensive. Movement within the region is also negatively affected by the Abbay River, which divides Benishangul Gumuz region into two parts. While the road network in the Amhara Region is more developed than the network in Benishangul Gumuz, there is only one bridge crossing of the Abbay, namely at the Nekemte-Bure Bridge. In the absence of bridge crossings use is made of traditional boats. People use these boats to cross the Abbay River for trade, visiting relatives, health services and other personal reasons. The prefeasibility studies for the Border and Mandaya Dams indicate that there are in the region of four crossing points along the section of the Abbay River affected by the proposed dams.

- **Education;** education levels in the three regions located in the Abbay section of the sub-basin are low (Socio-economic Synthesis Report, 2007). More than half of the primary school age population (7 to 12 years) in each of the three regions did not attend school. The attendance levels for secondary school pupils were even lower, with over three-fourth of the population eligible for secondary education not attending school. Given that the majority of the population are rural it is likely that children of school going age are involved in agricultural activities and or do not have access to schools. The literacy levels in the three regions are also low. Based on the 2007 Census data only 26% of the rural population are regarded as literate

Blue Nile (Sudan)

- **Water;** Based on the 2008 Census data for Sudan the access to safe water in the more isolated rural states, such as Blue Nile and White Nile, is 43% and 49% of the population respectively.

- **Sanitation:** The figures for Sinnar (78%), Gezira (81%) and Khartoum (80%) are significantly higher. The same trend is reflected for sanitation, with limited access to sanitation in the Blue Nile (5.3%) and While Nile States (34.4%) compared to Khartoum (51%). However, the majority of the population in the Blue Nile do not have access to sanitation.

- **Education;** The rural literacy rates in the Blue Nile Sub-Basin (Sudan) range from 43% in the Blue Nile to 67% in Khartoum. The urban literacy rates are on average 15-20% higher than the rural rates in each of the states that fall within the Blue Nile Sub-Basin.

- **Transport;** At present the Blue Nile and the Tekeze-Atbara basins in the Sudan are connected to railway network, which is not the case with the Akobo-Sobat Basin.

6.3.2 Baro-Akobo-Sobat And White Nile Sub-Basin

- Overall, there is a dearth of infrastructure in the sub-basin, specifically in terms of road networks, water supply and sanitation facilities, health and education services, provision of credit and extension services.
- Water supply and Sanitation: Within the Ethiopian section of the Baro-Akobo sub-basin the 2006 Census data indicates that 70% of the population in Gambella had access to safe drinking water. Based on other data this figure appears to be high. The figure for Oromia was 42%. In South Sudan 62% of the population in Jongoli, followed by 52.2 % in Eastern Equatoria and 31.3% in Upper Nile had access to safe drinking water (Sudan Census 2007). A study undertaken by the Government of the Republic of South Sudan in 2011 (GOSS, 2011b. "Environmental Impacts, Risks and Opportunities Assessment: Natural Resources Management and Climate Change." Ministry of Environment, South Sudan) found that only ~ 27 % of the people have access to improved water supply, and only 15 % have access to improved sanitation. The figures from the 2007 Census therefore appear to be optimistic and potentially misleading.
- Education: The majority of the population in the Ethiopian section of the sub-basin has limited access to education. The rural literacy rates in the Oromia and Gembella were 26% and 36% respectively (2006 Census). In South Sudan the literacy rates in the three states was

in the region of 20% (2007 Census). The situation in the South Sudan section of the sub-basin has likely deteriorated with the civil unrest in the area.

6.3.3 Tekeze-Setit-Atbara Sub-Basin

The Tekeze-Atbara basin population, both on the Ethiopian and Sudanese sides, is characterized by differential access to social (education and health) and physical (water supply and roads) infrastructures. Due to the allocation of limited productive and investment resources favouring urban areas which was characteristics of government policies during and before the 1980s most of the rural population along the basin lacked basic social and physical services. Added to this were the protracted civil wars that consumed northern Ethiopia (in the 1970s and 1980s) and Sudan (in the 1980s and 1990s), both of which fall within the Tekeze-Atbara basin. There have been some improvements in the 1990s and afterwards in terms of increasing school and health coverage in the rural parts of the basin and also building road networks connecting the basin population with each other and with other regions. However, much has to be done to make the basin accessible to social and infrastructure and improve quality of life of the basin population.

- **Drinking Water and Sanitation:** The 2007 Census Ethiopian Census data indicates that 50% of the population in Amhara and 71% in Tigray had access to safe drinking water. The sanitation data for Ethiopia indicated that 60% and 50 % of the population had access to sanitation. The figures in Sudan were 34% in Kassala and 62% in Nahr Elnil. In terms of access to sanitation the figures were 22% and 42% respectively (Sudan Census 2008).

- **Education:** Based on the enrolment data, more than 50% of the school going population in the Ethiopian section of the sub-basin do not attend primary school. The figures for secondary school are even higher, with 75% of the population eligible for secondary education engaged in other activities. The enrolment levels in Sudan are higher, and range from 60.5 % in Elgadarif state to 74.9 % in Kasala and 97.9 % in Nahr Elnil states. The lower enrolment rates in Ethiopia are reflected in the rural literacy rates. In Ethiopia the rural literacy rates were in the region of 30%. In Sudan the rates were higher, namely 42% in Kassala and 70% in Nahr Elnil. The figures indicate that the levels of education on the Ethiopian section of the sub-basin are low

- **Access to roads:** The Ethiopian side of the sub-basin is connected with the rest of the country by one asphalted road, which crosses the north eastern section of the upper basin and links the area with Addis Ababa to the south. All weather gravel roads provide a link between Tigray region in the north and the Amhara region to the south. An all-weather gravel road also provides a connection between the north western parts of Ethiopia and the eastern parts of Sudan. This road facilitates the movement of goods (fuel and agricultural products) and people between the two countries..

  The Sudanese side of the basin is better served in terms of road infrastructure. There is one all season road connecting the basin (Nahr Elnil state) with Khartoum. The town of Atbara is also linked by rail to other regions of Sudan, including the capital, Khartoum. Sudan has the oldest and most extensive rail system in Africa, extending for more than 4 570 kms.

6.3.4 Main Nile Sub-Basin

- **Water Supply:** The Nile is the main source of drinking water for those Egyptians that live along the banks of the Main Nile. In Sudan, 87% and 62% of the households in the Northern State and Nile Regions have access to safe water (Sudan Census 2008). The majority of the population in the Northern and Nile Regions are concentrated along the Main Nile. The Main Nile is therefore the key source of water for the majority of the population living in the Northern and Nile Regions. In Egypt 98% of the population have access to safe water (Egypt Census 2006).

- **Sanitation:** In terms of access to sanitation, 74% and 43% of the households in the Northern State and Nile Regions have access to sanitation (Sudan Census 2008). In Egypt 85% of the population have access to sanitation (Egypt Census 2006).

- **Education:** The adult literacy rate in Egypt was 74% while the youth literacy rate was 89% (World Bank, 2012). The literacy rate for people over 15 years of age in Sudan was 71% (Sudan Census, 2008).

- **Health:** The major endemic diseases include tuberculosis, trachoma, schistosomiasis, and malaria. With the construction of the Aswan High Dam there has been an increase in the incidence of schistosomiasis in Upper Egypt.

Annex 7

The Eastern Nile Basin:
EN MSIOA Methodology

Annex 7: Method Details

A7.1 The Eastern Nile Basin Simulation Model

Modeling Objectives

The general objective of the EN Basin Simulation Model is to support strategic planning decisions at the scale of the EN region, through assisting to foresee the impacts of future possible water resources management and development states in the EN region. The specific objectives are to model the:

- functioning of the EN region hydrological systems, including natural and man-made reservoirs, wetlands, irrigation and hydropower schemes in the EN river systems and its main tributaries.
- satisfaction of the water demand, under different water resources management and development states, including different development levels of: (1) irrigation water demand; (2) hydropower water demand; (3) water storage operations; and (4) environmental flows requirements

Model Setup

The EN Basin Planning Model is a water distribution model, distributing water through the main branches of the water system, on a monthly basis, over the period 1900-2002. Because the time of concentration of the water in the river is less than one month in the various branches, no river routing has been used. Propagation delays only occur because of surface water reservoirs, which are used to simulate natural and manmade reservoirs as well as significant wetlands. The analysis includes the 4 EN sub-basins from their headwaters in the Ethiopian highlands up to the Mediterranean sea. The key characteristics of the model can be summarized as follows:

- 52 demand nodes to model both existing and potential future water abstractions;
- 2 wetlands and spill flows, Machar Marshes & Tawlor spills, in the Baro-Akobo-Sobat-Pibor river system
- 30 reservoir nodes to model both existing and potential water storage infrastructure in the basin.

The schematics of the EN Basin Planning Model, as it has been elaborated under MIKEHydro, are illustrated below in the case of the Baro-Akobo-Sobat Sub-basin (Figure A7.1).

Model Input

The configured EN Basin Planning Model also allows the modeling of many hydropower and irrigation schemes, including water storage reservoirs. Model inputs include:

- catchment inflows
- potable water demand
- irrigation water demand
- water storage (required for the satisfaction of the downstream water demand)
- environmental flow requirement downstream any abstraction or storage nodes
- lakes and reservoirs characteristics and operation rules (if any)
- Hydropower plants characteristics

The model receives as an input the following time series and data sets:

- Monthly historical time series records for incremental catchment flows over the period (1900-2002)
- Average monthly demands for all water abstraction nodes.
- Reservoir characteristics data which include the following:
  - Stage-Volume-Area characteristics for each reservoir,
  - Average monthly rainfall and evaporation data for each reservoir;
  - Hydropower plant and Turbine characteristics for each reservoir;
  - Operation rules for existing reservoir which include the monthly guide curve of reservoir water levels and/or reservoir releases;
  - Environmental flow requirements which set the minimum flow releases for each reservoir and target releases against certain demands downstream;

- Average monthly Environmental flow requirement for set of control nodes downstream,

Figure A7.1: Blue Nile Sub-basin Schematics

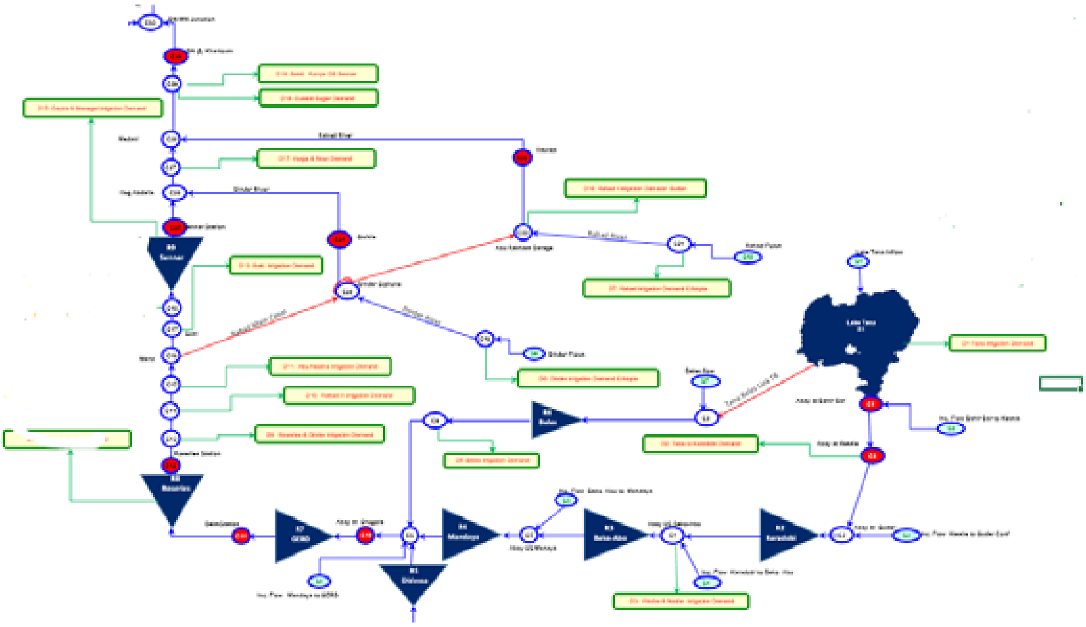


Figure A7.2: Tekeze-Atbara-Setite Sub-basin Schematics

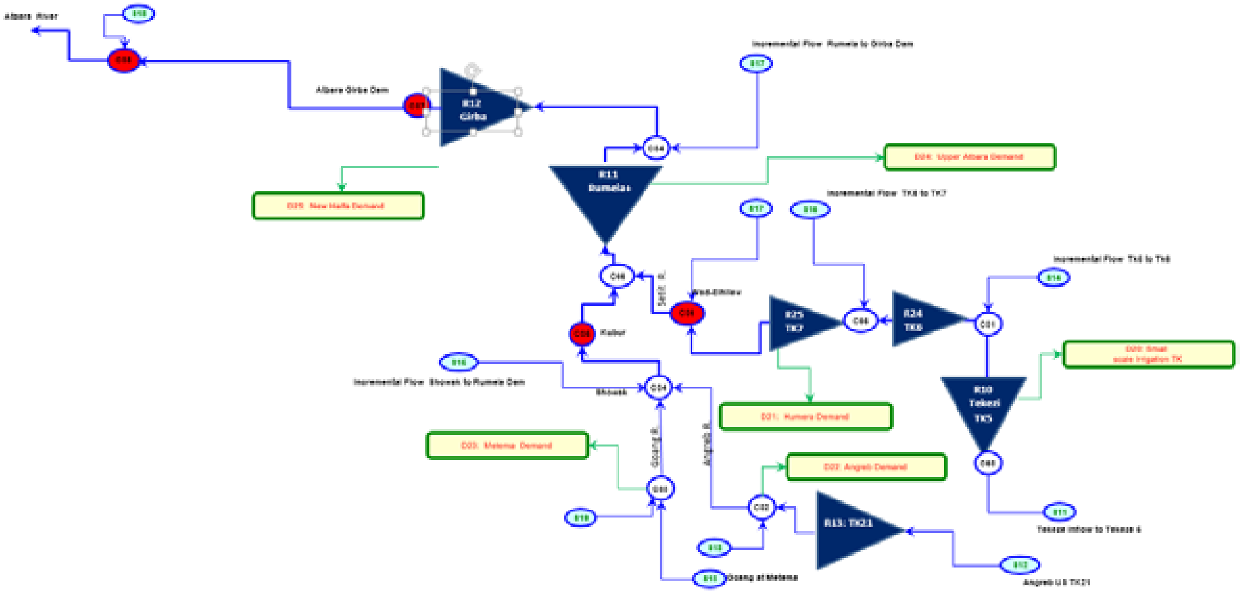
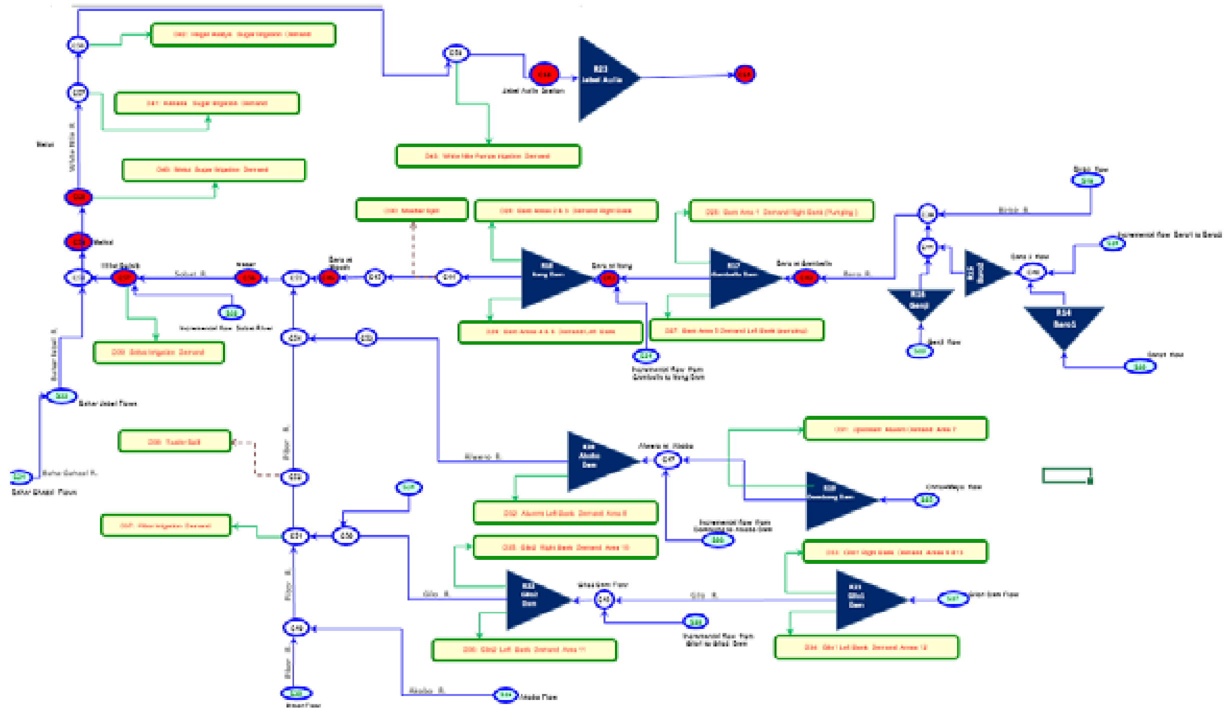


Figure A7.3: Baro-Akobo-Sobat Sub-basin Schematics



The density of nodes represents the level of detail of the model. It is quite clear that if one looks at a specific small sub-basin (e.g. Khor Gila and Pibor River basin), the level of detail is very limited: one catchment inflow, possibility to consider one irrigation water demand with associated storage, possibility to consider a downstream hydropower scheme, possibility to consider one downstream environmental flow requirement. Therefore, it is worth stressing the fact that the EN Basin Planning Model should **not be used for modeling complex water systems at the local level** since it is designed for this purpose, but only for the purpose of analysis at the scale of the entire EN region.

Model Output

The EN Basin Simulation Model provides two outputs:

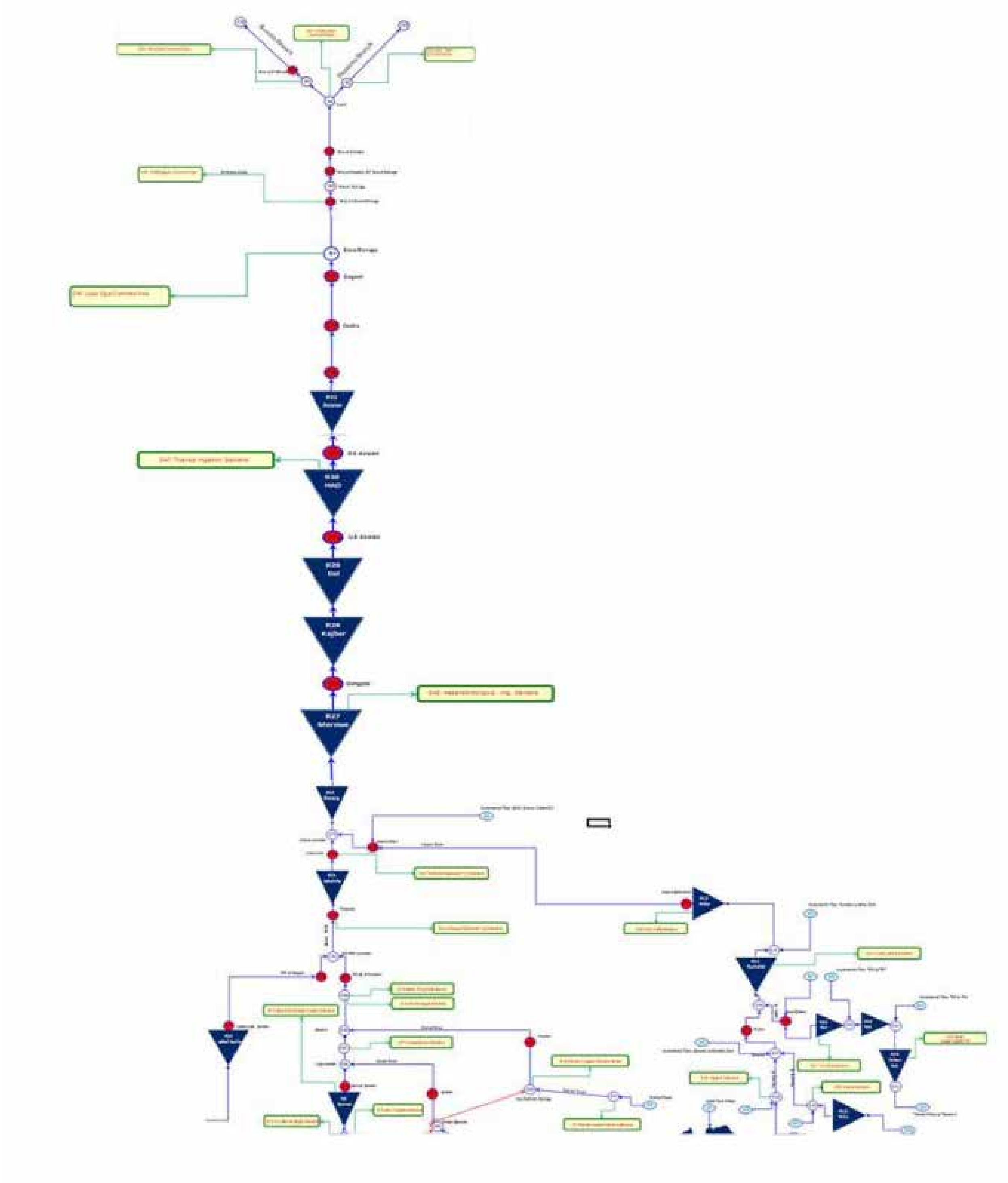
- to feed the simple annual water balance model and the economic assessment model for the economic analysis of different combinations of water management and development activities,
- to show key characteristics of the EN water system under different combinations of water management and development activities.

An Excel-based Annual Water Balance and Economic Analysis Tool was developed to study the implication of different development states on water availability and for economic valuation of each development state. The annual water balance and economic analysis receives the following outputs from the Basin Simulation Model:

- Simulated average annual flows for all nodes under each development state;
- Simulated annual evaporation losses from each reservoir;
- Simulated monthly water uses for each abstraction node;
- Average annual energy production for all the hydropower plants (to be used for energy costing),
- Average surface area of the main water bodies (to be used for fisheries and environmental costing),
- Irrigated area satisfied in 4 out of 5 years (80% assurance) (to be used for irrigation costing) for the various sub-basins as well as for different sections of the Nile River itself,

- Water storage capacity required for the satisfaction of the potable water, irrigation water and environmental water requirements, for the various sub-basins as well as for different sections of the Nile River itself.

Figure A7.4: Main Nile Sub-basin Schematics



Model Performance

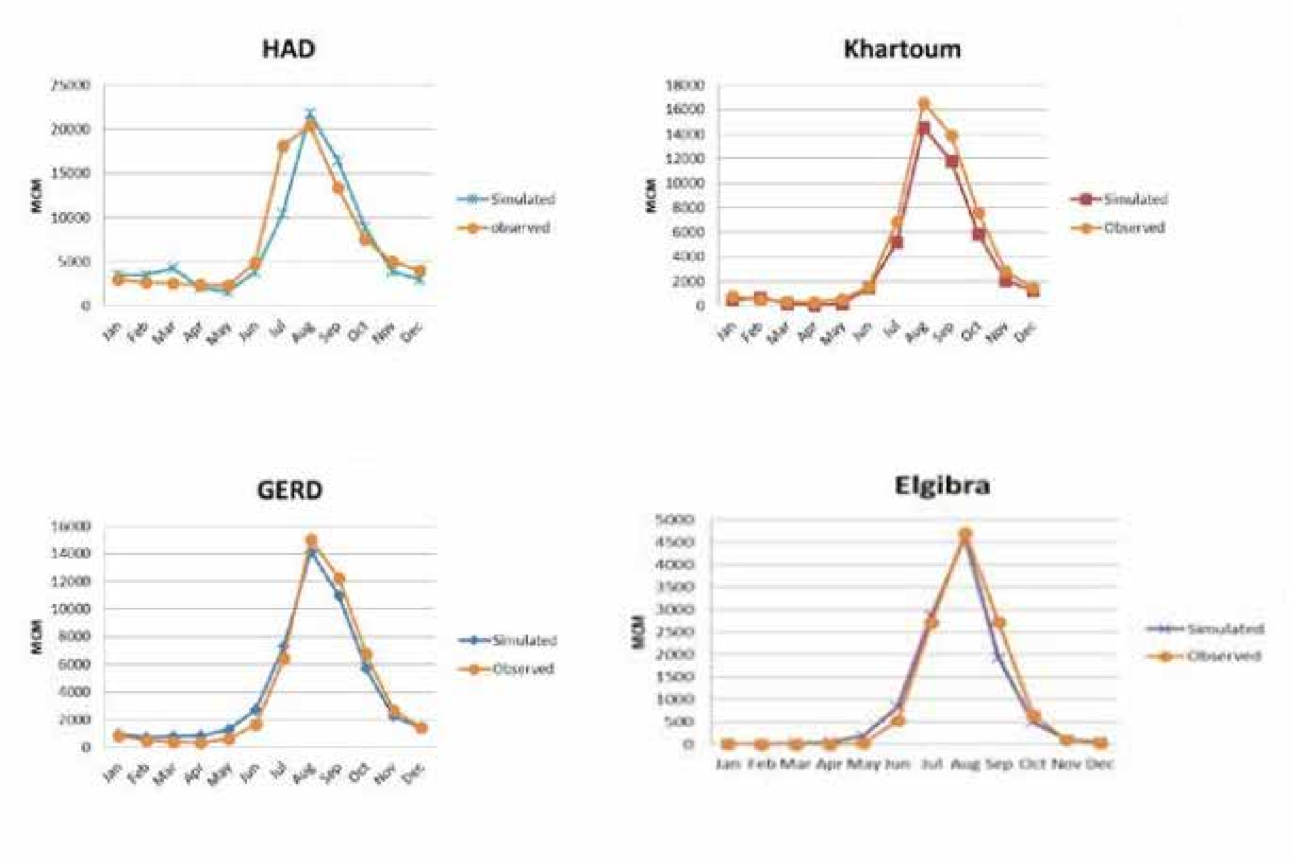
Validation was carried out by comparing the observed flows with outputs of Mike Hydro models at the selected stations of Jebelaulia, Elgibra, Border, Khartoum and High Aswan Dam inflow. To facilitate the evaluation, visual as well as statistical comparison was carried out. Statistical parameters such as use of Nash-Sutcliffe Efficiency (NSE), Coefficient of determination (R2), Mean Relative bias (PBAIS) and Root Mean Square error (RMS) were used. The simulated flow has been plotted against the observed flow for the validation periods (see Figures A7.2). There is a good agreement between simulated and observed monthly flows. The low flows are quite well represented and there is good overall agreement in the shape of the hydrograph. In the context of low flow, the observed and simulated flow matched each other well. The model has simulated the behavior of the observed flow during the validation period. The rising and falling limbs have been captured.

A7.2 The Annual Water Balance And Economic Assessment Tool

While the annual water balance analysis aims to study the implications of different development states on water availability at each node in the system, the economic assessment tool evaluates, from an economic point of view, the multi-sectoral development opportunities in the EN region. This Tool includes the following:

- Detailed project database and description for all existing and potential investment schemes. This include infrastructure, scheme operation and productivity, historical water abstractions and economic viability of the scheme.
- Updates of unit rates for potential irrigable projects in Egypt, Sudan and South Sudan. In the case of Ethiopia the Diagnostic component of the EN Irrigation and Drainage Study provides fairly adequate and updated economic analysis of potential irrigable schemes in Ethiopia. Access to Data and information about existing and potential schemes from different

Figure A7.5 : Comparison of simulated and observed mean monthly flows at key points



sources were mainstreamed as part of the EN-MSIOA Knowledge base platform.

- Detailed costing analysis and systematic computation procedure for evaluation of Initial Infrastructure investment costs and recurrent costs for all irrigation schemes;
- Computations of water requirements for irrigation, livestock and feed water requirements, pumping requirements for all irrigation schemes. This includes estimates of water requirements per unit hectare, equilibrium price of water and cost of pumping per unit hectare.
- Estimation of production costs and net revenues generated from existing and potential irrigable projects. This permit analysis of the impact of different irrigation modernization options and economic valuation of the feasibility of rehabilitating low performing irrigation projects.
- Detailed socio-economic analysis based on consistent set of indicators for prioritizing the set of investment projects. This include the following:
    - Net Revenue Generated
    - Net Present Value (NPV)
    - Employment generated from each irrigation scheme
    - Livestock and fisheries productivity

A detailed draft description of the Water Balance and Economic Assessment tool, how it would work, inputs required, linkages with the EN Basin Planning Model and anticipated outputs was submitted to ENTRO in December 2014 and subsequently presented at a Client/Consultant meeting. This ensured that the economic model would deliver the expected results. Potential combinations of water development activities were also discussed with ENTRO.

The aim of the Annual Water Balance and Economic Model is to assess from a water resources availability and economic point of view the multisector development opportunities in the EN region. The structural investments (mainly hydropower and irrigation investments) taken into account in the model are those already identified in the situational analysis main report and reviewed in the Scoping Report, which saw the list reduced. Added to the identified structural investments, a number of hypotheses have been taken to estimate the potential improvement in others sectors such as integrated watershed management; fisheries, fish farming, livestock.

Description of the Tool

The economic assessment is carried out over a 30 year time period. A shorter period, such as 25 years, is considered too short to assess the benefits of major infrastructure investments such as dams. Indeed, with a time line of only 25 years, a large part of the benefits derived from these major investments would be lost and will in fact reduce automatically, because of the discounting rate and the cost benefit ratio. All the monetary data are provided in USD. The model has been built in Microsoft Excel. The Excel spread sheets file is clearly organized in order to facilitate understanding and to ensure that the economic model is a living component of the analytical framework that will be handed over to the Client at the end of the study for future application. The structure of the file is as follows:

- A "Mainpage" spreadsheet for testing and visualizing the results from each development state;
- A "Schematic" spreadsheet. This sheet shows detailed description of the EN System, its components, and provide linkage for the EN reservoir and irrigation database as well as access to historical time series flow records at each gauging nodes in the system.
- A "massbalance" spreadsheet. This sheet provide detailed annual mass balance computations at each node in the sense and its interactive in the sense that Annual mass balance computation at each node will be updates with changing the selected development state.
- A "scenariomanager" spreadsheet. This sheet provide controls for the potential investment projects and their development level that the user would like to consider as part of the scenario analysis. It is on this sheet that the user can create and test new development states. For each of the existing and potential investment projects, A multiplier set of 4 elements is provided under each development level (CS, IS, LD, FP). These multiplier elements could either take a value of 1 or 0. By changing the value

from 0 to 1 or vice-versa, this would switch the development level for that particular project on and off. Such arrangement would enable the formulation of development states based on different combinations of levels of development and to rank and prioritize projects based on user defined set of socio-economic indicators and/or from national country priority perspectives. Such tool could be very powerful in facilitating informed decision making and joint fact findings or negotiations around alternative development options among conflicting users and stakeholders in the basin.

- The rest of the sheets provide details of the economic analysis and the database used in the Study.
- The unit rates for all irrigation projects in Sudan and Egypt were updated based on the most recent data that were available. As far as possible, the unit prices used for the various economic analyses are grouped together and made accessible for each irrigation scheme spread sheet. This include:
  - Additional value/gross margin (per type of benefit);
  - Selling prices;
  - Investment costs;
  - Labor cost;
  - Monetary rate;

  Most of the figures used in the price schedule come from the literature. They can all be easily updated at any time as required and this will automatically change the result of the model through the dynamic links in place.

The methodology to set up the economic model is briefly described below.

Irrigation Schemes: Water Requirement Calculations

To ensure consistency with the data sets used in previous ENSAP projects, the unit rates used in the calculation of the project water requirements (m3/ha) for the Ethiopian irrigation projects is the same as the ones used in the EN Irrigation and Drainage Study. The information is based on the calculations carried out during preparation of the Abbay Basin Master Plan (BCEOM, 1994-1997). For the Sudan projects these types of calculations were not available and therefore, a standard crop water calculator was developed and provided for each specific scheme. The calculator permits the exploration of different standard cropping patterns and crop types that are common in Sudan. These figures have been used to determine the overall water requirements for Sudan. Egypt Crop Water computations were made by disaggregating Egypt into 5 command areas. These are: Upper Egypt, Middle Egypt, East Delta, Middle Delta and West Delta.

Irrigation Schemes: Costing

Costing of irrigation schemes was based on three components:

- <u>Estimate of initial infrastructure investment cost.</u> This is based on secondary data obtained from most recent documents. The main source of costing data for Egypt irrigation projects were extracted from the World Bank Project Appraisal Document for West Delta Project. Detailed break down of the initial Infrastructure investment cost per unit feddan is provided in Annex B.1. For Ethiopia Irrigation Project, detailed estimates of unit rates and costing of irrigation projects has been recently updated as part of the diagnostic component of the ENIDS. Hence to maintain consistency and avoid duplication of efforts the costing of irrigation schemes in Ethiopia was based on the estimates provided as part of the ENIDS project. For the case of Sudan, it was realized that the unit rates adopted in the ENIDS study were outdated and need revision. Hence resort was made to update the unit rates based on consultation with the relevant agencies and Ministry Staff in Sudan as well as secondary data collected from different sources. One of the main source of information for costing irrigation projects in Sudan is the feasibility study report entitled "SUDAN AGRO-INDUSTRY INVESTMENT OPPORTUNITY" prepared by the Sudan Federal Ministry of Agriculture.
- <u>Estimate of Recurrent Cost.</u> Standard Excel calculator is developed to estimate the energy requirements and cost of pumping. To maintain consistency and to provide a fair background for comparing projects, the standard maintenance rates used in estimating the recurrent cost for Ethiopia projects under the ENIDS

Study were adopted for the Case of Egypt, Sudan and Sudan Sudan maintenance of irrigation schemes.

Economic Analysis

- Detailed Economic analysis has only been carried out for Sudan, South Sudan and Egypt irrigation investments (for new development, irrigation modernization and investments on rehabilitating existing schemes).
- The economic analysis for Ethiopia irrigation project has been recently updated under the ENIDS Study. Values of EIRR, NPV and B/C ratio for each project were extracted from the ENIDS study.
- The economic analysis for large scale hydropower schemes in Ethiopia and Sudan has been conducted under the EN Power Trade Study and recently updated through a number of feasibility and pre-feasibility studies. Hence Values of EIRR, NPV and B/C for hydropower projects were extracted from the Site Specific feasibility studies for these projects.
- Standard templates were constructed to evaluate unit cost of productions of irrigation schemes, the net revenue generated per unit hectare and to perform the cost benefit analysis.

Outputs of the Economic Tool

Given that poverty reduction is a key objective of ENSAP and its Member States, the following were analyzed for each development state:

- Economic Net Present Value (NPV) and Economic Internal Rate of Return (EIRR). For each of the combinations, the NPV and EIRR are provided.
- Output employment: This presents an estimate of the generation of employment per country and per sub-basin for each combination of water development activities. The hypothesis used to estimate the employment generated are shown in the following table:

A7.3 Multi-Criteria Analysis

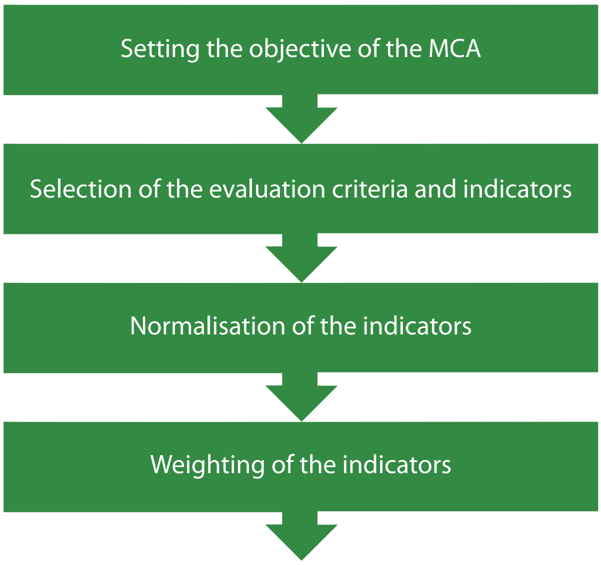
Multi-criteria analysis was used to make a comparative evaluation of the development states evaluated using the EN Basin Simulation Model as already introduced earlier in this chapter. This comparative evaluation should allow the discarding of some development states and the ranking of the remainder in terms of how they meet the water resources developments and management expectations of the Eastern Nile countries.

Methodology

Multi-criteria analysis is a well-accepted approach to the analysis of choices/options when this cannot be done in using standard statistical methods or other approaches. As its names implies, MCA allows the use of a range of often quite different criteria to be used to evaluate options, in this case a number of water resources development states. These criteria should obviously reflect the key management and development issues that are the focus of each development state, and there has to be some way of measuring the criteria or the degree to which they are met/satisfied. This is done through the use of “indicators”. Indicators should be measurable otherwise it is difficult to use them in the MCA. A challenge facing the application of MCA and its use of a wide range of criteria covering different themes, is that these themes may have

Table A7.1: Hypothesis on employment

Field	Unit	Direct Employment
Irrigation Egypt:	Employment/Ha	17.857
Irrigation Ethiopia	Employment/Ha	10.714
Irrigation Sudan	Employment/Ha	5.000
Irrigation South Sudan	Employment/Ha	4.770
Hydropower	Full time jobs/GWh	0.200
Livestock ownership	TLU/Person	5.190
Fisheries	Tons of fish/year/fisherman	3.000
Other (construction; operation; etc.)	% of total Employments	20%



relatively greater or lesser significance in terms of the choices or options being analyzed. To address this challenge, different criteria were assigned different weights. The steps in developing and applying the MCA can be summarized as follows:

Objective
The objective of this MCA is to evaluate a number of water resources management and development states in terms of how they meet the sustainable development expectations of the Eastern Nile riparian countries.

Criteria/Indicator Selection
The selection of criteria was stakeholder-driven. After presentation of the methodology, guidelines and some examples, stakeholders representing both the necessary thematic areas and Ethiopia, South Sudan and Sudan, were given the task of proposing appropriate criteria and to look at their potential relative importance (weighting).

Normalization
Normalisation means to rescale the numeric variable to a specific range. All indicator have been normalized so their scores range from 0 to 10, Zero reflecting the minimum value observed in the distribution and 10 the maximum value.

Weighting
The next step required the stakeholders to give their preference on how to weight each indicator in order to ensure that the key criteria had the greatest importance for the comparison of development states. To elicit the preference of the stakeholders, the "Pair-wise Matrix Ranking" method was used. Pair-wise ranking is a structured method for ranking a list of indicators in a priority order, where stakeholders were asked to fill a Table by comparing each pair of indicators in each blank cell. This is the final step in the preparation of the MCA criteria to be used for the comparison of results.

ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative
Egypt, Ethiopia, South Sudan, Sudan

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